Digitization of the water sector - practical examples from around the world

Sprocati, Riccardo; Blum, Jan-Michael

Published in:
13th DWF Water Research Conference - Abstracts

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

13TH DWF WATER RESEARCH CONFERENCE

ABSTRACTS

Contents

Session 2 & 3; Ground Water

CHAIR: Bjørn K. Jensen and Lars Skov Andersen

Title	**Presented by:**
The Indian Wells Valley basin in California – Danish solutions as part of reaching sustainable water resources management	Max Halkjær, Rambøll
Is one conceptual model sufficient for well capture zone delineation?	Elisa Bjerre, IGN-UCPH
Challenges faced when trying to export the Danish Model of groundwater management to California	Casper B. Mejer, I•GIS*
Investigation and remediation of pesticide point sources in Region Zealand	Nanette Levanius Schouw Christiansen, Region Zealand
Concept for managed aquifer recharge at Pingtan Island	Peter Thomsen, Rambøll
Exploiting flexible meshes for modelling groundwater flow and reactive transport in Quaternary deposits: applications at two Danish sites	Nicola Balbarini, DHI
NoNewBAM: diflufenican degradation and potential leaching	Pedro N. Carvalho, AU Envs
Improving flood risk modelling in a national water resources model for Denmark	Raphael Schneider, GEUS
An integrated modelling framework for nutrient management	Rasmus Rumph Frederiksen

The Indian Wells Valley basin in California – Danish solutions as part of reaching sustainable water resources management

Max Halkjaer, Rambøll, E. Auken, Aarhus University **, P. Thorn, Rambøll****

Abstract

The Indian Wells Valley Water District (IWVWD) is situated just east of the southern Sierra Nevada and relies exclusively on groundwater for all water supply needs. Groundwater levels have been steadily declining since at least the 1950s and the area is now categorized as one of 21 "Critically Overdrafted Basins" within the state of California. The Indian Wells Valley groundwater basin (IWV) is located at the southeastern corner of the Sierra Nevada Range in the northern portion of the Mojave Desert. This province is characterized by numerous northwest trending faults, dominated by alluvial sediments and playas. The basin water demand is approaching 31mio m^3/yr with an annual sustainable yield estimated at 9m m3/yr, meaning that there will be significant effort required to bring the basin into balance as required under the Sustainable Groundwater Management Act (SGMA). To meet SGMA mandates, local agencies have found that desalination of brackish groundwater can potentially be affordable and is an attractive component in reaching sustainability.

A unique part of the desalination plan is the fact that the two private companies, Coso Geothermal and Searles Valley Minerals can make use of the brine and the fact that the groundwater is brackish and not saline sea water makes desalination economical feasible.

An important part in the desalination study has been to locate brackish water as a resource for desalination. Even though the groundwater basin has undergone numerous investigations over the years we have found that there is a need for further investigations and a compilation of all the data as basis for the development of a Hydrogeological Conceptual Model (HCM).

One of the activities towards achieving a better hydrogeological understanding is the Stanford GAP project. A multidisciplinary team lead by Stanford University that was hired by DWR, local agencies and the Danish Ministry for Environment have been tasked to develop the optimal workflow on how to develop HCMs for SGMA. The project includes gathering a broad range of existing data, storing the data in a Data Management System (DMS), evaluating data gaps, conducting airborne geophysical surveys, and developing traditional HCMs based on cross sections and development of more complex geostatistical HCMs with the purpose to quantify the uncertainties related to HCMs. Indian Wells Valley has been selected as one of three pilot study areas in California. We have now reached a point where we have used the airborne geophysical system SkyTEM to collect a large-scale data set across the basin, we have digitized more than a thousand well completion reports and we are finalizing a very detailed HCM.

We have achieved an improved areal delineation of the geologic structure and architecture of the major aquifers and aquitards. We have examined the connectivity between the shallow and deep portions of the aquifer system and we have gotten a clear description of the extent of brackish water across the basin. Finally we have delineated areas with coarse shallow sediments feasible for infiltration of surface water drainages coming out of the Sierra Nevada.

From a Danish perspective we have created a show-case demonstrating the value of Danish solutions developed during the Danish Groundwater Mapping program such as geophysics, data management and detailed HCMs.

* maxh@ramboll.com: Olof Palmes Alle 20-22, DK-8200 Aarhus N, Denmark

** esben.auken@geo.au.dk: Høegh-Guldbergs Gade 2, 8000 Aarhus C, Denmark

*** path@ramboll.dk: Hannemanns Allé 53, 2300 København S, Denmark

Is one conceptual model sufficient for well capture zone delineation?

E. Bjerre, UCPH and GEUS, A.L. Højberg**, GEUS, P.K. Engesgaard***, IGN-UCPH*

Abstract

In a decision-making context hydrological models are most often designed to provide specific predictions of interest. In groundwater management so-called particle tracking is commonly used for capture zone delineation of abstraction wells to identify where to target groundwater protection, such as nitrate or pesticide mitigation measures. That is, particles can be used to track from where the pumped water originates. A major source of uncertainty in groundwater models is the conceptual model of the geology. Nevertheless, conceptual uncertainty (that is, more than one geological model is probable with the sparse data we have) is very seldom integrated in decision-making. We have studied the case of Vester Hjerk waterworks, where capture zone delineation is of importance as there is a demand for groundwater protection due to steadily increasing nitrate concentrations. Vester Hjerk is a small waterworks located on the peninsula of Salling, Denmark (Figure 1). The drinking water is abstracted from a sandy shallow aquifer at 30 m depth within a buried valley. The local stakeholders have been presented with two vastly different capture zones from the authorities (1 and 2, Figure 1), which has created lack of confidence in the model results as a decision platform amongst the local farmers. Thus, a model ensemble was built to qualitatively analyse the influence of parameter and conceptual uncertainty. We found that the discrepancy between capture zones 1 and 2 could be explained by parameter variation. Different representations of the hydrogeological system showed that conceptualisation of the buried valley had a major impact on the location of the capture zone (capture zone 3). Thus, detailed mapping of buried valleys is of crucial importance for correct identification of capture zones in this area. We found that a model ensemble can be used to test conceptual hypotheses, e.g. in relation to connectivity of buried valleys, and to identify where to collect discriminatory data to choose between models. If discrimination is not possible, multiple models must be accepted as equally valid and should be considered for groundwater protection. The findings of the study show that decision makers in groundwater management can benefit from extending the current modelling scheme to include development of multiple models that address conceptual uncertainty rather than relying on single-model predictions. This approach poses new challenges with regards to communication of the results to stakeholders.

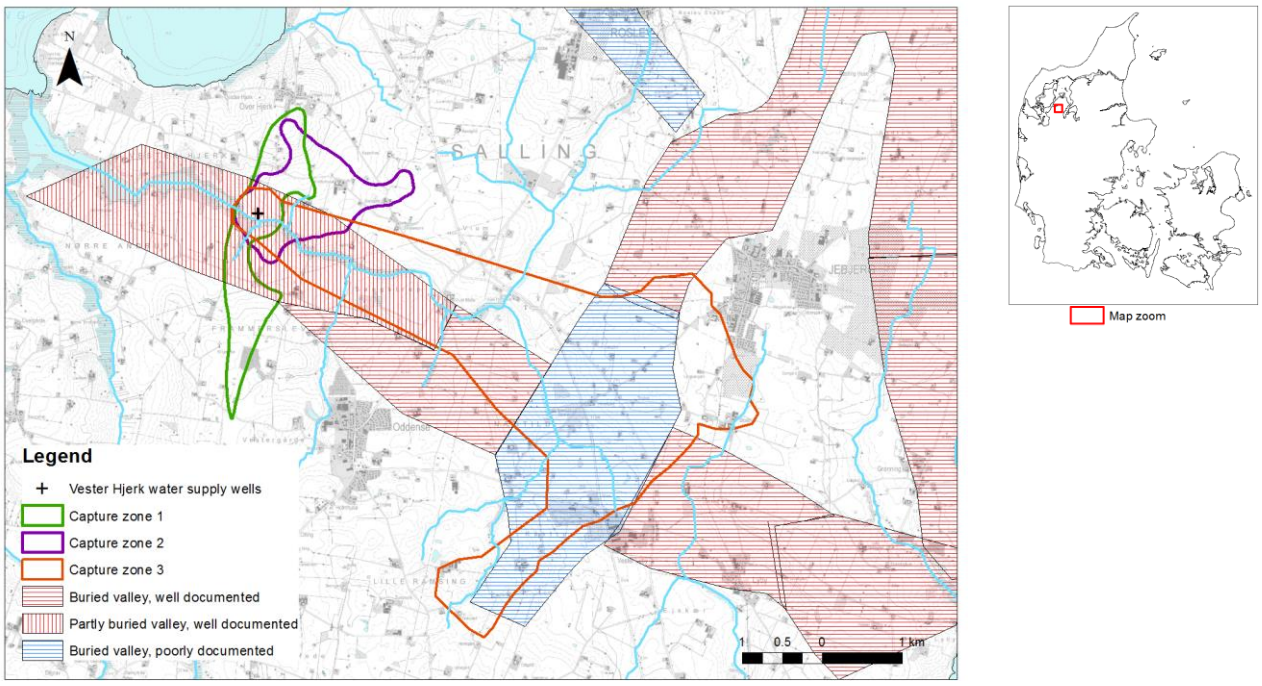


Figure 1 A selection of multiple capture zones calculated for Vester Hjerk waterworks.

* ebj@geus.com: *Øster Voldgade 10, 1350 København K*

** alh@geus.dk: *Øster Voldgade 10, 1350 København K*

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

Abstract, Challenges faced when trying to export the Danish Model of groundwater management to California.

*Casper B. Mejer I•GIS**

Abstract

California has embarked on a historic journey to achieve groundwater sustainability with the passage of the Sustainable Groundwater Management Act (SGMA) in 2014. Local agencies are vested with the responsibility for achieving sustainability, with the first step for each agency being the preparation of a groundwater sustainability plan (GSP). A specific legislative requirement is the development of a hydrogeologic conceptual model (GSP Regulation §354.14). Historically the "conceptual model" was often a very general description of subsurface layering but the "conceptual model" required by SGMA is a 3D hydro-stratigraphic model capturing the spatial heterogeneity of the subsurface needed as the input for flow modelling.

The same challenges facing California today were faced by Denmark in the early 1990s when groundwater legislation was passed that required all municipalities to characterize and manage the groundwater systems.

In September 2017 California & Denmark signed a memorandum of understanding (MoU) on water to promote increasing knowledge sharing and collaboration on areas of mutual interest.

Since 2017 I•GIS has been part of the Danish Water Technology Alliance (WTA) which is a strategic collaboration that involves Denmark sharing knowledge with the US gained through decades of experience within the areas of water and wastewater treatment technology, energy management, torrential rainstorm operations and related issues.

In collaboration with Stanford University three pilot project are being carried out using the "Danish Method" creating precedents for "best practice" in groundwater mapping.

Several challenges are faced during these exercises. Lack of digitization of well completion reports and accurate location, private ownership of data, lack of geological information, and no history in using geophysical methods in groundwater mapping is a challenge the WTA partners must overcome.

This presentation will explain the challenges we are facing and methods on how we plan to overcome them.

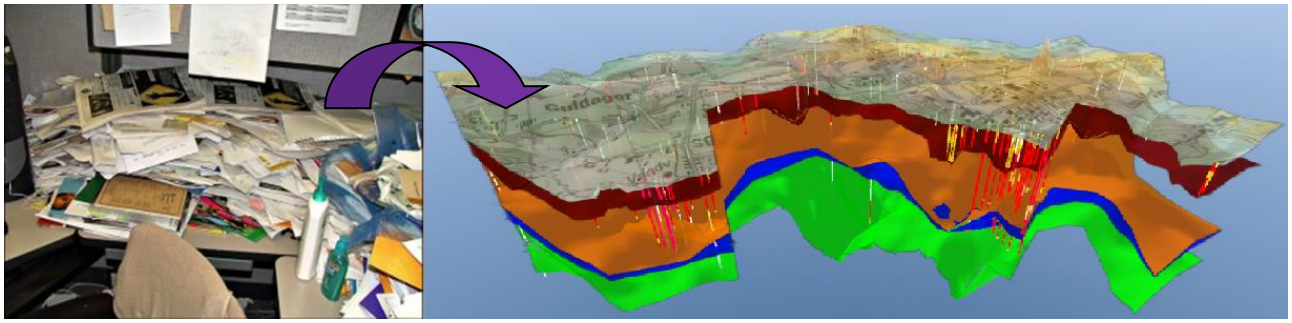


Figure 2 transforming analogue data into a digitized 3D geological model is a challenge faced by Californian groundwater authorities these days

* cam@i-gis.dk Voldbjergvej 14A, 1 st floor, DK-8240 Risskov

Investigation and remediation of pesticide point sources in Region Zealand

Stella Agger, Henrik Jannerup** and Nanette Schouw, Region Zealand****

Abstract

The Regions in Denmark are responsible for investigation and remediation of point sources (large amounts of contaminants in a small area) that pose a threat towards the groundwater quality. In recent years, the regions have included point sources with pesticides in their work. This effort has led to surprising findings of forgotten pesticides and their /metabolites. Municipalities and the Environmental Protection Agency are responsible for the current use of pesticides in the fields and thereby any potential contamination from surface sources. The regions actions towards point source contamination have led to identifying several new substances, which are of serious concern to the water supplies in Denmark.

Region Zealand has handled the task in two systematic manners:

- where pesticides already are found in drinking water wells, we track down the cause and find the possible point sources upstream in the catchment area and remediate it
- where drinking water wells currently are free from pesticides, we complete a broader investigation of the possible point sources in potential groundwater abstraction areas to prevent future contamination

Results

In Stevns some of the drinking water abstraction wells are contaminated with the phenoxy acid and metabolite: dichlorprop and 4-CPP. Region Zealand initiated an investigation to collect historical data on pesticide use and handling in the catchment area. Interviews with local farmers and review of old achieves lead to 14 possible locations. Samples of soil and groundwater from borehole investigations on these locations were analysed for several persistent pesticides. Especially the area for washing the pesticide dispersion equipment and the chemical waste storage area at one farm were identified as severe point sources, and responsible for the contamination. In 2018 the region started building a remediation facility with pump and treat via an activated carbon filter near the point sources to avoid further contamination of the aquifer. Stevns is an example of regional action towards present pesticide contamination in a water supply.

In other areas of the region, point sources are identified and handled to prevent contamination of the aquifers. An example of this is the small island, Bogø, where the quality of water supply is vulnerable due to salt intrusion. Out of their 8 km^2 area with potential drinking water approx. twelve farms with large-scale pesticide dispersion activities were identified as possible contaminated sites. So far groundwater samples have shown that two locations are severely contaminated with pesticides. Remediating these will remove the threat of pesticide point contamination from the water work at the island in the future.

Perspectives

Collaboration between water supply companies, the municipalities and the regions is crucial to obtain the long-term goal of groundwater protection. Region Zealand collaborates by participation in coordination forums when action plans of groundwater protection are prepared by the municipalities. We look forward to how the handling of the pesticide point sources can play an even greater role in these action plans.

Ultimo 2018 a collaboration between GEUS, The Environmental Protection Agency of Denmark and the Regions has resulted in the development of a new much broader analysis package of pesticide analysis. The perspective of this achievement is wide: effective cleaning up of pesticide point sources, broader monitoring programs, comprehensive knowledge of the actual occurrence of pesticides in groundwater, improved planning of future drinking water wells.

*sda@regionsjaelland.dk, **hej@regionsjaelland.dk: ***nls@regionsjaelland.dk: Alléen 15, DK-4180 Sorø

Concept for managed aquifer recharge at Pingtan Island

*Jan Kürstein, Rambøll,** Peter Thomsen Rambøll, ***Jens Aamand GEUS,***Wanglin Li Jinan University

Abstract

Pingtan Island, also called Haitan Island has an area of 267 km^2 and a population of around 400.000 (2009). In the future there is expected a drastic increase in the size of the population due to a general development and the construction of a bridge between Pingtan and the Chinese mainland in 2010. Water supply is today based on surface water, but the increase in population, will lead to a water shortage in the future. The Fujian provincial Government has increased focus on the water shortage at Pingtan, and several initiatives have been initialized to meet future water challenges. One initiative is the implementation of groundwater as part of the water supply, and in line with that to increase the available groundwater resource by Managed Aquifer Recharge (MAR) of rain- and surface waters.

Rambøll has in cooperation with GEUS and Jinan University in China developed a pre- design for MAR at Pingtan Island. The design has been based on field investigations including Electrical Resistivity Tomography (ERT), infiltration tests and water quality sampling. Moreover, the design has been based on hydrological and hydraulic modelling simulating the ground- and surface water system. The design includes a combination of rapid infiltration basins combined with injection wells at the coastline to avoid intrusion of saltwater. In the pre-design infiltration basins have been placed at the most suitable locations concerning aquifer response, possible locations of future abstraction wells, and surface water availability. The pre-design also includes solutions for collection, transport, storage and pre-treatment of rain- and surface water before infiltration to the groundwater. The next phase the project is expected to include an implementation phase, with construction of one or two of the proposed infiltration basins. The implementation phase will begin with a pilot test of a smaller infiltration basin before the establishment of large-scale infiltrations facilities. The test phase will include detailed investigations regarding sediment chemistry and long-term aspects of mixing of different water qualities. Long-term pumping test will also be suggested for the next phase to get a more accurate estimate of the aquifer response and for detailed design of the locations of injection wells.

* jnku@ramboll.dk: Hannemanns Alle, 2300 København S
** PRT@ramboll.dk Hannemanns Alle, 2300 København S
*** jeaa@geus.dk Østervoldgade 10 , 1350 København K
****Wanglin Li cswlw@163.com Jinan University

Exploiting flexible meshes for modelling groundwater flow and reactive transport in Quaternary deposits: applications at two Danish sites

Nicola Balbarini, DHI Alexandra Marie Murray, DTU Environment**, Mette Martina Broholm, DTU Environment***, Kirsten Rügge, COWI A/S****, Michael Brian Butts, DHI*****

Abstract

Contaminated sites pose a major risk to the environment and to human health. Because of their large number in Denmark (35.461 /1/) and the high costs of data sampling, collecting reliable datasets at all sites is not possible. Numerical models provide a physics-based framework to interpret data, support field campaign planning, and plan cost-effective remediation strategies. The use of numerical models can be particularly valuable when dealing with heterogenous Quaternary clay till and sandy deposits, which often comprise the geology in some parts of Denmark. At these sites, understanding groundwater flow and contaminant transport is challenging because of the difficulty of interpreting the sparse data in an heterogenous environment.

The aim is to investigate the applicability of detailed finite element numerical models to capture the variability when simulating groundwater flow and contaminant transport in highly heterogenous Quaternary deposit environments in Denmark. The finite element is a numerical model method, which allows locally refining the complexity of the model, accordingly to the level of heterogeneity and the data availability. The investigations were carried out at two contaminated sites with extensive chlorinated ethene plumes. The first site at Møllevej, Zealand, is characterized by a complex heterogenous clay till and sandy geology /2/. The second site is Rødekro, in southern Jutland, is characterized by simpler geology, but a complex distribution of contaminant concentrations due to the geochemical reactions taking place /3, 4/.

Geological data and models are combined with hydrogeological data, such as slug tests and grain size analysis, to develop hydrogeological groundwater flow models using FEFLOW. At the Møllevej site, a pumping test has been performed and data will be used to provide better understanding and interpretation of the flow and transport in the sand lenses. At the Rødekro site, the flow simulation is combined with a reactive transport model developed in FEFLOW and PHREEQC to describe the effect of thermal remediation on the redox conditions. The results are compared with water quality measurements collected over a 11 year period.

The use of finite element methods by FEFLOW allowed an accurate delineation of the sand lens geometry at Møllevej. This, supported by a detailed geological model, provided an accurate framework for the pumping test interpretation. Combining pumping tests and numerical groundwater modelling provided insight on the groundwater fluxes between sand lenses imbedded in clay till deposits, as well as on the hydraulic conductivity of the sediments. Water flux estimation between the hydrogeological units is a fundamental step of the risk assessment because it describes the rate at which groundwater and, thus, contaminants migrate.

Reactive transport models developed using FEFLOW and PHREEQC allowed reproduction of the changes in redox species observed at Rødekro. The model combined with chemical data provides insight on geochemical and microbial degradation processes taking place at Rødekro and the result of a thermal source remediation.

The investigations at Møllevej and Rødekro show the potential of applying numerical finite element models for supporting hydrological data and contaminant concentration data interpretation for Quaternary sand and clay till deposits. The models will contribute to a better risk assessment on groundwater.

/1/Jordforureningslovens Areal Register database, 2017

/2/ Region Hovedstaden (2018), Møllevej 9, Nivå, Afgrænsende forureningsundersøgelser. COWI, Projekt nr. A037259, Version 3.0

/3/ Hunkeler, D., Abe, Y., Broholm, M.M., Jeannottat, S., Westergaard, C., Jacobsen, C.S., Aravena, R., and Bjerg, P.L., 2011. Assessing chlorinated ethene degradation in a large scale contaminant plume by dual carbon-chlorine isotope analysis and quantitative PCR, J. Contam. Hydrol., 119, 69-79.

/4/ Badin, A., Broholm, M.M., Jacobsen, C.S., Palau, J., Dennis, P., Hunkeler, D., 2016. Identification of abiotic and biotic reductive dechlorination in a chlorinated ethene plume after thermal source remediation by means of isotopic and molecular biology tools. Journal of Contaminant Hydrology, Vol. 192, p. 1-19.

** niba@dhigroup.com: Agern Allé 5, DK-2970 Hørsholm, Denmark*
*** almu@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby, Denmark*
**** mmbr@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby, Denmark*
***** kiru@cowi.com : Parallelvej 2, 2800 Kongens Lyngby, Denmark*
****** mib@dhigroup.com: Agern Allé 5, DK-2970 Hørsholm, Denmark*

NoNewBAM: diflufenican degradation and potential leaching

P.N. Carvalho, AU-ENVS, S. Svendsen, AU-ENVS*, C.N. Albers, GEUS**, O.S. Jacobsen, GEUS**, K. Bester, AU-ENVS*, C.S. Jacobsen, AU-ENVS**

Abstract

Pesticides presence in groundwater is one of the hottest topics in Denmark. The extensive use in the past of herbicides has resulted in serious contamination of groundwater, e.g. dichlobenil transformation to 2,6-dichlorobenzamide (BAM). A new persistent, pre-emergent herbicide (Keeper-L) is sprayed in the urban areas, e.g. courtyards, driveways, tiled squares, and other places to avoid plant growth. AU-ENVS and GEUS, under an MST funded project, have focused on the herbicide diflufenican that, along with glyphosate (Keeper-L), is sprayed in Denmark in paved areas. The product registration was based on the data obtained from agricultural soil that typically contain much more organic matter and hence show higher sorption capacity and microbial activity. Thus, we hypothesized that in urban applications, diflufenican and its transformation products may end up contaminating both surface waters and groundwater.

Laboratorial studies were done to compare sorption and the degradation kinetics of diflufenican in soil and gravel. In addition, two separate outdoor experiments, subject to natural rain and meteorological conditions, were set up to separately study both emission routes. 1) to study surface runoff and leaching from paved surfaces, big steel trays with a depth of 12 cm were filled with sand/gravel overlaid with either concrete tiles or standard gravel paving forming a full-section of 1 m^2. 2) to compare the potential leaching to groundwater from five different soil types, a multicolumn lysimeter (21 columns, each 50 cm long and 15 cm in diameter) was set up. A sandy and a loamy agricultural soil, and three types of commercial gravels were assessed. Both outdoor setups were sprayed with Keeper-L following the manufacturer instructions. Leachate from both systems was collected for up to 1-year and analysed.

Diflufenican degradation in soil and gravels fitted zero and first order kinetics models, showing half-life's in the range 173 to 294 days, while the formation of the transformation product AE-B was measured for both soil types. Sorption data revealed that the transformation products are more mobile than the parent compound and that the sorption to agricultural soil was higher than to gravels. Thus, suggesting potential for higher leaching of the transformation products from gravels. The two outdoors paved surfaces leached diflufenican immediately in the first rain event, both through surface run-off and infiltration. Concentrations were as high as 11 µg/L in the run-off and leachate, while both known aerobic transformation products (AE-O and AE-B) were detected 7 days after the spraying. Different retention patterns were observed depending on the pavement material. The leachate from the outdoor multicolumn lysimeter revealed no leaching of diflufenican within a 1-year period. Nevertheless, concentrations up to

1.6 µg/L of both transformation products, AE-B and AE-O, were measured for the gravels but not for the agricultural soils. The different gravels showed also different transformation products formation and retention patterns.

In sum, transformation products are formed in gravel and paved areas, while diflufenican itself seems to pose a higher risk for stormwater contamination of surface water than for groundwater. Further assessment of different pollution scenarios is needed.

* pedro.carvalho@envs.au.dk, sibs@envs.au.dk, kb@envs.au.dk, csj@envs.au.dk: *Aarhus University, Department of Environmental Science, Frederiksborgvej 399, Roskilde 4000, Denmark*

** cal@geus.dk, osj@geus.dk: *Geological Survey of Denmark and Greenland, Department of Geochemistry, Øster Voldgade 10, 1350 København K, Denmark*

Improving flood risk modelling in a national water resources model for Denmark

R. Schneider[1], S. Stisen[1], M. Ondracek[1], H. J. Henriksen[1], E. Boegh[2]*

Abstract

The national water resource model of Denmark (DK model, www.vandmodel.dk) is a distributed transient groundwater-surface water model, set up in MIKE SHE. During its 20+-year-history it has been, amongst others, used to assess the available groundwater resource, as basis for regional models for mapping wellfield capture zones, to evaluate nitrate retention, and to assess the impact of climate change on the hydrological cycle and groundwater.

The work presented here focusses on improving the representation of shallow groundwater levels and water levels in rivers by use of the DK model. This aims at developing a national flood risk model for use in climate change adaptation, disaster risk reduction and water management. Two case studies, each covering about 1000 km^2, were used in the model development – the Storå and the Odense Å catchment. For those two areas, the effect of a more detailed model resolution (100 m compared to the original 500 m model grid of the DK model) was evaluated. We incorporated additional groundwater level observations in the uppermost 10 m below the surface in the calibration and validation of the model. For the calibration, we used a modified objective function based on the Continuous Rank Probability Score (CRPS) in order to minimize the adverse effect of outliers in the observations and model structure errors. Furthermore, we applied a hydrodynamic solution for water level simulations in the surface water model (MIKE HYDRO River), together with surveyed cross sections and detailed data on structures.

For the models with the finer 100 m resolution, the shallow groundwater level in depths of up to 10 m below surface could be modelled with an accuracy of 1 to 2 m (mean absolute error for the best 90% of

observations), which is slightly better than what can be achieved with a 500 m model resolution. Also stream discharge was improved for the 100 m compared to the 500 m resolution. Water levels in streams could be modelled with an average accuracy of up to 20 cm. The work compared the effect of different model resolutions, downscaling, simple routing and hydrodynamic solution with respect to their applicability to the national scale, and the ability to provide visualisations relevant for screening of areas at risk of flooding from groundwater or rivers. Moreover, a qualitative evaluation of the spatial accuracy of modelled flood water was performed with the aid of remote sensing observations.

**corresponding author: rs@geus.dk*
[1]De Nationale Geologiske Undersøgelser for Danmark og Grønland (GEUS), Øster Voldgade 10, 1350 København K, Danmark
[2]Styrelsen for Dataforsyning og Effektivisering (SDFE), Rentemestervej 8, 2400 København NV, Danmark

An integrated modelling framework for nutrient management

R.R. Frederiksen[1], T.N. Vilhelmsen[2], S. Christensen[3], A. V. Christiansen[4], B. Hansen[5], C. D. Børgesen[6], E. Auken[7]

Abstract
Estimation of the leaking of nitrate from the farm fields is the focus of the project "Open landscape nitrate retention mapping (rOpen)" funded by Innovation Fund Denmark. The project develops a number of different tools focusing primary on creating very detailed hydrological models incorporating geophysics in 3D, hydrogeochemistry and hydrology. The models are used to predict the leakage of nitrate into the streams, which fields it originates from, and the uncertainty of these estimates. To be able to run these complicated models we have developed a script-based integrated hydrological modelling framework which is highly data-driven, easy to update with new data, and geared towards scenario analysis.

The framework builds on FloPy, a Python package to create, run, and post-process MODFLOW-based models. The rOpen framework implements several types of input data and prepares and projects data onto the numerical model. Dense 3D geophysical data from the tTEM system together with lithological data from the Jupiter database are utilized for setting up the subsurface structures. A digital elevation model is used to define the model outline, layer elevations, sub-basins, and river networks. GIS layers are used to define location of additional boundary conditions and specify spatial distribution of climate, soil and crop type data. Percolation and nitrate leaching estimates calculated using the Daisy root-zone model are spatially distributed. Finally, groundwater flow and nitrate transport is modelled using MODFLOW and MODPATH. All of the data going into the framework are independent of the finite difference grid used in the numerical model facilitating easy model design modifications, e.g. horizontal and vertical discretization of the model. The rOpen framework is a general framework for setting up models for which site dependent modifications can be made to make it applicable in other areas. This allows fast, transparent, and data-driven model development.

In the presentation we will show a number of examples of input data preparation for the numerical groundwater flow model as well as examples of post-processing the model output. We also demonstrate how the framework efficiently is used for uncertainty analysis.

[1]*rasmus.rumph@geo.au.dk: C.F. Møllers Allé 4, DK-8000 Aarhus C, Denmark*
[2]*troels.norvin@geo.au.dk: C.F. Møllers Allé 4, DK-8000 Aarhus C, Denmark*
[3]*sc@geo.au.dk: Høegh-Guldbergs Gade 2, DK-8000 Aarhus C, Denmark*
[4]*anders.vest@geo.au.dk: C.F. Møllers Allé 4, DK-8000 Aarhus C, Denmark*
[5]*bgh@geus.dk: C.F. Møllers Allé 8, DK-8000 Aarhus C, Denmark*
[6]*christen.borgesen@agro.au.dk: Blichers Allé 20, DK-8830 Aarhus C, Denmark*
[7]*esben.auken@geo.au.dk: C.F. Møllers Allé 4, DK-8000 Aarhus C, Denmark*

Session 4; Urban water:

CHAIR: Marina B. Jensen & Peter E. Holm

Title	**Presented by**
Quantification of environmental damage and benefit of four different stormwater management systems	Sarah Brudler, Vand Center Syd
Groundwater recharging, erosion control and city greening – a novel nature-based system for road drainage	Alazar Assefa, CPH IGN
Nature enhancing SUDS: A case study on the planning, design, implementation and short-term evaluation of a full-scale bio-SUDS	Rikke J. Monberg, CPH-IGN
The benchmarking testing for GIS-based objective-oriented sub-model screening method	G. Zhao, CPH-IGN
Object based image analysis of WorldView 3 data for use in catchment scale urban hydrologic modelling	Mark Taylor Randall, CPH IGN

Quantification of environmental damage and benefit of four different stormwater management systems

Sarah Brudler, VCS Denmark / DTU Environment, K. Arnbjerg-Nielsen, DTU Environment**, M.Z. Hauschild, DTU Management Engineering***, C. Ammitsøe, HOFOR****, M. Rygaard, DTU Environment******

Abstract

Stormwater management (SWM) prevents uncontrolled flooding and pollution, while at the same time causing environmental impacts through 1) implementation, operation and decommissioning of stormwater infrastructure; and 2) point source emissions from discharges of polluted stormwater to the environment. We carried out a life cycle assessment (LCA) to quantify the long-term environmental damage of both emission sources for four different SWM systems for the Skibhus catchment in Odense: two subsurface systems (combined and separate), and two green infrastructure systems (soakaways and swales). All assessed systems comply with existing Danish flood safety standards. We quantified infrastructure processes based on documentation for implemented and planned SWM systems and literature and developed a comprehensive generic inventory of stormwater pollutants to assess point source emissions. The resulting damage of the four systems highlights a trade-off between increased resource consumption and decreased point source emissions (Figure 1). The subsurface system, where stormwater is treated in a central wastewater treatment plant, causes the highest resource availability damage (8.8E+03 USD/yr), while discharging least pollutants to receiving water and consequently causing least ecosystem damage (8.2E+07 species.yr/yr). Green infrastructure systems are less efficient in removing stormwater pollutants in vegetation and filter soil leading to higher ecosystem damage (9.9E+07 to 1.2E+08 species.yr/yr), but also require significantly less resources. When green areas are implemented on existing roads and plastic is recycled at the end of life, resource damage can even be avoided (-3.7+03 to -5.2E+03 USD/yr). These results highlight the importance of carrying out a holistic assessment including all relevant emissions and environmental impacts in order to optimize the environmental sustainability of SWM.

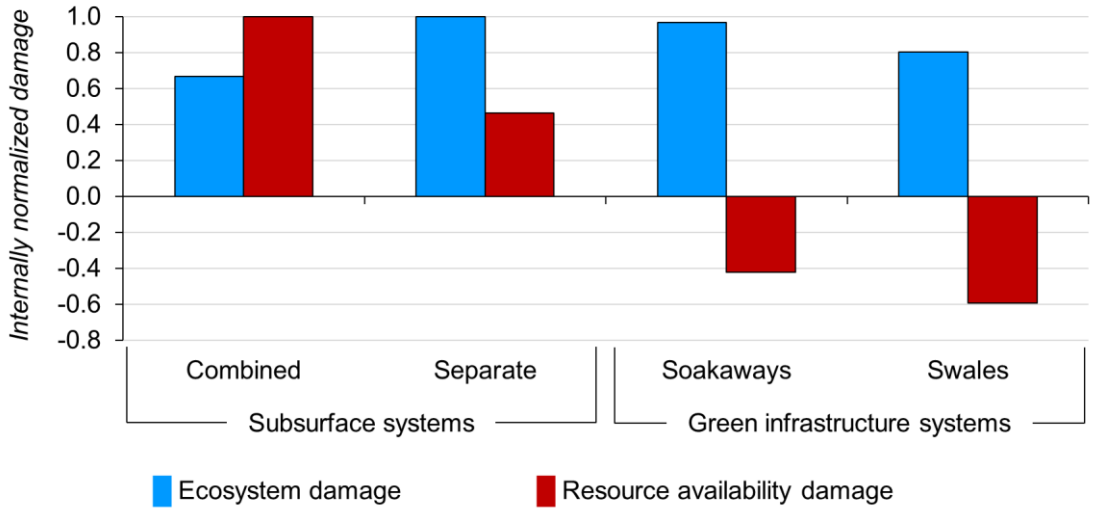


Figure 1. Internally normalised ecosystem and resource availability damage for four different stormwater management systems for the Skibhus catchment (Brudler, S., 2019. Life Cycle Assessment of Stormwater Management Systems – Quantification of environmental impacts for decision support. PhD thesis, DTU Environment, Lyngby)

** sbr@vandcenter.dk: Vandværksvej 7, 5000 Odense C*
*** karn@env.dtu.dk: Bygningstorvet, Bygning 115, 2800 Kgs. Lyngby*
**** mzha@dtu.dk: Produktionstorvet, Bygning 424, 2800 Kgs. Lyngby*
***** cham@hofor.dk : Ørestads Boulevard 35, 2300 København S*
****** mryg@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Kgs. Lyngby*

Groundwater recharging, erosion control and city greening – a novel nature-based system for road drainage

Alazar Assefa1,2, Marina Bergen Jensen2 and Kumelachew Yeshitela1*

Abstract

Contemporary practices of stormwater management in urbanized catchments seem to be shifting from conventional pipe-based discharge systems towards more nature-based retention systems. We designed a drainage system that can trap road runoff by use of infiltration trenches placed perpendicular to runoff direction and connected to tree pits, thus preventing downstream flooding and erosion while enhancing groundwater recharging and supporting green infrastructure. The design was tested on a typical, sloping cobblestone street in Addis Ababa, Ethiopia. From analysis of drainage patterns as logged with pressure transducers over a 24 d long rainy period we conclude that the infiltration trench received runoff not only from the road surface, but also from a below-ground sheet flow in the gravel layers serving as bedding for the cobblestones. If spaced correctly, the suggested infiltration trenches hold promise of a future multibeneficial drainage system that can be implemented as stand-alone elements constructed with gravel materials.

Keywords: infiltration trench, street tree irrigation, groundwater recharging, infiltration bumper with tree planter, climate adaptation, flood control

Illustration of the proposed and tested design for on-site management of stormwater runoff from cobblestone streets, referred to as 'Infiltration Bumper with Tree Planter'

1Ethiopian institute of Architecture, Building Construction and City Development, Addis Ababa University, 2Department of Geosciences and Natural Resource Management, University of Copenhagen

Nature enhancing SUDS: A case study on the planning, design, implementation and short-term evaluation of a full-scale bio-SUDS

R.J. Monberg[1], KU-IGN, A.G. Howe[2], KU-IGN, S. Kepfer-Rojas[3,] KU-IGN, H. P. Ravn[4], KU-IGN, O. D. Sørensen[5], Municipality of Allerød**, M. B. Jensen[5], KU-IGN*

Abstract

The ability of urban green areas to provide ecosystem services including biodiversity conservation and local climate regulation is increasingly recognised and triggers a demand for methods to improve urban nature qualities. Sustainable urban drainage systems (SUDS) are implemented to alleviate stormwater management issues but large design flexibility allows for development of designs targeting desired habitat types or species groups. While biodiversity in SUDS types such as green roofs and retention ponds are well studied, relatively little work examines terrestrial SUDS, such as dry basins, raingardens and swales which only hold water temporarily and often resemble various types of grasslands. Further, few studies examine how the detailed design of SUDS can contribute towards maximising nature qualities.

This study explores the potential of developing SUDS with enhanced ecological qualities (bio-SUDS). The study followed an applied science approach in which a full-scale bio-SUDS was tailored to a case site in Lynge, Denmark. The resulting Lynge bio-SUDS was a redesign of a grassland to provide a full stormwater solution for a 23.5 ha catchment at return periods of T=5 y. This study evaluates matches and mismatches between design principles derived from restoration ecology and SUDS design requirements, and further assesses the impact of the new bio-SUDS on ecological qualities in terms of plant species community composition and abundance of floral resources for pollinators.

The derived design principles provided useful inputs to enhance ecological quality in SUDS designs. However, ecological targets were compromised when trade-offs had to be made between ecological, stormwater and recreational targets. Ecological surveys showed that Lynge bio-SUDS significantly increased plant diversity at site level (beta-diversity) and contributed to increased floral resources in the first few years after implementation.

The study contributes to bridge the gap between ecological research and urban design aiming to enhance urban nature. Further, it illustrates a new possible level for urban stormwater management and urban nature practice and shows how SUDS can be used as a lever to promote urban ecological qualities.

[1]rikkejmonberg@gmail.com, [2]andy@ign.ku.dk, [3]skro@ign.ku.dk, [4]hpr@ign.ku.dk, [5]Ole.DahlqvistSorensen@Alleroed.dk, [6]mbj@ign.ku.dk

** Institut for Geovidenskab og Naturforvaltning, Rolighedsvej 23, 1958 Frederiksberg*
*** Municipality of Allerød, Bjarkesvej 2, 3450 Allerød*

The benchmarking testing for GIS-based objective-oriented sub-model screening method

G. Zhao, KU-IGN, T. Balstrøm, KU-IGN**, O. Mark, DHI***, M.B. Jensen, KU-IGN*****

Abstract

The urban flooding is one of the most critical natural hazards around the world which pose the significant threat to the human civilizations. To mitigate the flooding risk, the one-dimensional (1D) and two-dimensional (2D) model have been applied worldwide to gain a better understanding of flow dynamics as well as to provide feasible flooding hazard adaptation strategies. In contrast to the 1D model, by incorporating the complexity of the urban heterogeneity across the uniform 2D modelling grids, the cell-based flux derived from 2D models can achieve a more realistic simulation of the overland flow. However, these obtained benefits of modelling accuracies come at a substantial computational expense of 2D models particularly when the resolution of the modelling grid goes finer. Recently, due to the advancement of the remote sensing technologies, the produced decimetric resolution of digital elevation models (DEMs) may compound this issue even further. For these reasons, the computational efficiency of 2D models have limited their further implementations towards real-time simulation, high-resolution simulation and large-scale simulation.

In this research, we proposed a GIS-based objective-oriented sub-model screening method to optimize the computational efficiency of 2D models by generating a single-case representative model. By defining a flooding targeting object, this GIS automatic procedure would identify sub-impact zones by backwards tracing the continuity of overland flow. These reduced modelling areas can serve as the input to establish the minimal computational domain with a high-resolution modelling grid, which shapes a sub-model in 2D. Therefore, this sub-model screening approach can provide a significant computational efficiency to 2D models while preserving its modelling accuracy. To further validate this modelling approach, we conducted a benchmarking test for this method based on a Danish case area by using the MIKE FLOOD. The obtained results revealed the computational time can reach a factor of 200 faster as opposed to the directly hydrodynamic processing the original DEM at the basin scale; the computational accuracy towards flooding extents, depth and flow velocity are yield at an acceptable level. In addition, the test regarding an optimal modelling boundary for the generated sub-model has been discussed.

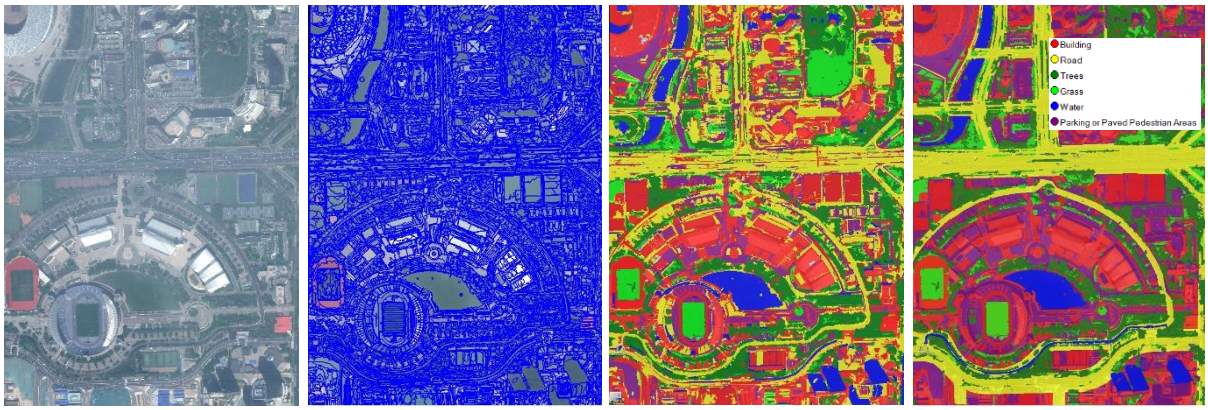
* *gz@ign.ku.dk: Rolighedsvej 23, 1958 Frederiksberg C*
** *tb@ign.ku.dk: Rolighedsvej 23, 1958 Frederiksberg C*
*** *omj@dhigroup.com : Agern Allé 5, DK-2970 Hørsholm, Denmark*
**** *mbj@ign.ku.dk: Rolighedsvej 23, 1958 Frederiksberg C*

Object based image analysis of WorldView 3 data for use in catchment scale urban hydrologic modelling

M.T. Randall, University of Copenhagen (IGN), Y. Zhang, Chinese Academy of Sciences**, M.B. Jensen, IGN University of Copenhagen (IGN)****

Abstract

Sponge City implementation in China will include widespread installation of various Sustainable Urban Drainage Systems (e.g. green roofs, rain gardens, permeable pavement) at a large scale in at least 30 cities across the country. Hydrologic modelling can support city planning at the catchment scale, however the detailed GIS data required for model input can be challenging to compile from the various authorities in China, or, if available may not be sufficiently detailed or updated. Remote sensing methods show great promise for mitigating this challenge due to their ability to quickly classify satellite images into categories relevant to a specific application. In this study Object Based Image Analysis (OBIA) was applied to WorldView-3 satellite imagery to create a detailed landcover map covering a 130 km^2 urban catchment in Beijing. The resulting landcover classification was used to parameterize a hydrologic model capable of quantifying reductions in runoff volume and peak flow provided by various levels of catchment wide Sponge City implementation for a range of return period events. While landcover classification results based on a Bayesian classifier alone provided an overall accuracy = 63 %, the subsequent inclusion of a series of refining rules in combination with supplementary data (including elevation and parcel delineations), yielded the significantly improved overall accuracy of 76%. Results of this study highlight challenges of automated classification based on satellite imagery alone and the potential value of supplementary data and manual adjustments to refine landcover classification results for use in hydrologic models.



Magnification of an example area shown as: Worldview-3 Pansharpened Image (0.4m) (a) Segmented Image (b) Bayes Classified Image (c), and Bayes Classified Image (after refining rules) (d)

* mtr@ign.ku.dk : Rolighedsvej 23,1958 Frederiksberg, Denmark
** zhangyy003@igsnrr.ac.cn: 11A, Datun Road, Chaoyang District, Beijing 100101, China
*** mbj@ign.ku.dk : Rolighedsvej 23,1958 Frederiksberg, Denmark

Session 5 & 6; Drinking water

CHAIR: Torben Lund Skovhus and Hans-Jørgen Albrechtsen

	Title	**Presented by**
13:00	The microbiome of bacteria released from pipe biofilm into drinking water, following installation of a hybrid ultrafiltration process in Varberg, Sweden.	Catherina J. Paul, Lund University, Lund Sweden
13:20	Front Loading the Design of PAS Technology	Thomas Aktor, Aktor
13:40	Softening of drinking water - Are other processes in the treatment impacted?	Hans-Jørgen Albrechtsen, DTU Environment
14:00	Performance indicators for the drinking water treatment process. Characteristics, barriers, and full-scale examples	Loren Ramsay, VIA University College
14:20	Manganese removal processes at 10 Danish full-scale drinking water treatment plants	Ines Lousinha Breda, Skanderborg Forsyning A/S
14:40	Stratification of physical parameters in dual media filters at 10 waterworks	Majbritt Lund, VIA University College
15:00-15:30	**Coffee Break**	
15:30	Development of a water forecasting tool based in Prophet to improve the management of Lorca's water supply system	Antonio Vigueras-Rodríguez, Universidad Politécnica de Cartagena (UPCT)
15:50	Campaign Process Analytical Technology - a PAT framework for recovered process-water in the food industry	Peter Bæk Skou, UCPH FOOD
16:10	Valve status identification by temperature modelling in water distribution networks	Jonas Kjeld Kirstein, DTU Envir
16:30	Water management in Kalundborg	Søren T. Nielsen, Kalundborg Forsyning
16:50	Poster presentations	
17:10	**European Junior Water Programme**	Naomi Timmer
17:20		

The microbiome of bacteria released from pipe biofilm into drinking water, following installation of a hybrid ultrafiltration process in Varberg, Sweden.

S. Chan, K. Pullerits**, Alexander Keucken***, K.M. Persson****, P. Rådström***** and **C.J. Paul*********

Drinking water is delivered from the treatment plant to the consumer through kilometres of pipes, with bacteria being constantly exchanged between the pipe biofilm and flowing water. However, with high numbers of bacteria in the water leaving the treatment plant, identifying those cells originating from the biofilm is difficult. Membrane hybrid processes (coagulation coupled with ultrafiltration (UF)) achieve enhanced removal of natural organic matter (NOM) and reduce membrane fouling while removing virtually all bacteria. In November 2016, the Kvarnagården Waterworks in Varberg, Sweden was upgraded with a UF facility (capacity of 1080 m^3 h^{-1} net permeate flow rate) providing the opportunity to observe the microbial consequences of exposing a distribution system previously exposed to high cellular counts, to a virtually cell-free water phase. By observing which bacteria entered the UF-treated water, those entering the water phase from pipe biofilm could be determined.

Water samples were taken before, three days after, and for one month after, installation of UF, for flow cytometry (FCM) and Illumina 16S rRNA gene amplicon sequencing. Samples from the UF feed showed an average of 8 x 10^5 cells/mL while filtered water contained 1.5 x 10^3 cells/mL after the installation of UF. Water samples from three locations in the distribution system, and at increasing distance from the treatment plant, showed an increased total cells, with, on average, an addition of 2.1 x 10^3 cells/ mL, contributed from bacteria leaving the biofilm. These bacteria were intact cells with an increasing nucleic acid content, relative to the water leaving the treatment plant.

16S rRNA amplicon sequencing of water samples revealed that the community present in the disitrbuted water originated from the biofilm. The community in the distributed water was distinct from the finished water, and differed with respect to location within the distribution system. Both species richness and diversity in the distributed water decreased following installation of UF. Differential analysis of sequencing reads counts by DESeq2 identified statistically significant operational taxonomic units (OTUs) that had changed in the water as it was in contact with the pipe biofilms. These included *Hyphomicrobium, Nitrospira, Sphingomonas, Mycobacterium* and *Rhodobacter* as well as several unidentified genera and as no specific mode of motility is represented by these taxa, suggest that release of bacteria into the flowing water is not determined by a specific mechanism. How the overall microbiome of both the biofilm and the water phase in this distribution system will adapt to the UF treated water over a longer time period will provide additional information about how pipe biofilms respond to large changes in the microbiology of distributed water.

**Sandy.chan@tmb.lth.se: Sydvatten AB, Hyllie stationstorg 21, 532 Malmö, Sweden.*

*** Kristjan.pullerits@tmb.lth.se : Lund University, Naturvetarvägen 14, 22 100; and Sweden water research AB, Ideon Science Park, 223 70, Lund, Sweden.*

**** alexander.keucken@vivab.info : Vatten & Miljö i Väst AB, Box 110, 311 22 Falkenberg, Sweden*

***** Kenneth_m.persson@tvrl.lth.se :Water Resources Engineering, Dept.of Building and Environmental Engineering, Lund University 223 63Lund, Sweden; Sydvatten AB, Hyllie stationstorg 21, 532 Malmö, Sweden; and and Sweden water research AB, Ideon Science Park, 223 70, Lund, Sweden.*

****** Peter.Rådström@tmb.lth.se : Lund University, Naturvetarvägen 14, 22 100 Lund, Sweden.[5]*

********catherine.paul@tmb.lth.se Water Resources Engineering, Dept.of Building and Environmental Engineering, Lund University22 100 Lund, Sweden 223 63, Lund, Sweden.*

Front Loading the Design of PAS Technology.

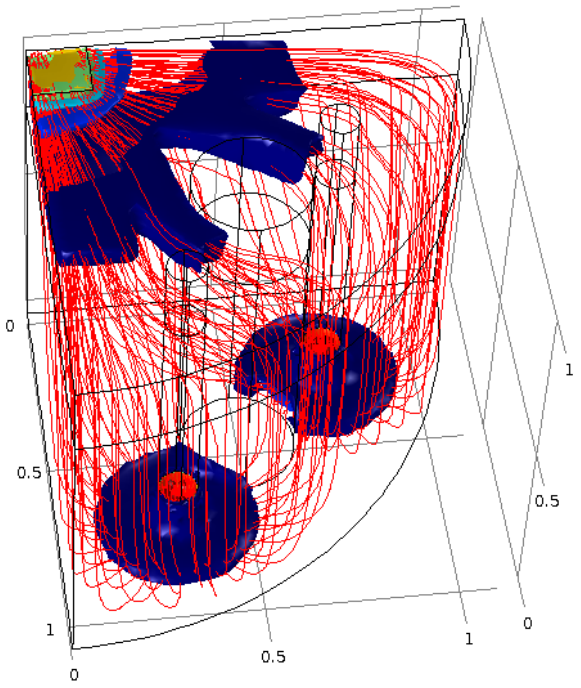
Thomas Aktor, L. Aktor** & H. Aktor****

Abstract

Bringing new ideas to market are often time-consuming and costly, and as new technology gets outdated fast, it gives an incentive to accelerate the design and development processes. AA-Water is a small business focused on developing a patent pending water-softening technique called PAS and have tried to work around the limited resources available and still make fast progress.

In order to mitigate the cost of mistakes and learn the most from the mistakes that do happen, we have been using mathematical modelling. Using these tools have allowed us to predict the differences between branching design choices and explain experimental results. The technology relies mainly on the coupling between the microscopic diffusion limited mass transfer that controls the precipitation of calcite, and macroscopic fluid flow. By modelling the flow using CFD in the PAS filter, we have significantly simplified the design and cut development cost and select the successful parts of a specific design that can be carried on to the next generation. This strategy has reduced the amount of experimentation, and thus cost and time, needed for successful designs.

We show some situations where the models helped us reassess our intuitive choices and practical experience and changed the design in a meaningful way.



* thomas@aktor.dk : AA-W
** lars@aktor.dk : AA-Wate
*** aawater@aawater.dk : AA-Water ApS

Abiotic denitrification and Nitrogen recycling using Zero-valent Iron and Zeolite

Adrian F. Florea, H. C. B. Hansen**, University of Copenhagen*

Abstract

Intensive application of nitrogen-based fertilizer to agricultural fields results in high leaching of nitrate to the aqueous environment, further resulting in poor water quality, lowering of biodiversity, poor conditions

for fishery and high remediation costs. Additionally, high costs and high-energy consumption associated with industrial synthesis of ammonia trigger the need of new treatment concepts for agricultural drainage water.

With agricultural drainage water as potential source of nitrogen, the aim of this study was to develop a filtration system that can remove nitrate (NO_3^-) and recover nitrogen as ammonium from agricultural drainage water. Therefore, zero-valent iron (ZVI) and clinoptilolite (a natural form of zeolite), were used as filter materials, and with the ZVI filter part preceding the clinoptilolite trap.

The reductive properties of ZVI are highlighted by a high efficiency of nitrate removal from agricultural drainage water, including stoichiometric reduction of nitrate to ammonium. Using 900 grams of ZVI, results showed 82 % overall nitrate removal efficiency over 40 days of continuous operation of the filter system. A total amount of 480 L agricultural drainage water, containing 9 mg/L NO_3^--N, was filtrated during the experiment. However, only approximately 57 g of the ZVI was consumed in the process, corresponding to 6.33% of the total amount of ZVI used in the column experiment. As nitrate reduction by ZVI is a corrosive process, the ZVI material got partly inactivated probably due to surface passivation/corrosions, a strong limiting factor for use of ZVI filters.

Ammonium concentration measured accounted for 100% of the nitrate reduced by ZVI, at any time interval for the first two weeks of the experiment. Conversion of nitrate to ammonium decreased after this initial period and reached a leve of 75% - 85%. This incomplete conversion could be due to multiple factors as analytical standard error, production of unmonitored nitrogen gas species (NO_2, N_2O, N_2H_4), sorption of nitrate or ammonium ion on surface of ZVI or microbial processes.

The zeolite was able to retain all ammonium formed in the process over the first 12 days of the experiment. Zeolite's retention capacity decreased slowly over time, but with no total saturation.

The experiment proofs the principle of the system. However, the system needs improvement such as reestablishment of the initial conditions of the ZVI and regeneration of the zeolite. Nitrate reduction to ammonium would be an important way to reduce energy consumption for industrial ammonium production and to apply the concept of circular economy to nitrogen.

* aff@plen.ku.dk: *Department of Plant and Environmental Science, Thorvaldsensvej 40, DK-1871 Frederiksberg C* ** haha@plen.ku.dk : *Department of Plant and Environmental Science, Thorvaldsensvej 40 DK-1871 Frederiksberg C*

Softening of drinking water – are other processes in the treatment affected?

H.-J. Albrechtsen, DTU Environment, C.O. Lee, DTU Environment, K.K. Johansen, HOFOR. M.J. Hedegaard, HOFOR, S.C.B. Christensen, HOFOR, T. Beyer, HOFOR, A.-K. Pedersen, HOFOR***

Abstract

Currently, softening of drinking water is being initiated at a number of water works in Denmark. A range of technologies are used for softening – one of most frequently used is the pellet reactor-technology. The principle is to precipitate $CaCO_3$ on suspended pellets in an up flow reactor. A base (typically NaOH) is injected in the bottom of the reactor to increase pH to above 10. Under these conditions $CaCO_3$ precipitates on the sand grains, forming chalk pellets. The water is neutralised by addition of CO_2 before the water leaves the column. The formed pellets are collected from the bottom of the column, and are replace by fresh sand, and the sand grains are the precipitation nucleus for $CaCO_3$ and form new pellets.

The water is thus affected by substantial changes in pH and by precipitations, where several ions can precipitate together with Ca^{2+}. At Brøndbyvester Vandværk (HOFOR) the anaerobic raw water is softened before aeration, so iron and manganese have not been removed before softening, and can subsequently precipitate in the pellets. In this way the removal of iron and manganese is radically different from

traditional oxidation and removal during sand filtering. This opens opportunities for longer run-time before the sand filters have to be backwashed than if iron is precipitation in the sand filters.

This change in the management of the sand filters, and the precipitation processes during softening could affect some of the processes usually running in the sand filters. One of these processes is removal of ammonium, which is microbially oxidized to nitrate by nitrification. Ammonium monooxygenase (AMO) is a central enzyme in this process, and this enzyme depends on copper to work optimally. If copper unintentionally is removed from the water during softening, the nitrification may be affected. Furthermore, if the precipitation of $CaCO_3$ is not stopped efficiently, when the water leaves the pellet reactor, the precipitation of $CaCO_3$ may continue. In absence of precipitation nuclei this may lead to formation of 'fines' in terms of micro crystals of chalk. They may end up in and clog the sand filters. If the sand added to the pellet reactor as precipitation nucleus contains are so fine particles, that they are washed out of the reactor, these fines may also affect the management of the sand filters.

Metals such as nickel and chromium are usually removed from the water phase when iron is precipitated in the sand filters – but if iron already was removed during softening, can nickel and chromium then be removed sufficiently? Should this happen already during pellet formation in the pellet reactor?

These questions are addressed in investigations before and after the implementation of softening at Brøndbyvester Vandværk by sampling water from central points in the water treatment and from different depths of the sand filter. The investigation also included filter material from both a new sand filter as well as from a sand filter which has been in operation for many years.

Preliminary results show no inhibition from softening on nitrification – neither regarding new or old filter material. On contrary, it seems as if the efficiency of nitrification is increased, and that the process is lifted upwards in the filter. The majority of the iron and manganese is removed in the pellet reactor. In this way the removal of nickel is reduced in the sand filters, and it is therefore crucial that nickel also is removed in the pellet reactor, which seems to be the case.

The project is supported of VUDP, and has the following partners:
HOFOR v. Sektionsleder Ann-Katrin Pedersen
DTU Miljø, v. Professor Hans-Jørgen Albrechtsen
Frederiksberg Forsyning A/S, v. Vandchef Henrik Bay, Herman Juel
Krüger A/S, Innovation Manager - Water Supply, v. Rasmus Boe-Hansen
* *hana@env.dtu.dk: Bygningstorvet, Bygning 115, 2800 Lyngby*
** *akpe@hofor.dk: Ørestads Boulevard 35, 2300 København S*

Performance indicators for the drinking water treatment process Characteristics, barriers, and full-scale examples 13th annual Danish Water Forum, Copenhagen, Jan. 31, 2019

L. Ramsay, VIA University College; M. Ramsay**, CEATH Company*

Abstract

Performance indicators (PIs) are used to evaluate the success of organizations in fields ranging from education to healthcare. In the field of drinking water, PIs are typically limited to the financial domain, i.e. production costs/m^3. Other domains, such as the water treatment, have received less attention. This study focusses on the technical aspects of the drinking water treatment process in pursuance of best practices for water treatment and an ultimate goal of the redesign of waterworks.
PIs are typically product-based rather than process-based. Process-based PIs, however, are better suited for providing operators with the tools needed to implement evidence-based decisions. Although several

studies have looked at technical PIs for the water treatment process, no studies focussing on the water treatment process in water treatment plants (WTPs) using groundwater sources and biofiltration were found.

In this study, the first step was to identify relevant PIs. In general, relevant PIs are characterized by three major factors. Firstly, a PI should provide insight into an important challenge in the water treatment process, such as treatment efficiency, drinking water quality, energy use, etc. Secondly, the variation of the PI between different WTPs should be large, since there is little opportunity for learning if the variation is small. When a new PI is developed, an initial high variation between plants typically narrows over time as personnel learn from each other's practices and implement improvements. Finally, the cost and effort required to obtain PI data (i.e. sampling and analysis) should not exceed the potential benefits of the insights that may be obtained.

Several barriers to implementing process-based PIs were identified in this study. There is currently no legislation requiring the collection of data on the water treatment process. Furthermore, relevant technical PIs for the water treatment process have yet to be adopted. At the outset of this project, Denmark had no database for water treatment PIs, even though the national Jupiter database for well and water quality data is world class. The cost of obtaining the needed data is also a potential barrier. Finally, there is a need for a critical mass of participating WTPs to ensure a valid benchmark and there is a need for a forum for sharing data and heightening awareness of the potential benefits of implementing water treatment PIs.

In 2018, a rigorous sampling and analysis programme was carried out at 10 full-scale waterworks in Denmark. PIs were developed and visualisations prepared in areas such as filter loading, removal rates, filter medium growth, filter footprint, tank utilization, etc. As the first of its kind, a database, Merkur, was designed and data from the 10 WTPs entered. Results show how PIs can provide operators and designers with needed feedback.

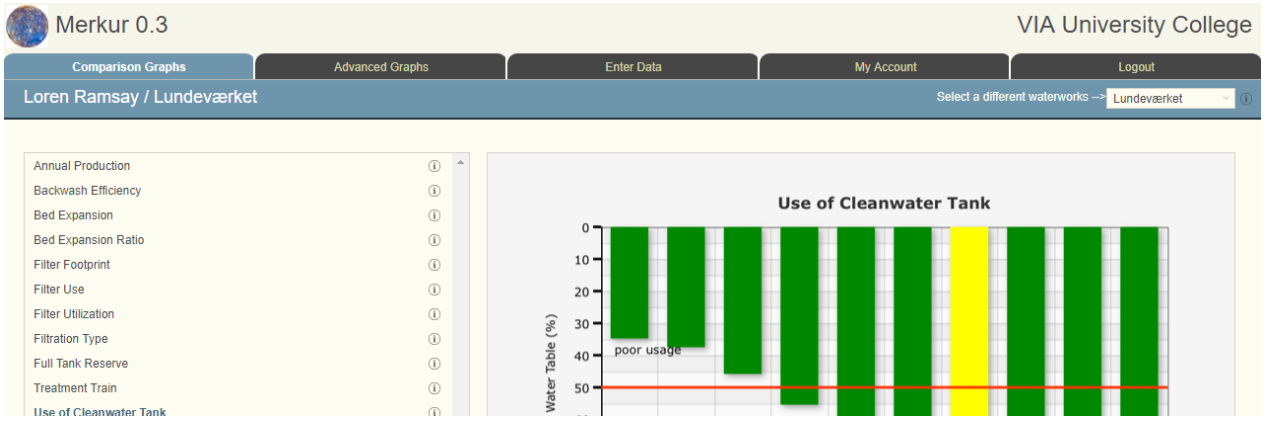


Figure 3 Partial screen shot of the Merkur dashboard.

The authors gratefully acknowledge the entire sampling and analysis team. This work was financed in part by the Danish MUDP programme and was performed by Aarhus Water, VandCenter Syd, Vand og Teknik, Amphi-Bac, Dansk Kvarts Industri, NIRAS and VIA University College with assistance from CEATH Company and Virtual Water Technology.

* *lora@via.dk; Chr. M. Østergaards Vej 4, 8700 Horsens, Denmark* ***mail@ceath.com; 1788 Hwy. 1016, Berea, KY 40403 USA*

Manganese removal processes at 10 Danish full-scale drinking water treatment plants

I. *L. Breda, Skanderborg Forsyning A/S *, D. A. Søborg, VIA University College **, L. Ramsay, VIA University College ***, P. Roslev, Aalborg University*****

Abstract

Manganese (Mn) removal in drinking water filters is facilitated by biological and physico-chemical processes. However, there is often limited information about the dominant processes for Mn removal and the spatial distribution of activity in full-scale matured filters with different filter media. In this study, water and filter material were collected from 10 Danish full-scale drinking water treatment plants over 20 cm depth intervals of the filters (Figure A-B), to classify the Mn removal processes (biological or physico-chemical), evaluate the potential use of enhancers, and gain further insight on operational conditions of matured filters for efficient Mn removal. The first order Mn removal constant at the 10 DWTPs varied from 0.02-0.17 min-1. The amount of Mn coating the filter material grains showed a strong correlation with the amount of iron, calcium and total coating, but no correlation with concentration of ATP (Figure C). Inhibition of biological activity showed that Mn removal in matured filters was dominated by physico-chemical processes, with variation between 70-93% among the different waterworks (Figure D). Addition of phosphorous and trace metals showed variable effect on Mn removal capacity, indicating that enhancement of Mn removal in matured filters is possible but challenging. In addition, this investigation provides practical guidance to the design and operation of drinking water filters for efficient Mn removal. On a practical note, results showed a limited detrimental effect of NH4 and a limited effect of filter material type (quartz sand, anthracite, calcium carbonate) on the Mn removal capacity of matured filters. Further, results indicate a switch in the stratification of Mn and NH4 removal processes over filter depth as the filter matures (Figure E).

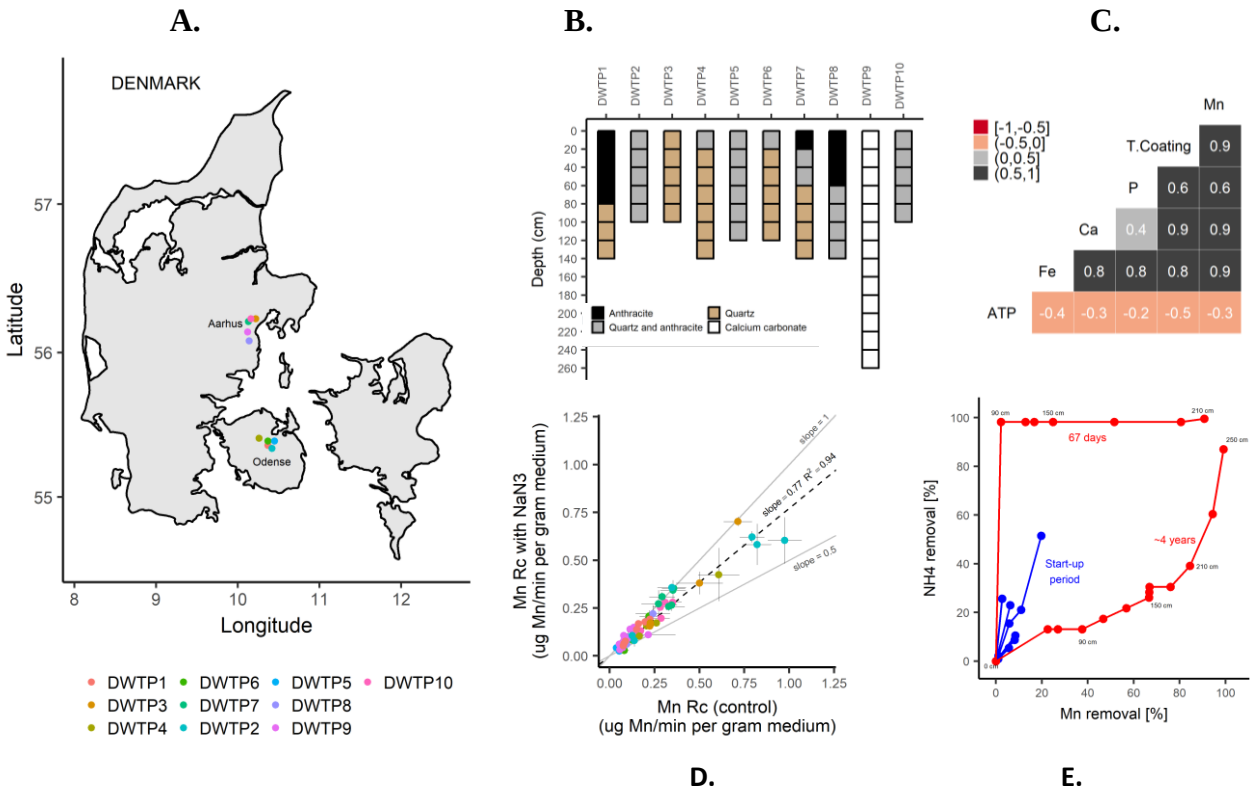


Figure A. Location of the 10 waterworks included in the study. **B.** Filter material distribution over depth at each waterworks. **C.** Pearson correlation between selected filter material properties from filter medium samples. **D.** Plot of Mn removal capacity (*Rc*) with NaN_3 versus Mn *Rc* without NaN_3 (control). **E.** Mn versus

NH_4 removal (percentage) from water samples collected at every 10 cm depth of the filters in relation to inlet concentrations at each of the 10 waterworks.

* ilb@skanderborgforsyning.dk: Døjsøvej 1, 8660 Skanderborg, Denmark.
** dans@via.dk *** lora@via.dk: Chr. M. Østergaards Vej 4, 8700 Horsens, Denmark.
**** pr@bio.aau.dk: Fredrik Bajers Vej 7H, 9220 Aalborg, Denmark.

Stratification of physical parameters in dual media filters at 10 waterworks

*M. Lund *, VIA University College; D.A. Søborg**, VIA University College;*
*L. Ramsay***, VIA University College*

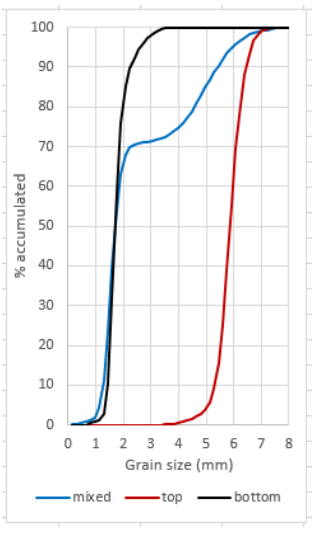
Abstract

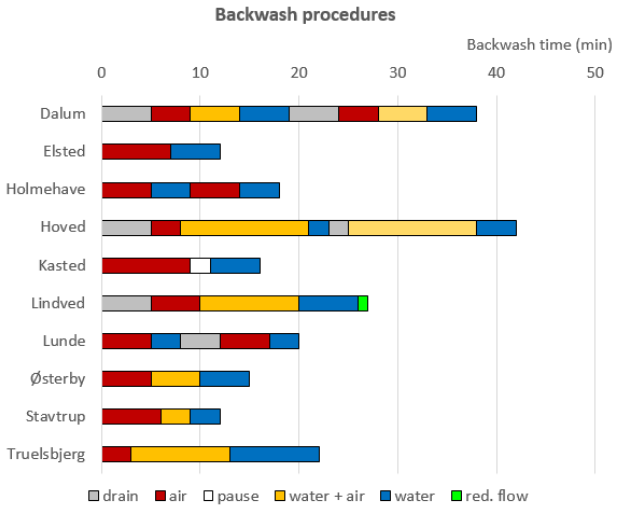
In Denmark, the use of dual media in rapid sand filters for drinking water treatment is widespread. In gravity filters with groundwater sources, the typical construction is a 50-100 cm layer of sand (granular quarts) overlain by a 30-50 cm layer of granular anthracite. The anthracite has a larger grain size than the sand, which purportedly reduces clogging and the required frequency of backwashing.

Filter backwashing can influence the layering of filter material. According to the textbook explanation, backwashing removes trapped iron oxides from the pore volume and returns the grains to their original layered position with the anthracite on top. This study examined this explanation in detail, using filter media samples from 10 waterworks. The study identified potential causes of stratification or lack thereof as well as the variation of selected physical filter media parameters with depth.

Large amounts of data were collected from various depths in the filters at 10 waterworks. Measured parameters included grain size distribution, grain coating, porosity, particle density, grain shape, bed expansion, iron mass balance, media age, media growth, and backwash procedures.

Results showed that almost every physical parameter that was measured varied greatly from one waterworks to another. Strong correlations between certain parameters were found. The take home message is that a new explanation regarding the effect of backwashing of dual media rapid sand filters must replace the existing textbook explanation. The new narrative is closely bound to the backwash procedure, the age of the filter media, the density of the granular material and other parameters. This understanding has wide-reaching consequences for the operation of drinking water treatment plants.





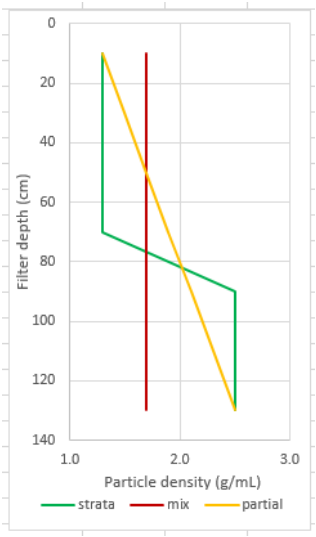


Figure 4 Particle density profile (conceptual), grain size profile and backwash procedures at 10 waterworks.

The authors gratefully acknowledge the entire sampling and analysis team. This work was financed in part by the MUDP programme and was performed by Aarhus Water, VandCenter Syd, Vand og Teknik, Amphi-Bac, Dansk Kvarts Industri, NIRAS and VIA University College, assisted by CEATH Company and Virtual Water Technologies.

* majl@via.dk *Chr. M. Østergaards Vej 4, 8700 Horsens, Denmark*
** dans@via.dk*: Chr. M. Østergaards Vej 4, 8700 Horsens, Denmark*
*** lora@via.dk*: Chr. M. Østergaards Vej 4, 8700 Horsens, Denmark*

Development of a water forecasting tool based in Prophet to improve the management of Lorca's water supply system.

*A. Casanova, A. Vigueras-Rodríguez, Luis G. Castillo & Juan T. García, UPCT**
*F. Piqueras, J. Ruiz, Aguas de Lorca***

Abstract

Lorca is the 2nd largest municipal district in Spain (1675 km^2). It also has one of the most longer water supply network (>1200 km) divided in 6 hydraulic districts. The water supply system is being real time monitored, feeding a PostgreSQL database. It allows to get a large amount of relevant information about the water supply system state and performance.
In this paper, a statistical model has been developed parting from one of the historical water meter's data. Such model has been done using Prophet, which is a time series forecasting model whose implementation is available as open source software in Python and R [1]. It uses a decomposable time series model [2] with three main model components: trend, seasonality and holidays.
In this real-case studio, we feed daily the statistical model with the PostgreSQL database. After that, we run a Prophet script which detects the trends, seasonality and self-adjusts. Once the statistic model has been adjusted and validated, the model is being used for forecasting the daily water consumption in the water meter mentioned previously for the following 14 days. Such forecast is shown in figure 1, where besides the daily water consumption forecast for the following 14 days, the upper and lower confidence interval is also shown as well as the real data. In this part of Lorca's water supply system the dataset updates daily, so the model self-adjusts itself and forecasts the following consumptions. The tool is being assessed as an alarm system triggered when the new dataset diverges of the predicted confidence interval.
This application pretends to improve the management of the water system as it can be used to optimised management of water resources for future periods as well as a possible way to detect relevant leakages or volumetric frauds.

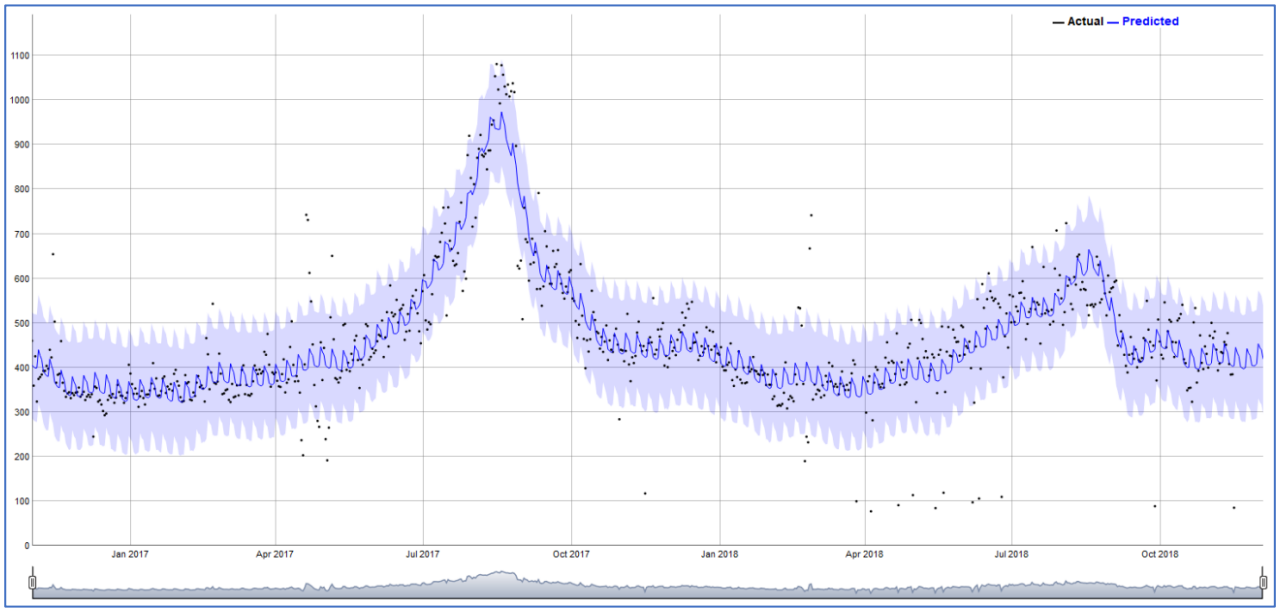


Figure 1: Statistic model of a water counter in the Water Supply system of Lorca (Murcia, Spain).

References

[1] Taylor, S. J., & Letham, B. (2017). Forecasting at Scale, 1–25.

[2] Harvey, A. & Peters, S. (1990), 'Estimation procedures for structural time series models', Journal of Forecasting 9, 89-108.

* casanovagonzalez.a@gmail.com, aviqueras.rodriguez@upct.es, juan.gbermejo@upct.es, luis.castillo@upct.es: *Dept. of Civil Engineering, Universidad Politécnica de Cartagena. Paseo Alfonso XIII 52, 30203 Cartagena, Spain*.

** piqueras@aguasdelorca.es, jruizman@aguasdelorca.es: *Technical Department, Aguas de Lorca. C/Príncipe Alfonso 4 Bajo (Edificio Teatro), 30800 Lorca (Murcia), Spain*.

Campaign Process Analytical Technology - a PAT framework for recovered process-water in the food industry

P.B. Skou & F.W.J. van den Berg, UCPH FOOD

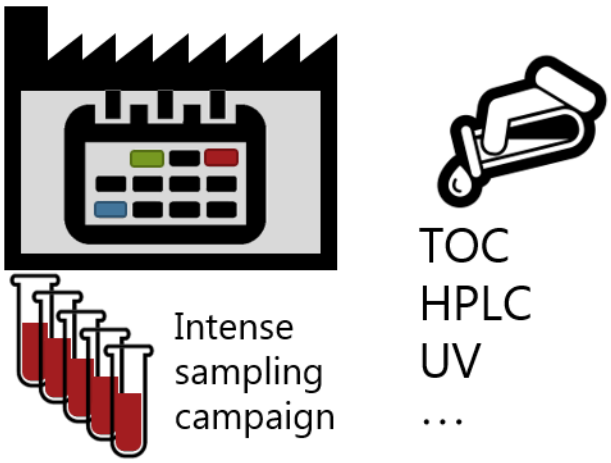
Abstract

The potential for replacing potable water with process-water in the dairy and food industry is enormous. However, food safety must be guaranteed under all circumstances, and utilizing recovered process-water might potentially form a new, unknown risk. One way to ensure sufficient quality at all times is through on-line monitoring of relevant quality parameters. For this goal we often resort to the Process Analytical Technology (PAT) framework where this real-time monitoring strategy is the paradigm. The PAT framework is however broader than just real-time monitoring.

Research in process-water quality suggests that reverse-osmosis membrane and evaporation processes (i.e. common processes in the food industry that produce large amounts of water as by-product) are very stable over run-time, but show fluctuations between production sites, operation settings, feed sources and the cyclic production-CIP-dynamics of the unit operation and water-sources. The quality of these recovered process-water streams is very high (TOC <50 $mg \cdot L^{-1}$ and <1 $CFU \cdot ml^{-1}$) which means that available on-line measuring technologies are not sensitive enough, and defining quality parameters (or target molecules) is challenging. In this scenario real-time, on-line monitoring is neither feasible nor necessary.

Instead, we suggest that producers rather than chase on-line solutions spend resources on detailed characterization of process-water quality over process-time. This characterization should be done with highly detailed, broad covering methods such as GC-MS or HPLC-MS(MS), either in-house, but probably more conveniently by external experts, supplemented with more conventional analysis such as near infrared and UV spectroscopy, TOC, conductivity, etc. The output is a representation of the recovered process-water streams in the nominal composition plus fluctuations due to the (unavoidable) production dynamics, and a translation of cumulative values like TOC and conductivity into their building blocks.

We propose the concept of so-called Campaign PAT for building up the necessary knowledge and understanding about the recovered process-water used to replace potable water. PAT provides the sampling strategy, the (initially untargeted) measurement strategy, and the process chemometrics for statistical model building on dynamic systems. This detailed campaign could be conducted for new implementations, when a significant change is made to the production process, the CIP regimes and/or the recovery process, or periodically to ensure safe use and understanding. In this paper we will show our practical experiences with Campaign PAT using investigations dairy ingredients industry.



* Peter.b.skou@food.ku.dk

Valve status identification by temperature modelling in water distribution networks

J.K. Kirstein, K. Høgh**, M. Borup*, M. Rygaard**

Abstract

Within recent years, drinking water utilities have started to collect daily, or even more frequent, data from the source to the consumers' households. In most cases, this information is used to monitor the state of the water distribution network, including the identification of differences in the supplied and consumed/billed water. Newer data streams, such as the collection of temperature data from household smart meters, can provide insights into the quality of the supplied water. Temperature data have another benefit that is not fully exploited: when the soil temperature is different from the source temperature of the water, the water may cool down or warm up and the change in temperature stores valuable information about its path to the consumer.

To explore the potential of distributed temperature measurements, we combined a heat transfer model with a hydraulic model to simulate the temperature change throughout a water distribution network. Our model was developed to facilitate an identification of valve location and status (opened/closed) in the networks without field visits. An unknown location or status of valves can complicate maintenance works or renovation projects of networks, or hinder accurate tracking of drinking water quality. Traditionally, checking and correcting unknown/incorrect valve status is time-consuming and costly, and therefore a nuisance for water utilities.

To identify the actual valve status throughout a water distribution network, we applied a genetic algorithm. The algorithm intends to converge towards a set of valves settings that minimizes the mean squared error, obtained by the residuals between the available observed and simulated pressure, flow and temperature data. To demonstrate our method we used two cases: 1) a theoretical set-up, with real temperature, pressure and flow measurements at the inlets of a real district metered area in Northern Copenhagen. In this set-up, five valves were closed and the temperature simulation based on this set-up was stored as the 'perfect solution'. Next, the genetic algorithm's aim was to identify the set of five closed valves by starting with a network where all valves were open. The robustness of this approach was assessed by adding noise to various parameters in the network (e.g. soil conductivity) and by varying the temperature data available (e.g. time scale). 2) a model set-up based on the Novafos transportation network, was generated. In this set-up, we used flow and pressure measured at inlets and outlets of the network, and temperature measured at two locations in the network. It was investigated whether the algorithm converged towards valve settings known to the utility.

Results of the first set-up revealed that the genetic algorithm converged successfully after around 10,000 simulations to identify the correct set of valves. Selected valves with a high effect on the temperature distribution in the network were identified as early as during the first generations of the genetic algorithm. Likely, the sole application of conventional pressure and flow measurements would not have identified these valves as their status has a very low impact on the pressure drop in the network. In the real case set-up, it was found that high discrepancies between modelled and simulated values were caused by incorrect network descriptions in the hydraulic model. The hydraulic model was not able to represent the real distribution of the water in the network and showed a marked difference between observed and modelled temperatures that could not be explained by errors in the thermodynamic model alone. Our modelling results revealed fundamental flaws in the hydraulic model set-up not previously identified. This shows a potential for exploiting water quality data such as temperature in the calibration and validation of hydraulic models for water distribution networks. Also, the real case study showed that high-quality input data are needed to run the method adequately. In the future, the method will be tested on a district metered area with real temperature measurements from smart meters.

** jkir@env.dtu.dk, morb@env.dtu.dk, mryg@env.dtu.dk : DTU Environment, Bygningstorvet, Bygning 115, 2800 Lyngby*

*** kvh@niras.dk: NIRAS A/S, Sortemosevej 19, 3450 Allerød*

Abstract, water management in Kalundborg

S.T. Nielsen, Kalundborg Vandforsyning A/S* og H.M.F Møller, Kalundborg Vandforsyning A/S*

Abstract

Kalundborg Water Supply (KALFOR) provides drinking water based on groundwater for the municipality of Kalundborg and the industries in the area. Historically, demand has risen by 1 million m³ in 10 years over the last 40 years, and there is no indication that the curve will break. Currently demand is 3.5 million m³/year.

KALFOR has permission to produce 2.2 million m³/year at the waterworks in Deigvad. The groundwater for the production comes from three well fields near the waterworks. Currently we produce 1.6 million m³/year, the rest is imported from two external suppliers one of which supplies 400.000 m³/year (one waterworks) and the other up to 1.9 million m³/year (nine waterworks). Deliveries are based on long term contracts.

It is KALFOR's view that external suppliers must meet the same requirements as we are subject to. We therefore conduct annual external audits at the 10 waterworks that provide external deliveries to ensure, at they also meet the requirements of DS EN 22000. Failure to comply with the requirements of DS EN 22000 results in a periodic or permanent ban on deliveries to KALFOR.

New 30-year permits for KALFOR's three well fields were given in 2017. This in combination with the findings of the pesticide degradation product Desphenyl Chloridazon below the quality requirement in three wells at two well fields called for action. KALFOR'S Board of Directors decided in spring 2018 that pesticide-containing water under the quality requirement must be used for drinking water purposes.

We have therefore conducted condition assessments of all water supply wells on the two well fields to identify the renovation needs. Archive information, dating of the water age, pump tests, geological modelling and borehole logging including video inspection revealed several wells in poor condition. This, in combination with the lack of monitoring possibilities, led to the decision to renovate the well fields.

soni@kalfor.dk : Dokhavnsvej 15, 4400 Kalundborg, Denmark
hmm@kalfor.dk : Dokhavnsvej 15, 4400 Kalundborg, Denmark

POSTERS

Monitoring of primary treatment: Estimation of the bioavailable organic carbon in wastewater by measuring the total organic solids (TSS) and turbidity	Sofoklis Karvelas
Water efficient process optimization by applying flotation technology for further reuse of landing water	Michelle Lison Rebsdorf
Aiming for a reduced chloride discharge at Arla DP - Simple means with significant effect	Rune Røjgaard Andreasen

Monitoring of primary treatment: Estimation of the bioavailable organic carbon in wastewater by measuring the total organic solids (TSS) and turbidity

S. Karvelas, H.R. Andersen, B. Valverde-Pérez,** DTU Environment*

Abstract

Nowadays, municipal wastewater treatment plants (WWTP) aim to become energy neutral (or even positive) by maximizing the energy recovery via anaerobic digestion and minimizing the aeration demand for biological pollutant removal. Primary treatment, which controls the particulate organic carbon send to biological treatment, can play a pivotal role to achieve net energy production. The primary effluent quality can be optimized by controlling chemical dosing in primary clarifiers or drum filters. Thereby, the maximum amount of bioavailable organic carbon (referred to as BCOD i.e. bioavailable chemical oxygen demand) in the raw wastewater can be recovered in the primary treatment units and sent to the anaerobic digesters at the WWTP. Additionally, the aeration demand of biological treatment could be minimized by supplying only the necessary amount of BCOD required for nutrient removal. However, up to date there are not simple, cheap and reliable methods for online monitoring of biologically available organic carbon, which prevents the development novel optimizing control strategies. State of the art COD sensors are available in market but they are expensive and they often show poor reliability and need of frequent calibration. An alternative solution is the monitoring of surrogate parameters such as turbidity or total suspended solids (TSS). By correlating these physical parameters with the BCOD, which is the bioavailable carbon for bacterial growth, the effluent carbon concentration could be monitored and thus new advanced control strategies may be designed for optimal energy recovery and nutrient removal. Up to date, turbidity measurements have shown good correlation to COD (Väänänen et al., 2017), but to the best of our knowledge correlations between BCOD and turbidity have not been explored yet.

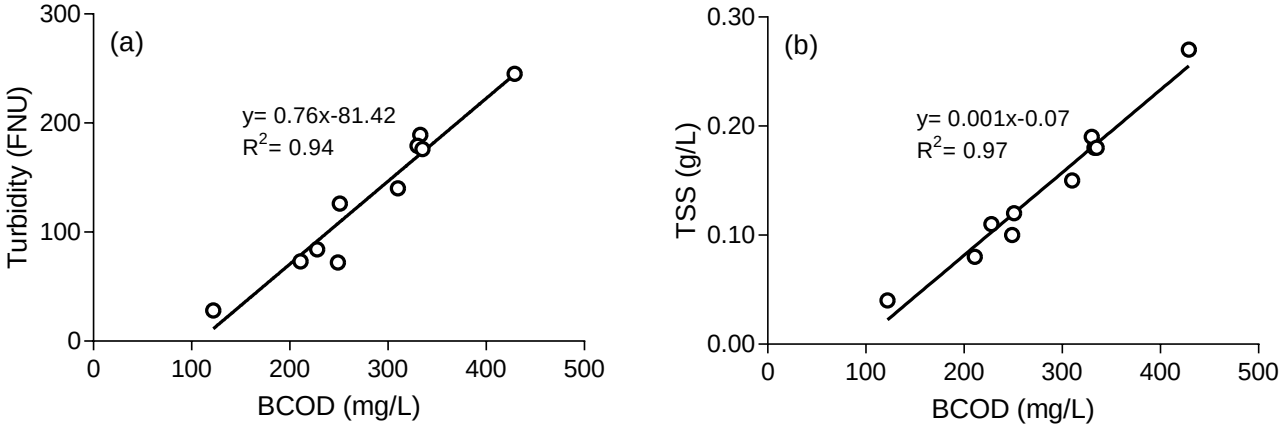


Figure 5: *Correlation in the primary effluent of Lundtofte WWTP from March 28 to May 7 for; (a) Turbidity (FNU) vs BCOD (mg/L), (b) TSS (g/L) vs BCOD (mg/L)*

Fig. 1 shows that BCOD correlates very well with both turbidity (R^2= 0.94) and TSS (R^2= 0.97). Thus, these parameters can be used as surrogates to estimate the bioavailable organic carbon in the primary effluent. This alternative method works efficiently at normal WWTP operational conditions. Large disturbances, such drastic changes in organic load, may compromise the application of these correlations. Yet, any of the existing monitoring tools can reliably monitor BCOD in highly dynamic systems without requiring similar or more calibration efforts. Thus, we suggest using conventional total suspended solids sensors (e.g. Solitax ts-line sc (Hach Lange, Germany)), sensors commonly used in WWTP, to predict BCOD in clarified effluents (i.e., in the absence of activated sludge).

* *sofkar@dtu.dk: Bygningstorvet, Bygning 115, 2800 Lyngby*
** *bvape@env.dtu.dk: Bygningstorvet, Bygning 115, 2800 Lyngby*
Väänänen, J., Memet, S., Günther, T., Lilja, M., Cimbritz, M., la Cour Jansen, J., 2017. Automatic control of the effluent turbidity from a chemically enhanced primary treatment with microsieving. Water Sci. Technol. 76, 1770–1780.

Water efficient process optimization by applying flotation technology for further reuse of landing water

Michelle L Rebsdorf, R.R. Andreasen, C. K. Rickers, Danish Technological Institute, J. Rasmussen, TripleNine**, T. Svendsen, BIO-AQUA****

Abstract

DRIP – Danish partnership for Resource and water efficient Industrial food Production – is a public/private partnership (founded by Innovation Fund Denmark) with the aim to obtain more water efficient productions within the Danish food industry without compromising product quality and food safety. Within this partnership TripleNine, and Danish Technological Institute has initiated a project with the potential of saving the company up to 1mio. DDK per year in terms of water consumption and subsequent process water treatment.

TripleNine apply almost 16,000 m3 water per year as transport media when fish are landed. To minimize water consumption, the landing water is reused without treatment as many times as possible, until further use is prevented due to increasing high dry matter content (i.e. blood, slime and fish parts). The water is then lead into the production plant where it is converted to product (fish meal and -oil).

Through the application of flotation technology for dry matter separation the project proposes a new solution for handling and treatment of the landing water, in order to:

- Remove dry matter from the landing water, enabling further reuse of the water, hence reduce the overall water consumption

- Increase dry matter concentration in the flotation foam as it enters the production facility, resulting in significant energy savings as less water has to be evaporated.

Figur 1. Landing af fisk hos TripleNine I Thyborøn

In this project a pilot scale flotation system from BIO-AQUA with preceding flocculation was tested on landing water at TripleNine. During the pilot test the BIO-AQUA flotation system was found able to reduce the dry matter concentration in the landing water from 4,84% to 0,88%, while obtaining a dry matter concentration of 13,7% in the flotation foam entering the production facility. Based on these results, TripleNine expect that they can reduce their water consumption related to lading water by 50-70% by applying a flotation system. Moreover, the fees and energy costs related to processing the landing water amounts to 75 DKK per m3 providing potential cost savings of up to DKK 600,000-1,000,000 per year.

At present TripleNine plans to implement a BIO-AQUA full scale flotation system in close collaboration with Danish Technological Institute.

* *mlr@teknologisk.dk / ran@teknologisk.dk / cakr@teknologisk.dk: Kongsvang Allé 29, 8000 Aarhus C*
** *jra@999.dk: Sydhavevej 14, 7680 Thyborøn*
*** *ts@bio-aqua.dk: Strøbjergvej 29, DK-3600 Frederikssund*

Aiming for a reduced chloride discharge at Arla DP - Simple means with significant effect

Rune. R. Andreasen, Teknologisk Institut, M. L Rebsdorf Teknologisk Institut**, D. Thaysen, Arla DP****

Abstract

Chloride discharge to inland waterbodies may cause unfavourable effects on the ecosystem. To protect the ecosystem production facilities are therefore often limited in their annual chloride discharge. Such limitation may ultimately limit the production capacity unless mean to reduce the effluent chloride concentration are identified.

Through the DRIP partnership (founded by Innovationsfonden) Arla DP and Danish Technological Institute has conducted a pre study to identify cost efficient means for reducing the annual chloride discharge. Arla DP currently comply with their chloride discharge limits However Arla DP still aims to reduce their chloride discharge even further as this will enable them to expand their production capacity without compromising the ecosystem of their recipient.

The proposed hypothesis for the project was that the most cost-efficient chloride reduction can be achieved by mitigating of a few single processes with high levels of chloride (hotspots). If a significant large amount of the annual chloride discharge are linked to a small volume at a chloride hotspot the specific

treatment of a small partial flow of the total discharged water volume may reduce the chloride by a much larger fraction.
Based on this hypothesis local hotspots were identified , characterized and finalle means to reduce their discharge was identified.
Through this approach Arla DP and Danish Technological Institute was able to identify 40% of the annual chloride discharge in less than 1% of the annual discharged water volume deriving from only 3 processes in the production facility:

- Product eluation by NaCl (10%)
- Ultrafiltration/Diafiltration of the eluate (20%)
- Regeneration of softening columns by HCl (10%)

Case solution
Simple means to reduce the annual chloride discharge at Arla DP were proposed and discussed, ending up with the following two initiatives.

- Direct reuse of a selected volume of high saline water from UF system in the product eluation processes. Discharge reduction potential = 15% of total discharge.
- Reduced HCl usage when regenerating the softening columns as 85-97% the mineral discharge was observed to take place with the flush of the first 1/3 of HCl volume. Discharge reduction potential = 6% of total discharge.

Perspectives
As these two initiatives alone have a chloride discharge reduction potential of 6 and 15% of Arla DP's total chloride discharge, Arla DP now plans to implement these simple means in close collaboration with Danish Technological Institute.

* *ran@teknologisk.dk : Kongsvang Allé 29, 8000 Aarhus C*
** *mlr@teknologisk.dk: Kongsvang Allé 29, 8000 Aarhus C*
*** *dorrit.thaysen@arlafoods.com : Sønderupvej 26, 6920 Videbæk*

Session 7 & 8: Wastewater

CHAIR: Hans-Martin Friis Møller

Title	Presented by
Full stream active pharmaceutical ingredients removal through ozonation at Kalundborg Utility	Jeppe Bregendahl, Kalundborg Forsyning
Bioreactor with woodchips	Finn Plauborg, Aarhus University, Agroecology
Control of anaerobic digestion for maximal biogas production under dynamic conditions	Borja Valverde-Pérez, DTU Envir.
Phosphorus removal, recovery and reuse by newly developed coated materials for use in decentralized wastewater treatment systems	Carlos A. Arias, Aarhus University, Bioscience
New innovative technology using peracetic acid ensures efficient reduction of antibiotic-resistant bacteria from untreated hospital wastewater	Sabine Lindholst, Technological Institute
Microbial Electrochemical-based Constructed Wetland (METland): test of an innovative setup for wastewater treatment	Carlos Alberto Arias, WATEC, Aarhus University
Strict biological removal of pharmaceuticals in wastewater effluents	Peter Rosborg, Technological Institute
Online sulphide sensor for an efficient and environmental-friendly control of wastewater	Kirsten Habicht, Unisense
UV-C tolerance of microorganisms from food processing water streams	Eirini Vitzilaiou, University of Copenhagen, Food
Abiotic denitrification and Nitrogen recycling using Zero-valent Iron and Zeolite	Adrian F. Florea, CPH PLEN
Absolute sustainability assessment of a Danish water utility company	Morten W. Ryberg, DTU Management
Blue steps towards sustainable development: A project mapping and assessing the sustainability of Danish climate adaptation projects	Hjalte Jomo Danielsen Sørup, DTU Envir.
Unmanned Airborne Vehicles (UAVs) for monitoring Danish streams and optimizing river maintenance	Filippo Bandini, DTU Envir.
An UPLC-QqQ Method for Analyzing Natural Toxins-Pyrrolizidine Alkaloids in Surface Water from a Ragwort Catchment, Vejle-Denmark.	Jawameer Hama, CPH PLEN

Full stream active pharmaceutical ingredients removal through ozonation at Kalundborg Utility

*J. Bregendahl, Kalundborg Utility**

Active Pharmaceutical Ingredients (API) is an increasing point of interest for the Danish utility community. Studies has proven that the main fraction of API at Danish wastewater treatment plants comes from private households, which shows the need for tertiary treatment at the central treatment plant. Switzerland has already introduced restrictions on API in the effluent water and Germany is building large scale facilities to handle the problem. In both countries the chosen method for API removal is ozonation which has proven reliable and effective. Kalundborg Utility has, as the first utility in Denmark, tested full stream ozonation to verify the effect on the wastewater and the API content.

Collaboration through the EU project CWPharma has ensured a deep knowledge and access to some of the foremost experts on the area and scientific analyzes of the wastewater at Aarhus University. Results shows a significant reduction of the total API-content after ozonation and validates the process as a mean of API reduction on Danish wastewater. Further investigations will focus on energy and oxygen efficiency and deciding the minimal ozone dosage for API removal in the Kalundborg case. The goal of the project is to verify a business case where Kalundborg Utility can do fulltime full stream ozonation in 2019, to demonstrate that API removal is a viable option for utilities, to achieve cleaner water and a better environment.

**jebr@kalfor.dk*: *Dokhavnsvej 15, 4400 Kalundborg*

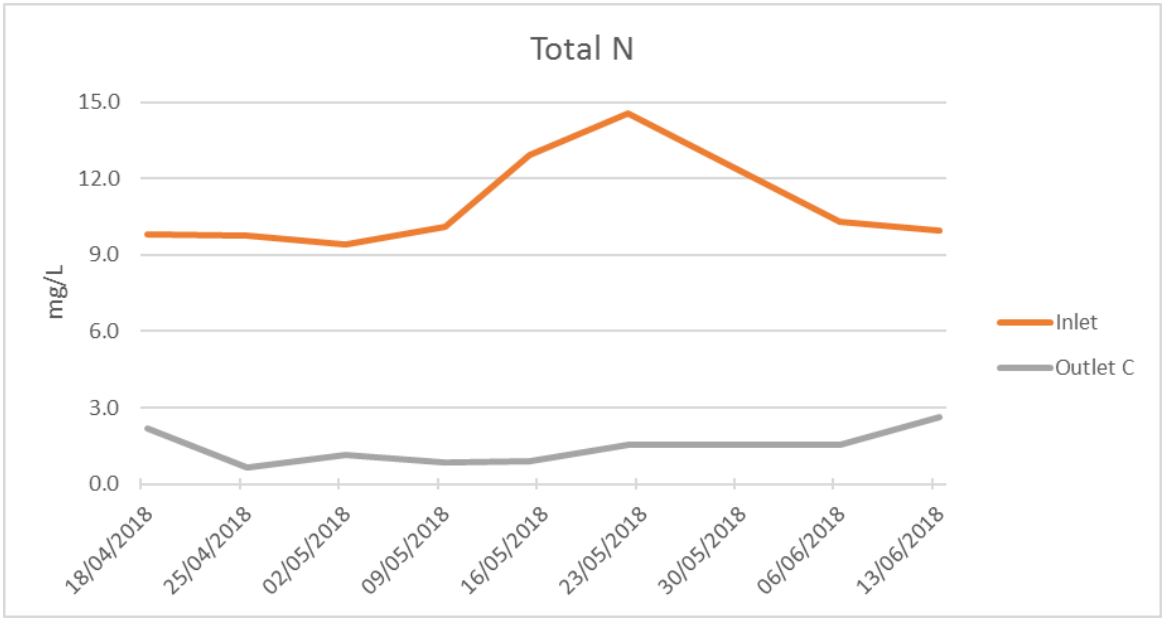
Bioreactor with woodchips

F. Plauborg, Aarhus University, Department of Agroecology (AGRO)*

Abstract

In April 2013, the Nature and Agriculture Commission published its recommendations for a reform of the existing environmental regulation of Danish agriculture. Central to the report was the recommendation of a paradigm shift in the regulation of agricultural nutrient emissions from general to targeted rules. With the Growth Plan for Food of April 2, 2014 and the Food and Agriculture Package Agreement of December 22, 2015, the first basic principles were formulated. By 2021, nitrogen emissions must be reduced yearly with 6,900 tonnes. Around half 3,400 tonnes must be achieved through collective measures. The other half

3,500 tonnes - the targeted regulation - must be achieved by means individual farmer need to establish. The collective measures include the establishment of constructed wetlands, natural wetland projects and afforestation. These measures are paid by the state and solve problems for a larger area (sub-catchment) and benefits farmers in that given sub-catchment. Results indicate that a bioreactor with woodchips (or subsurface constructed wetland with biofilter) is more efficient than a surface flow constructed wetland. In 2017-2018 AGRO has constructed six bioreactors in different geo-regions in Denmark based on funding from the Ministry of Environment and Food of Denmark. This paper present some preliminary results.



* finn.plauborg@agro.au.dk: *Blichers Allé 20, Postboks 50, 8830 Tjele, Denmark*

Control of anaerobic digestion for maximal biogas production under dynamic conditions

Parisa Ghofrani Isfahani[1,2], Borja Valverde-Pérez[1], Merlin Alvarado-Morales[1], Mohammad Shahrokhi[2], Manouchehr vossoughi [2], Irini Angelidaki[1]***

Abstract

Anaerobic digestion (AD) relies on metabolic activity of a diverse group of microorganisms for degradation of bio-wastes with simultaneous methane production. Typically, AD is used in wastewater treatment plants for reducing the volume of sludge generated during aerobic treatment, thus significantly reducing the costs related to sludge handling. Furthermore, WWTPs are considering the use of other wastes (e.g., bio-pulp) for increasing the energy production and thus increasing benefits by selling energy. However, digester may suffer overload or inhibition when changing feedstocks and are usually run at sub-optimized conditions to avoid process instability. In this study we have developed a supervisory control structure able to maximize methane production by monitoring volatile fatty acids (VFA) and pH in the digester and controlling the organic loading rate (OLR). The control strategy was applied in a 9 L (7.5 L working volume) continuous stirred tank reactor (CSTR) at thermophilic conditions (54 ± 1 °C). The control strategy consists of a supervisory structure where the slave loop is a feedback control structure using a proportional controller that manipulates the feed flow rate to achieve the desired gas flow rate. The master loop is a supervisory controller that defines the set point for the inner loop according to CH_4 production, VFA level and pH in the digester. The digester was fed only with diluted cattle manure, 2% volatile solids (VS), for 39 days (Fig. 1). Then, several step changes were introduced in the feed. First, the VS content was increased from 2% to 6% by addition of glucose to the feed at day 39. CH_4 production increased instantly and VFA accumulated in the reactor due to the acidification resulting from quick glucose fermentation. The controller manipulated the loading rate to set back VFA to the same level as before glucose addition, while CH_4 production was maximized and tracked the set point. From day 68, ammonium chloride was added to reach TAN 6 g-N L^{-1}, thus leading to inhibition of methanogenisis. However, the controller detected the accumulation of VFA and decreased the OLR, thus avoiding system failure and keeping high methane production. At 94 the feed was changed back to manure 2% VS and the controlled pushed the system to the initial conditions – an important achievement, as previous supervisory controllers were unable to distinguish between inhibition and underloads. After day 110, the feedstock was changed to bio-pulp and the controller successfully optimized biogas production without system acidification (data not shown due to space limitation).

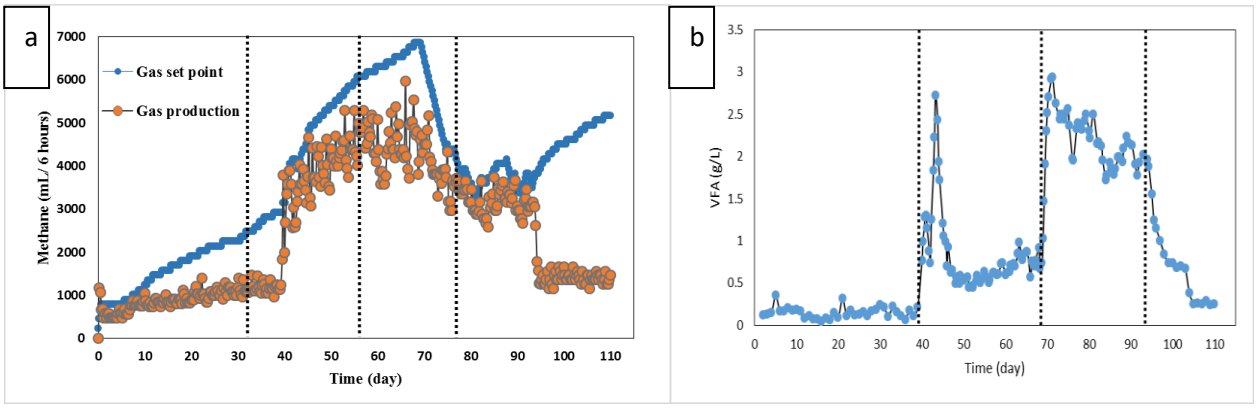


Figure 1. a) Methane production; and b) volatile fatty acid accumulation during dynamic conditions.

1) Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, DK-2800, Denmark bvape@env.dtu.dk, ** iria@env.dtu.dk*

2) Department of Chemical and Petroleum Engineering, Sharif University of Technology, Tehran, Iran

Phosphorus removal, recovery and reuse by newly developed coated materials for use in decentralized wastewater treatment systems

Solvei.M. Jensen*[〒¥], *H. Blaikie***, and H. Soehoel***, *H. Brix**[〒¥], *Carlos .A. Arias**[〒¥]

Abstract

Decentralised wastewater systems are engineered solutions targeting pollutants in waters affected by anthropogenic activities. The systems must be robust, reliable, easy maintained and require low external energy input, and the systems have proven efficient at removing certain pollutants. However, up to now, sustained phosphorus (P) removal has proven elusive regardless of the system. In a global perspective the removal, recovery and reuse of P is important, as the global supply of mineral P is becoming exhausted, while P demand is increasing. The available strategies in P removal include media adsorption, chemical precipitation, sedimentation and vegetation uptake with subsequent harvest.

In the present work, we screened more than 20 materials by testing P removal potential using adsorption isotherms (figure 1, picture). The isotherm screening determined a P-binding capacity range of -0.3 mg P g^{-1} dw up to 23.5 mg P g^{-1} dw. After the removal potential was confirmed, the materials with P removal capacity were submitted to different coating processes to improve P binding capacity, mechanical characteristics, and hydraulic performance. Once coated, the improved materials were also tested using isotherms experiments to confirm the P removal potential. Subsequently, long-term column experiment is currently being performed on the selected materials from the screening process. The experiments is still running and have been the past year to determined total P binding capacity, preliminary results have revealed consistent P binding capacities. Along with the P removal assessment, a physical-chemical characterization has been done and two of the coated materials that showed the highest potential are currently being tested under real operational conditions, treating secondary treated wastewaters in 1 m^3 filters in Spain.

Additionally to the P removal capacity and since one of the objectives is to recover the nutrients, the bioavailability of P bound in selected materials is being evaluated in greenhouse mesocosms to determine if P bound to the material is bioavailable for plant uptake.

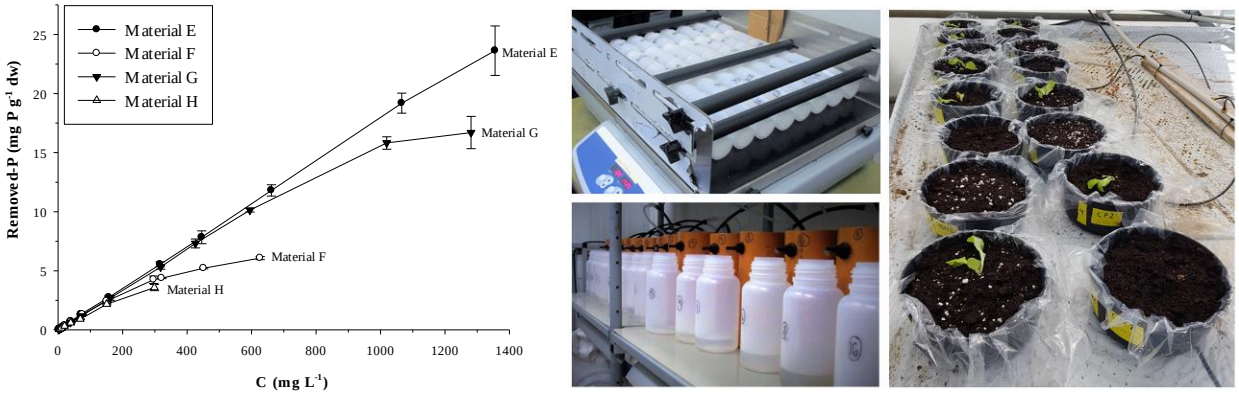


Figure 1: Isotherm experiment, relationship between removed P (mg P g^{-1} dw) and equilibrium P (mg P L^{-1}) at a selection of 4 tested materials. Pictures: isotherm experiment (top), column experiment (bottom) and bioavailability of P (right).

* solvei.mundbjerg@bios.au.dk hans.brix@bios.au.dk, carlos.arias@bios.au.dk
Aarhus University, Department of Bioscience, Ole Worms Allé 1, bygn. 1135, 8000 Aarhus C, Denmark.
〒 Sino-Danish Center for Education and Research, Niels Jensens Vej 2, Building 1190, 8000 Aarhus C.
¥ WATEC, Aarhus University, Building 1521, Ny Munkegade 120, DK-8000 Aarhus C.
*** fhb@teknologisk.dk, hsl@teknologisk.dk Danish Technological Insitute Kongsvang Allé 29, 8000 Aarhus C, Denmark.*

New innovative technology using peracetic acid ensures efficient reduction of antibiotic-resistant bacteria from untreated hospital wastewater

C. Kragelund, Danish Technological Institute, Thomas Møller, Aarhus University Hospital**, Sabine Lindholst, Danish Technological Institute*, Thomas Eilkær Hansen, Norlex Systems****

Abstract

Hospitals are widely considered as large contributors to point source pollution of pharmaceuticals and antibiotic resistant bacteria due to discharge in wastewater. Recent research has demonstrated that the most efficient removal of pharmaceuticals from wastewater (both hospital and household) can be obtained at the wastewater utilities as a biological polishing step (Kragelund et al., 2017). However, the antibiotic-resistant bacteria are unwanted in the environment as they represent a threat to the working environment of sewage workers as well as workers at the utility.

Therefore, there is a need to selectively eliminate these microorganisms from the untreated wastewater. Since there are no requirements for antibiotic resistant bacteria present in the wastewater, the consortium has been in dialogue with both the water supply (Aarhus Vand) as well as the municipality (Aarhus Kommune) to determine the required reduction of antibiotic resistant bacteria. It was decided to use ciprofloxacin-resistant bacteria as model organisms, as ciprofloxacin is a commonly used broad-spectrum antibiotic (Møller, 2014), which therefore is expected to result in the highest number of antibiotic-resistant bacteria from hospital wastewater. No guiding limit values exist for ciprofloxacin- resistant bacteria, so it was decided to use inlet values from a municipality with no hospital influence (blue line in figure below).

Experimental work has been conducted in laboratory, to determine the required concentration of PAA to sufficiently reduce the ciprofloxacin-resistant bacteria as well as the total number of bacteria present in the untreated wastewater. Therefore, different concentrations of PAA and corresponding reaction times have been carried out to identify the optimal concentration and reaction time, see below figure. Pilot scale test based on injecting PAA directly in the untreated wastewater in the sewer at AUH will be conducted in the beginning of 2019.

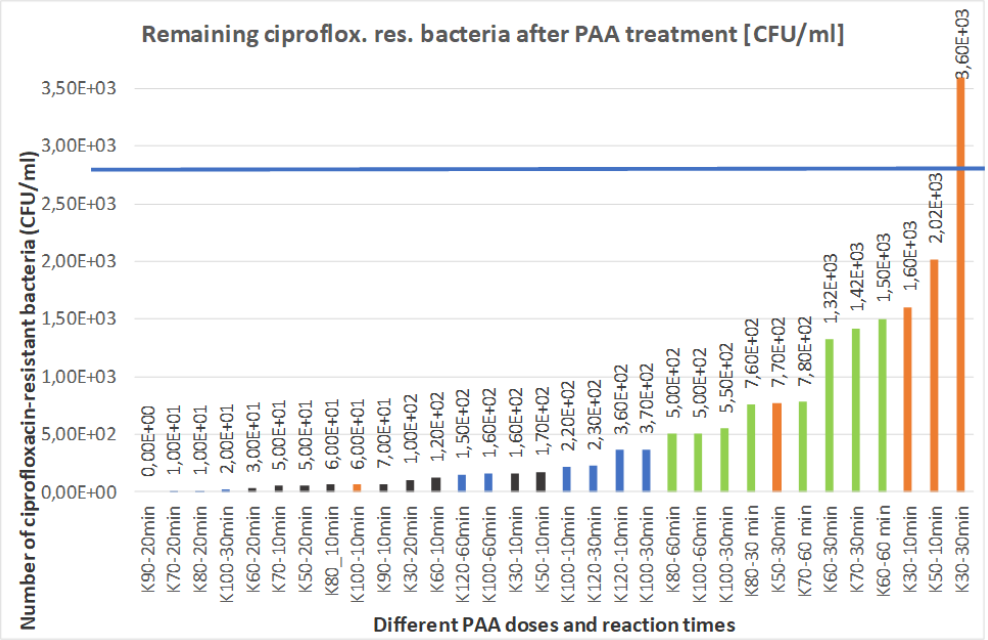


Fig. 1 a) Overview of PAA doses and reduction of antibiotic resistant bacteria.

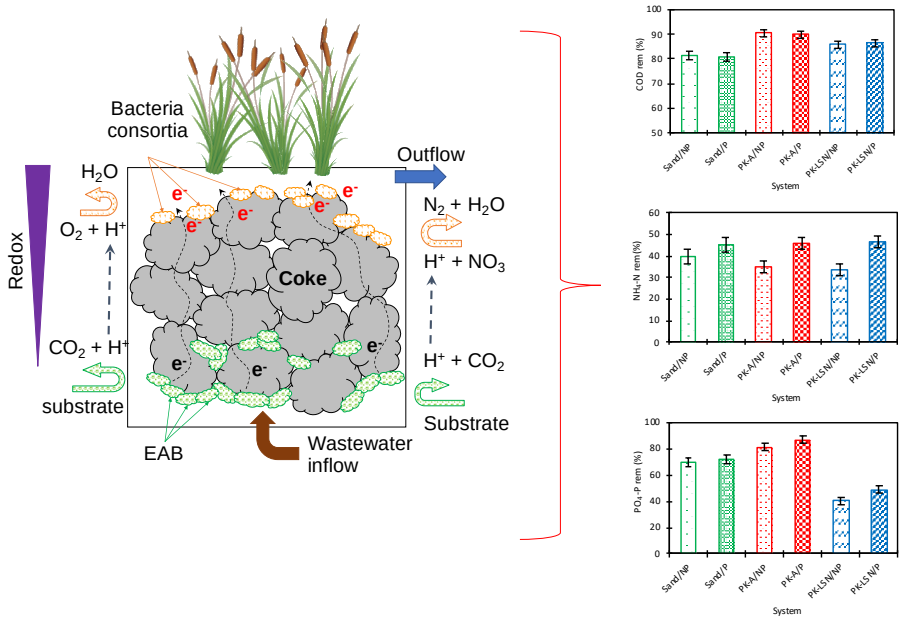
*cakr@dti.dk, sbl@teknologisk.dk: *Kongsvang Allé 29, 8000 Aarhus C,*
** thomamoe@rm.dk: Aarhus Universitetshospital, *Palle Juul-Jensens Blvd. 50, 8200 Aarhus N*
*** teh@norlex.com: *Norlex ApS · Bistrupvej 172, 3460 Birke*

Microbial Electrochemical-based Constructed Wetland (METland): test of an innovative setup for wastewater treatment

C.A. Ramirez-Vargas, Department of Bioscience / WATEC, Aarhus Universitet, C. A. Arias, Department of Bioscience/WATEC, Aarhus Universitet **, A Esteve-Núñez, Department of Analytical Chemistry and Chemical Engineering, University of Alcalá***, Solvei M. Jensen, Department of Bioscience /WATEC, Aarhus Universitet/SDC SDC **** H. Brix, Department of Bioscience /WATEC, Aarhus Universitet/SDC ******

Abstract

Constructed wetlands (CWs) performance enhancement can be achieved with intensification strategies. A recent strategy still in being developed is the coupling of CW with Microbial Electrochemical Technologies (MET). An alternative system using electro-conductive biofilters instead of electrodes and circuits used in MET, resulted in the development of a Microbial Electrochemical-based CW (METland). The system relies on electroactive bacteria (EAB) metabolism to transfer electrons to an electro-conductive material, thus boosting substrate consumption, and diminishing electron availability for biomass build-up and methane generation. In previous studies, this biofilters have shown an improvement in biodegradation rates in comparison with subsurface flow CW. However, this set-up is still in development, hence, there are uncertainties regarding the dynamics involve in the removal of pollutants. Considering that, this work aimed at establishing the capacity and removal kinetics of organic matter and nutrients in a METland-based set-up. Two electro-conductive materials were tested (PK-A and PK-LSN) in planted and non-planted mesocosms, and compared to inert sand-filled mesocosms as reference. The mesocosms were fed with real wastewater and continuous upflow mode for 32 weeks. The electro-conductive systems reached removal efficiencies up to 90% for COD, 46% for NH_4-N, and 86% for PO_4-P. Organic matter removal in electro-conductive systems was possible even at loading rates 10-fold higher than recommended for horizontal flow CWs. First-order area-based removal constants (*k*), calculated for organic matter and nutrients are higher than values typically reported for saturated CW and in certain cases comparable with vertical flow CW. The organic removal was correlated with electron current densities measures, as indicator of the presence of EAB. The tested METland-based set-ups profiles as a promising CW type for the removal of organic matter and PO_4-P with margin for modifications to improve nitrogen removal. Future studies with pilot/real scale systems a being done to validate the findings of this study.



* c.a.ramirez@bios.au.dk: *Aarhus University, 8000 Aarhus C, Denmark*

**carlos.arias@bios.au.dk: Aarhus University, 8000 Aarhus C, Denmark

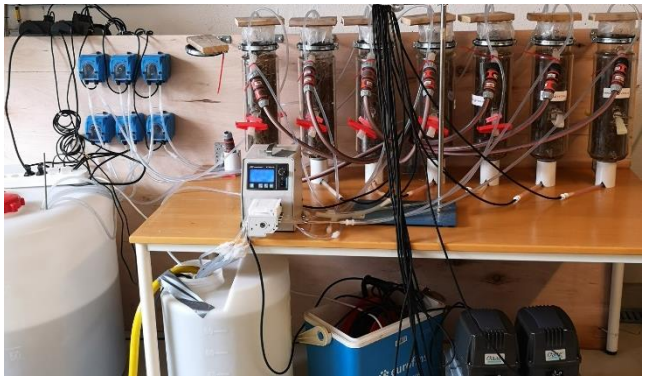
*** abraham.esteve@uah.es University of Alcalá, 28871 Alcalá de Henares, Spain

****solvei.mundbjerg@bios.au.dk Aarhus University, 8000 Aarhus C, Denmark

**** hans.brix@bios.au.dk Aarhus University, 8000 Aarhus C, Denmark

Strict biological removal of pharmaceuticals in wastewater effluents

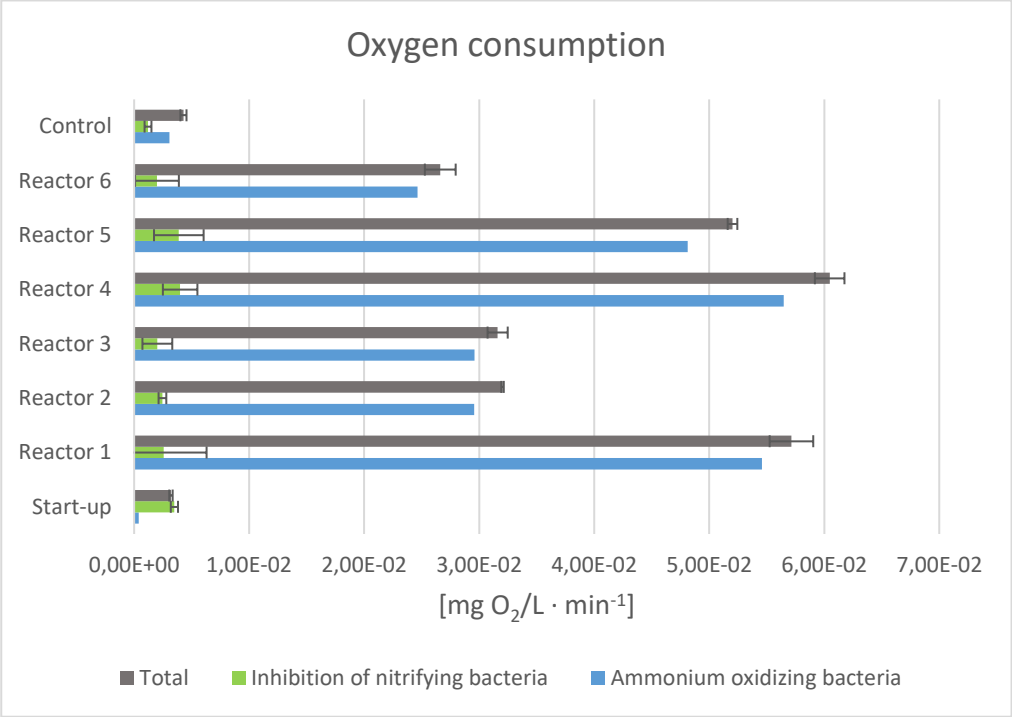
P. Rosborg, DTI, K. Tang, DTU**, S. Lindholst, DTI*, C. Sund, Krüger***, A.A. Hansen, Krüger***, T. Møller, Aarhus University Hospital ****, J.D. Andersen, Herning Vand, *****, N. Møller, Herning Vand*****, H.R. Andersen, DTU** Peter Underlin******, C. Kragelund, DTI**



There has been an increasing focus on unwanted pharmaceuticals in wastewater (both from point sources and from household) and therefore several projects have investigated how to remove the pharmaceuticals most economically efficient. One of the most promising technologies is the moving bed biofilm reactor (MBBR) principle where a biofilm specialized on removing pharmaceuticals are promoted. Studies have identified the link between ability to nitrify and ability to remove pharmaceuticals (Tang et al., 2017) and therefore testing of nitrification ability of different reactor configurations is a simple and cheap measure to investigate potential improvements in degradability of pharmaceuticals prior to spiking experiments where pharmaceuticals are added to reactors and then degradation is followed over a time period.

In this project, 7 MBBR lab scale glass reactors (3L) were set up at Egå WWTP to identify the optimal periods of starvation (only effluent water) and feast (small amounts of settled raw wastewater added) conditions for a highly-specialized biofilm. This work is based on the previous work by Tang et al., 2017 who demonstrated how periods of starve and feast significantly enhanced the ability to degrade pharmaceuticals.

Nitrification experiments were carried out for the best performing reactors (highest COD and ammonia removal) and the activity of nitrifying bacteria was estimated based on oxygen consumption and addition of an inhibitor. The experiment resulted in an oxygen consumption from ammonium oxidizing bacteria nineteen times higher than the control. As evident in figure 1, the nitrification capacity could be significantly increased compared to control reactor, which only received effluent wastewater. Ability to remove pharmaceuticals were determined by mineralization studies and by spiking experiments and data is currently under investigation.



The data indicate that more COD can be added since no significant growth of heterotrophic bacteria has been observed. It was concluded that reactors receiving 600 mg COD per day with a short feast period and long starving periods had the best potential for removing pharmaceutical residues.

*cakr@dti.dk, asbl@teknologisk.dk: Kongsvang Allé 29, 8000 Aarhus C,
** kait@env.dtu.dk, hran@env.dtu.dk: Miljøvej 113, 2800 Kgs. Lyngby
*** christina.sund@veolia.com,avh@kruger.dk, Krüger A/S / Gladsaxevej 363 / 2860 Søborg / Denmark
***** thomamoe@rm.dk, Teknisk Afdeling, Palle Juul Jensens Boulevard 50, 8200 Aarhus N
****** nmj@herningvand.dk, jda@herningvand.dk, Ålykkevej 5, 7400 Herning
********Pun@hfors.dk, Ægirsvej 4, 3400 Hillerød

Online sulphide sensor for an efficient and environmental-friendly control of wastewater

K.S. Habicht and E.K. Vestergaard**, Unisense A/S*

Abstract

Continuous sensor measurements directly in wastewater are increasingly being used to control wastewater treatment processes. Unisense has developed an online, real-time IMEC sensor for dissolved sulphide measurements, and in this presentation we show how this sensor can be used for optimization of the collection system. We provide examples of how the sulphide sensor can be used to give a full picture of the production of sulphide directly in the wastewater, and we discuss how the sulphide monitoring can enable a minimization of both emissions and chemical use for sulphide mitigation in the sewage system. With proper control of the sulphide production, it is hence possible to save both resources and be environmentally friendly.

Sulphide is a major problem in the utilities' sewage network, where the toxic gas causes odour problems and can lead to hazardous incidents for sewage workers. Sulphide can furthermore be converted into sulfuric acid in biofilms and cause corrosion on the drainage network, wells, pumping stations and treatment plants. To minimize the amount of sulphide emission from the wastewater, large amounts of chemicals are added to wastewater, which is both costly and environmentally disadvantageous. In the talk

we present a new and large demonstration project where Unisense together with Aarhus Vand, Aalborg Forsyning and Thames Water will demonstrate the potential for minimizing chemical dosing and saving on asset management cost by acquiring an overview of the daily and seasonal variations of sulphide load in their collection systems.

IMEC sensor

* kha@unisense.com: Tueager 1, 8200 Aarhus N, Denmark

** ekv@unisense.com: Tueager 1, 8200 Aarhus N, Denmark

UV-C tolerance of microorganisms from food processing water streams

E. Vitzilaiou, S. Knøchel**, University of Copenhagen*

Ultraviolet (UV) irradiation is becoming increasingly popular for process water treatment. UV-light is highly effective against a wide spectrum of microorganisms and an easy-to-use technology. The food processing industry may apply Reverse Osmosis (RO) membrane filtration and UV-C treatment to recondition process water for re-use. Although RO membranes in principle remove all microorganisms, some microorganisms may still be found on the permeate side and biofilms may be formed on permeate membrane surfaces. Here, we investigated the UV-C tolerance of several microorganisms isolated from whey water permeate streams and RO membrane surfaces. The microbial strains examined belong to the filamentous yeast species *Saprochaete clavata* and *Magnusiomyces spicifer*, and the gram-negative bacteria *Klebsiella sp., Raoultella sp.* and *Pseudomonas fluorescens.* Their UV-C tolerance was also compared to that of a heat resistant *Salmonella* isolate as well as a Methicillin resistant *Staphylococcus aureus (*MRSA) strain. The compact UV-LED device PearlBeam™, from Aquisense Technologies (Kentucky, USA) was used in a lab-scale set-up (Figure 1). The experimental procedure was conducted according to the protocol of Bolton and Linden (2003). Different UV-doses at 255nm were applied to yeast and bacterial inocula. The filamentous yeasts showed significantly higher resistance than bacteria, decreasing only 1-2 $\log_{10}$ after a UV-dose of 10 mJ/cm^2, while bacteria decreased by 4-5-$\log_{10}$ .The filamentous yeast strains needed doses 4-6 times higher to reach a similar reduction. Sporadic survivors were regularly seen after high intensity exposure with this equipment. The use of UV irradiation is expected to increase and new developments affecting energy consumption and inactivation efficacy may come into use, incl. LED and the use of mixed wavelengths. In the food industry, it will be important to know the UV tolerance of different target microorganisms. Here, we have shown that membrane-associated filamentous yeasts are significantly more tolerant to UV-C irradiation than bacteria. In order to ensure a safe and fit-for-purpose water reuse in the food industry, the UV tolerance of relevant microorganisms to different wavelengths and doses should be investigated, as well as the potential for protection, microbial repair and reactivation.

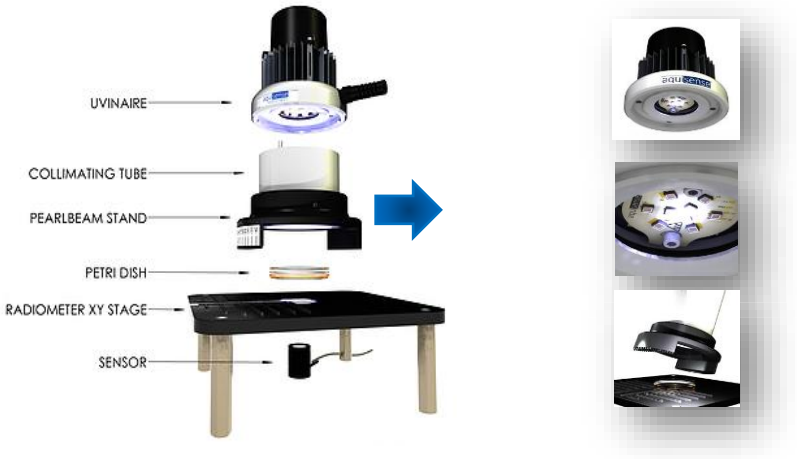


Figure 1: UV-C LED PearlBeam™ instrument. Aquisense Technologies (Kentucky, USA).

References

Bolton, J.R. and Linden, K.G. 2003. Standardization of Methods for Fluences (UV Dose) Determination in Bench-Scale UV Experiments, *Journal of Environmental Engineering, 129, No. 3, pp. 209-215.*

***** *eirini@food.ku.dk* **:** *Rolighedsvej 26, DK-1958 Frederiksberg C, Denmark*

** *skn@food.ku.dk: Rolighedsvej 26, DK-1958 Frederiksberg C, Denmark*

Absolute sustainability assessment of a Danish water utility company

Morten W. Ryberg, DTU Management, T.K. Bjerre, VandCenter Syd***

Abstract

Pressures exerted by humans on the Earth are starting to affect and destabilize the Earth System as expressed by the Planetary Boundaries (PB) which delimits a safe operating space for humanity to act within. To ensure a stable Earth System and become sustainable in an absolute sense, humanity must reduce its pressures to be within within the safe operating space. This includes utility companies which supply water and treat wastewater. Thus, we sought to assess if the utility company VandCenter Syd (VCSyd) could be considered absolutely sustainable relative to the PBs. Absolute sustainability assessment requires three inputs: (i) the environmental footprint of the assessed activity; (ii) the environmental boundary; and (iii) the share of environmental boundary assigned to the assessed activity. To be absolutely sustainable, the activity's footprint must not exceed the assigned share of the environmental boundary. As environmental boundary, the PBs as defined by Steffen et al. (2015) were used. Potential limitations of directly applying these are discussed. The environmental footprint of VCSyd was quantified using life-cycle assessment (LCA) which includes and inventories all resource used and emissions associated with VCSyd. The inventory was expressed in the metrics of the PBs by use of the Planetary Boundaries based life-cycle impact assessment methodology by Ryberg et al. (2018). To assess absolute sustainability, the share of the total safe operating space, that VCSyd can be considered entitled must be determined. Shares of safe operating space were assigned based on different sharing principles such as contribution to employment, revealed consumer preferences, and existing contribution to environmental impacts.

Tentative results of the assessment are shown in Figure 1 where VCSyd exceeds its assigned share of safe operating space in 10 out of 16 impact categories. For instance, to be absolutely sustainable for climate change, VCSyd would need to reduce greenhouse gas emissions by a factor 2.5 to 76, depending on the selected sharing principle. For nitrogen and phosphorus emissions, the exceedance of the assigned share ranges from a factor 20 to 3800. This is likely overestimated due to the indicator used for the PBs and we recommend applying more environmentally relevant indicators. It is evident that choice of sharing principle largely influences the overall results and it is important to test influence of different sharing principles expressing different takes on how to share the safe operating space. The results of the absolute sustainability assessment provide VCSyd with science based targets that can be used in future sustainability oriented strategic planning. Moreover the approach allows for identifying the impact categories where they should prioritize reductions to become absolutely sustainable. Further, the holistic approach also ensures that reduction in impacts for one impact category does not occur at the expense of another impact category.

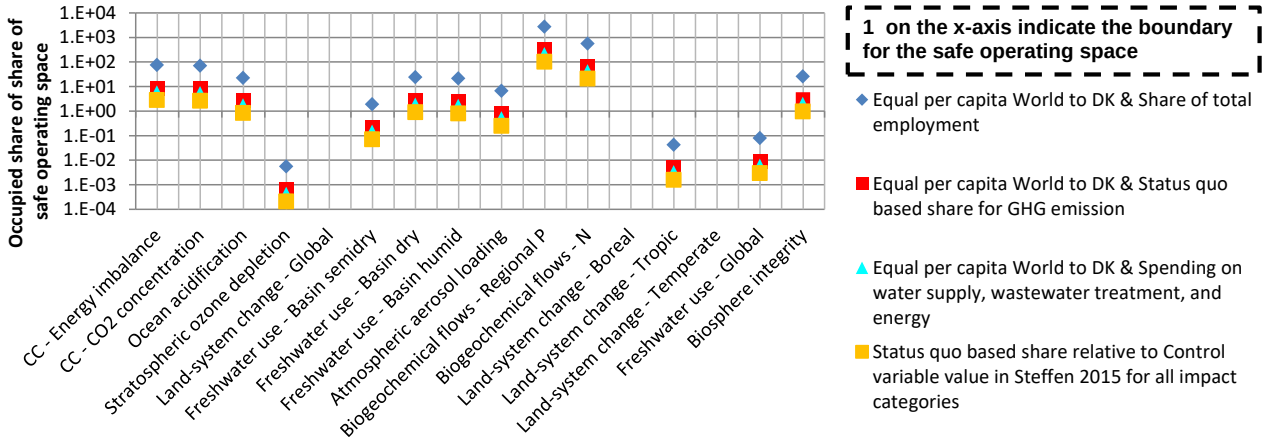


Figure 2. Results of absolute sustainability assessment of VCSyd. Impacts are shown relative to assigned share of safe operating space based on four sharing principles. To be absolutely sustainable, impact scores must be less than one.

** moryb@dtu.dk: Diplomvej, DK-2800 Kgs. Lyngby, Denmark*
*** tkb@vandcenter.dk: Vandværksvej 7,5000 Odense C*

Blue steps towards sustainable development: A project mapping and assessing the sustainability of Danish climate adaptation projects

Hjalte J.D. Sørup*, DTU Environment, K. Arnbjerg-Nielsen**, DTU Environment, M. Feilberg***, DANVA, L. Liu****, UCPH-IGN, O. Fryd*****, UCPH-IGN, K.A. Ulbak******, Teknologisk Institut, M.B. Jensen, UCPH-IGN

Abstract

Water is the only resource to have received a goal of its own in the UN SDGs, SDG6. Hence, SDG6 is often the main focus for water professionals. However, the purpose of urban water management is broader than what is covered by SDG6 and is reaching far into other targets; as for instance SDG11 on resilient cities and SDG13 on climate change. This underpins the necessity of analyzing the SDGs as a whole and not only focus on the most obvious.

Climate change adaptation of cities often, on top of handling water, delivers a multitude of other services to society. It is often used as a lever for transforming cities in a more livable, green, and resilient direction and these effects should be acknowledged as part of the services climate change adaptation deliver; a part that potentially can push society at large in a more sustainable direction.

In this study we identify a range of services that climate change adaptation measures can deliver within four overall domains:

- Stormwater management,
- Natural resources management,
- Urban livability, and
- Transition and innovation.

For each service, we identify relevant global targets under all 17 SDGs and their associated indicators. From these we then select what would be the most relevant target/indicator set(s) for assessing the sustainability of a given service at project/planning level. Our hypothesis is that target/indicators relevant at very small scale can still reflect the intention of the global targets and indicators.

We demonstrate through Danish examples from local site to city scale that the proposed methodology can help inform decision makers about the sustainability of climate adaptation measures. This is done by providing qualitative descriptions supported with quantitative measures relating to relevant UN SDG targets. This can lead to more focused and informed work towards achieving the UN SDGs.

** hjds@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby*
*** karn@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby*
**** mfe@danva.dk : Godthåbsvej 83, 8660 Skanderborg*
***** liu@ign.ku.dk : Rolighedsvej 23, 1958 Frederiksberg C*
****** of@ign.ku.dk : Rolighedsvej 23, 1958 Frederiksberg C*
******* kru@teknologisk.dk : Gregersensvej 1, 2630 Taastrup*
******** mbj@ign.ku.dk : Rolighedsvej 23, 1958 Frederiksberg C*

Unmanned Airborne Vehicles (UAVs) for monitoring Danish streams and optimizing river maintenance

F. Bandini, DTU Environment, O. Smith, I. K. Jensen, Orbicon**, N. G. Hansted, M. Butts, DHI***, B. Lüthi, Photrack AG****, L. Jiang, T. P. Sunding, P. Bauer-Gottwein, DTU Environment*

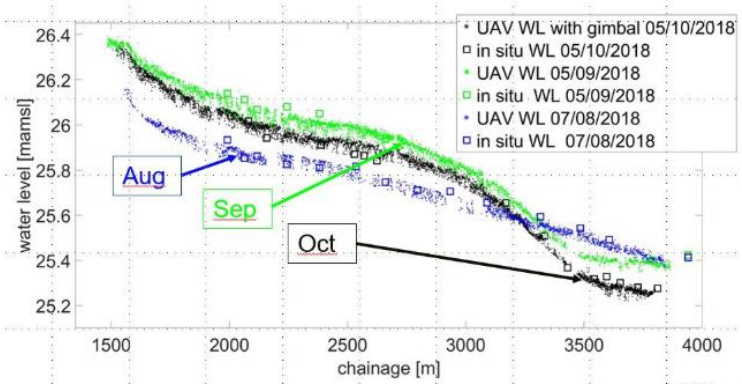
Abstract
Conveyance and shape control of Danish streams costs approx. 150-200 million DDK per year. Vandløbsregulativer (watercourse regulations) prescribe that each municipality is obliged to ensure the river shape or conveyance set by the current regulation. For this reason, 15-20 000 km public rivers in DK must be surveyed with in-situ measurements of bathymetry and discharge every 3-10 years. The majority of these rivers are regulated by shape (bathymetry) control, with less than 5% is regulated by conveyance control (rating curves). These surveys are conducted manually and are costly but are essential for targeting river maintenance, i.e. river vegetation cutting and bottom clean-up. Maintenance operations are also expensive, detrimental to the river ecological status but are necessary to avoid floods.

In this context, more efficient methods are required to monitor rivers and optimize river maintenance. Unmanned Aerial Vehicles (UAVs) can provide high spatial resolution and dense temporal coverage data, in quick turn-around time, with waypoint-based automatic flights. UAVs can be integrated with advanced and flexible payloads. However, weight and size are the main limitations for UAV-payload sensors. To retrieve

accurate UAV flight positions and angles, UAVs are generally equipped with accurate Global Position System (GPS) receivers and Inertial Measurement Units (IMUs).

This presentation demonstrates that a UAV, equipped with an accurate differential-GPS system and a lightweight radar chip, can monitor water level (i.e. water surface elevation about mean sea level). By subtracting the range between the UAV and the water surface (measured by the radar) from the altitude of the UAV above the geoid (measured by the GPS), water level can be measured. Surface velocity can be estimated with Surface Structure Image Velocimetry (SSIV), a special flavour of the cross-correlation techniques, applied to video frames retrieved from the on-board video camera. By observing the displacements between particles, such as leaves or foam, visible on the water surface, or by observing ripples generated by water turbulence, these cross-correlation techniques can predict water surface velocity. Surface velocity observations can be used to estimate discharge by following ISO standard EN ISO 748:2007, and by combining it with the water depth profile and a Manning number.

UAV-water level observations of a stretch of Åmose Å (Sjælland, Denmark) are shown in the figure below. UAV-observations (in meters above mean sea level (mamsl)) showed an accuracy of ca. 3 cm when compared to in-situ Real Time Kinematic (RTK) GPS observations. These UAV observations represent a new dataset for hydrology: river water level profiles with high spatial resolution (ca. 0.5 m). River water slope is an informative dataset to understand how rivers are affected by vegetation growth and river maintenance. Indeed, water level measurements were used to calibrate a hydrodynamic model and estimate spatially distributed Manning numbers, which have a controlling influence on channel conveyance.



* fban@env.dtu.dk: *Bygningstorvet B115, DK-2800 Kgs Lyngby, Denmark*
** *Høje-Taastrup, Linnés Allé 2, 2630 Taastrup*
*** *Agern Allé 5, DK-2970 Hørsholm, Denmark*
**** *Ankerstrasse 16A, 8004 Zürich, Swizerland*

An UPLC-QqQ Method for Analyzing Natural Toxins-Pyrrolizidine Alkaloids in Surface Water from a Ragwort Catchment, Vejle-Denmark.

Jawameer R. Hama, Bjarne W. Strobel

Phytotoxins consist of a large group of chemicals that produced by plants as toxic secondary metabolites and mechanism defense. They are loaded and contacted continuously with environment, but the environmental distribution and fate of these toxins are largely unknown. The aim of this study to present an analytical method to quantify Pyrrolizidine Alkaloids (PAs) in water and environmental samples.

Alkaloids and in particular Pyrrolizidine alkaloids (PAs) are found in a many plant in families of *Asteraceae, Boraginaceae* and *Fabaceae*, it accounted that approximately 3% of flowering plants contain at least one PA. PA consist of nitrogen between two fused five-membered rings. PAs are esters of hydroxylated methyl

pyrrolizidines, with a necine base- and necic acid moiety that can be either saturated or unsaturated with a double bond between the 1 and 2 positions. They can exist in basic free and N-oxide (PANO) form. Until now, more than 660 PAs have been found in nature.

Here, we report a quick and robust Ultra performance liquid chromatography-mass spectrometry (UPLC-MS/MS) method that developed by UPLC coupled with a TQ-MS. A Waters Acquity UPLC I-Class module was used for chromatographic separation, equipped with a 2.1 × 50 mm Cortecs C18 column, particle size 1.6 µm (Waters, Milford). MS was operated on a Waters Xevo TQD triple quadrupole MS with electrospray ionization in positive ion mode. LC mobile phase was composed of A (water + 0.01% FA) and B (acetonitrile + 0.01% FA). Gradient conditions were: 0−4 min 10% B, 7 min 20% B, 10 min 50% B, 15 min 90% B, 15−17 min 90% B. The column was equilibrated for 6 min before each run, and the total run time is 23 minutes. The column temperature was set to 35°C. The flow rate was set to 0.45 mL/min. The method is quick, robust and validated for quantification of PAs in wide range complex matrixes and environmental samples such as plant, soil and water. In addition, the solid-phase extraction step is validated to pre-concentration and cleanup extracts and water samples; even the volume of the loading sample is assessed. High MS resolution with multiple reaction monitoring (MRM) transitions were used for quantification. MRM transition is perfumed to detect fragmentation pattern and monitor PAs with saturate and 1, 2-unsaturated necine base even if they differ from their necic acids but share a similar core structure. The limit of detection of the method ranged 2-6 µg/L of the toxins in water bodies and environmental samples. As the result, 10 toxic PAs analysed in a surface water close to Ragwort catchment in Vejle-Danmark. To our knowledge, this method is the first to be validated to analyse PAs in environmental samples; for both water and soil.

This research project is part of European Training Network – NaToxAq, which has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 722493 (NaToxAq).

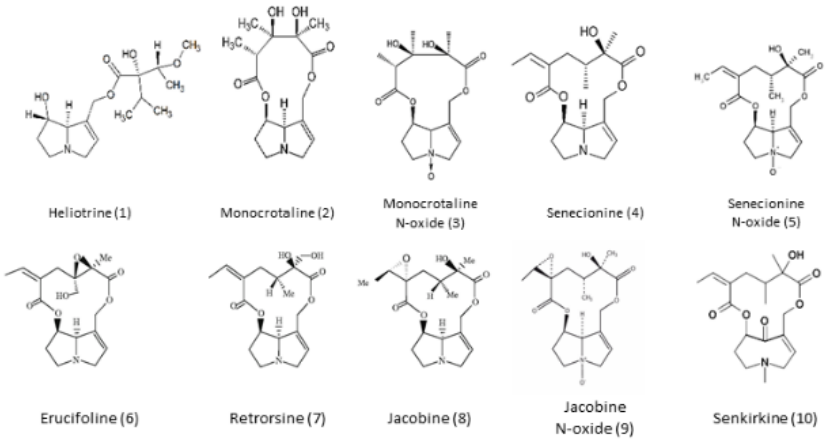


Fig. 1 Chemical structures of selected pyrrolizidine alkaloids.

Department of Plant and Environmental Sciences, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg, Denmark

Environmental surveillance and genomic characterization of *Vibrio cholerae* O1 from fish, phytoplankton and water in Lake Victoria

Yaovi M. Gildas Hounmanou[1], *Pimlapas Leekitcharoenphon*[2], *Rene S. Hendriksen*[2], *Tamegnon V. Dougnon*[3], *Robinson H. Mdegela*[4], *John Olsen*[1] *and Anders Dalsgaard*[1]

Abstract

Cholera is endemic in countries surrounding Lake Victoria. This study characterized the occurrence of toxigenic *Vibrio cholerae* O1 in Lake Victoria and their genomic profile in samples obtained during a non-outbreak period. A total of 360 samples of carps, phytoplankton and water were collected during dry and rainy season of 2017 in the Tanzanian basin of Lake Victoria. The surface water temperature fluctuated between 24.5 °C and 25.5 °C with an alkaline pH varying from 7.5 to 8.5 at sampling points. Samples were analyzed using standard culture procedures followed by *omp*W PCR and a direct multiplex PCR (*omp*W + *ctx*A) from enriched samples. Isolates were screened with polyvalent antiserum O1 then tested for antibiotic susceptibility. Whole Genome Sequencing was employed to investigate the genomic characteristics on 10 isolates. Online bioinformatics tools were used for sequences analyses. The study revealed that positive samples were more recovered in the direct PCR than culture-based detection (69% vs 21.3%, $p<0.05$), mostly irrespective of sampling seasons. Ten *V. cholerae* O1 strains were found among 22 *ctx*A positive strains. The direct PCR methods revealed 23 *ctx*A positive samples of which 15 were negative by culture methods. All strains were El Tor variants *V. cholerae* O1 of MLST type ST69 harboring the seventh pandemic specific gene. Virulence-associated genes, *ctxA*, *ctxB*, *zot*, *ace*, *tcpA*, *hlyA*, *mshA*, *rtxA*, *ompU*, *toxR, T6SS, alsD, makA* and pathogenicity islands VPI-1, VPI-2, VSP-1, and VSP-2 were present in all sequenced strains. The strains seem phage resistant as they lacked phage susceptibility islands, carried the SXT integrative conjugative element with phenotypically and genotypic resistant to aminoglycosides, sulfamethoxazole, Trimethoprim, phenicols and quinolones and a genomic similarity to *V. cholerae* ICEVchHai1. They belonged to the same clonal lineage of the seventh cholera pandemic and were genetically close to previous outbreak strains from Tanzania and Uganda with as low as three SNPs (Single Nucleotide Polymorphism). The presence of toxigenic drug resistant *V. cholerae* O1 with outbreak potentials in the aquatic environments during non-outbreak periods may play an important role in the epidemiology of cholera in the entire African Great Lakes Region.

Keywords: Microbial Ecology; *Vibrio cholerae*; Aquatic Reservoirs; Genomics; Neglected Tropical Diseases; whole genome sequencing

[1]*University of Copenhagen, Denmark;* [2]*National, Technical University of Denmark;* [3]*University of Abomey-Calavi, Benin;* [4]*Sokoine University of Agriculture, Tanzania*

Session 9: Young Water Professional Session

Chair: Agnete Ansbæk

Title	Presenter
Digitization of the water sector - practical examples from around the world,	Riccardo Sprocati & Jan-Michael Blum, DTU & Envidan
Urban Lab 2018 – Coastal Resilience	Marianne Skov, Rambøll
What is the value of Smart Meter Data?	Martin Møller Værum, Kamstrup
Discovering the Potential of Machine Learning in the Utility Sector	Bolette D. Hansen, AAU & Envidan
Bringing Big Data into the water sector	Charlotte Agata Plum, InforMetics
Workshop: Fast forward	Wadim Baslow, Quercus Group

A digital future for water utilities

Martin Møller Værum - Product Specialist, Kristian Rokkjær - Head of Product Management, Allan Nielsen - Product Manager (Kamstrup A/S)

Abstract

The digital water utility is rapidly evolving.

The rapid technological development is providing us with new resources and tools that are radically changing the utility's options for getting an overview of the entire distribution network - all the way to the consumers.

We have a world of knowledge available at our fingertips, and we can achieve a level of accuracy and efficiency that was unthinkable just a few years ago. It is no longer just a matter of increased accuracy and metering of water consumption. It is also about strengthening consumer relations and optimizing operations. About quality management, revenue protection, asset management and so much more. It is about being able to make the right choices and chose the right investments.

At Kamstrup, we aren't just talking about the digital utility. We are busy creating it! Smart metering creates value beyond what we thought was possible Assens Municipality, in central Denmark, has around 4,000 water consumers. Ordinarily, the water utility plays only a minor part in consumers' lives.

"The only time they ever think about their water supply is when they have to call in because something isn't working. When brown water starts flowing out of the tap for instance, or a pipe burst. Or when they get a water bill that's unbelievably high," says Anne Lyndorff Hovmøller, Civil Engineer and team leader for the water department of Assens Utilities.

By putting our customers at the heart of everything we do, listening to their needs and anticipating the challenges they will face in the future, enables us to consistently create innovative product ranges of hardware, software and services, including; consumption meters, communication infrastructure, meter data management systems, smart grid applications, hosted solutions and tools for data analysis.

What is the value of meter data?

Some of the benefits of today's smart water metering technology are immediately apparent, like saying goodbye to manual reading. But what's not as clear at first glance is what impact more frequent meter data can have on a utility's bottom line.

There is huge value in data. But data is only useful when you use it. Smart meters produce a lot of data, often more than what a lot of utilities know what to do with. So how do you calculate the value it can bring to justify the investment?

Digitization of the water sector - practical examples from around the world

Riccardo Sprocati, YWPDK & DTU Environment**, Jan-Michael Blum, YWPDK* & EnviDan A/S****

Abstract

In the last decade, breakthrough technologies and ground-breaking algorithms allowed users to benefit from services and products that use Artificial Intelligence (AI) as core of their operations. In this way, machines that are able to learn from large amount of data in order to provide useful results, have been developed, even in the absence of clear models managing the internal complex dependencies between inputs and outputs. This is the case for example of instant language translations, image recognition for autonomous vehicles, voice assistants for smartphones and predictive models for stock prices and supply chain optimization. AI technologies have also been implemented in several applications in different areas of the water sector. Some examples include (i) augmented reality and virtual reality, (ii) remote sensing & image analysis, (iii) drones for inspections, samplings and 3D surface models, (iv) blockchain technologies, (v) internet of things and (vi) smart controls for smart cities. The number of new study cases is constantly increasing and the several success stories clearly indicate that an important key for many state-of-the-art water technologies relies on AI, whereas a distinguishing success feature for water professionals in the next decade is the ability to use the novel digital technologies to increase the efficiency of existing infrastructure and to spot new business opportunities.

Through a globally connected world, we are nowadays furthermore able to learn from people around the world to receive inspiration for our home market. In this presentation, digitization projects from outside Denmark are presented to serve water professionals in the Danish market as a blueprint for future projects: what has been done elsewhere? What is applicable for Denmark? And how can ambitions be combined to advance water technology in the 21st century?

* *ai@ywp.dk: Young Water Professionals Denmark AI Workgroup*
** *risp@env.dtu.dk: Bygningstorvet, Bygning 115, 2800 Kgs. Lyngby, Denmark*
*** *jmb@envidan.dk: Fuglebækvej 1, 2770 Kastrup, Denmark*

Urban Lab 2018 – Coastal Resilience; YWPDK – "Young Great minds"

Marianne Skov, Rambøll

Abstract

Bringing 8 great minds together create a unique environment. Urban Lab 2018 was set in the city of Copenhagen investigating how to create resilience communities and livable cities while implementing storm surge protection.

Tackling the issues of climate changes can only be done from a holistic view with cross-disciplinary approach and the team soon discovered that the challenges to a larger extent was social rather than technical.

The work proposed entailed an approach and design for increasing coastal resilience of Amager Strand. The Copenhagen Lens was designed as a stakeholder engagement tool, to facilitate input gathering, community

engagement and knowledge sharing. The work is founded on broader principles of sustainable social, economic and environmental development. The design resided from the concepts and evolved on the basis of the core values identified.

Urban Lab demonstrate unique outcomes when we come together, providing capacity building to the young professionals and across the local and global water sector.

Discovering the Potential of Machine Learning in the Utility Sector

*B. D. Hansen, Envidan A/S and Aalborg Universitet**

Abstract

The utility sector is subject to ever-increasing demands regarding efficiency, service level and innovation. Through the years EnviDan A/S has collected a large amount of data from several processes performed in the utility sector. Other data intensive industries have gained high efficiency and valuable new knowledge by implementing machine learning in a wide range of scenarios. Within the utility sector machine learning can i.e. be used to predict biogas production, classification of the state of sewers and bringing new knowledge on the deterioration curves of the sewers. However, a large undiscovered potential for value creation with machine learning is still to be discovered within the utility sector.

How can this potential be discovered and realized across the sector? How to choose where to invest in implementation of Machine learning? And how to demystify the concept of machine learning so experts within the utility sector but with no knowledge about machine learning can offer ideas?

This talk rolls out the roadmap for a 3-year PhD project in collaboration with Aalborg University and EnviDan A/S. Approaches to investigate technical, social and economic challenges and opportunities are presented and the audience is introduced to the concept of machine learning.

Figure 6 Using a large amount of data on sewer states, surroundings, age etc. machine learning can give estimates on the state of sewers which have not been inspected.

* *bdh@envidan.dk: Vejlsøvej 23, 8600 Silkeborg, Denmark*

Bringing Big Data into the water sector

*Charlotte A. Plum, InforMetics**

Weather radar is a well-established technology presenting an improvement in our knowledge about rainfall over the traditional rain gauges. But use of radar data in the utility companies is limited, since getting the most out of radar data is a task requiring both expert knowledge about the data, a large file storage and good computational facilities.

Therefore, InforMetics is working on making radar data more accessible for utilities by handling the storage and processing in the cloud. This way the data can be processed and made available to customers within minutes, and it opens for many ways of customising the products from the radar data. For example, the data could be used for forecasting, exported for use in hydraulic models or combined with other data types in different machine learning applications.

* cp@informetics.com Hauser Plads 10, 4. sal; 1127 København K