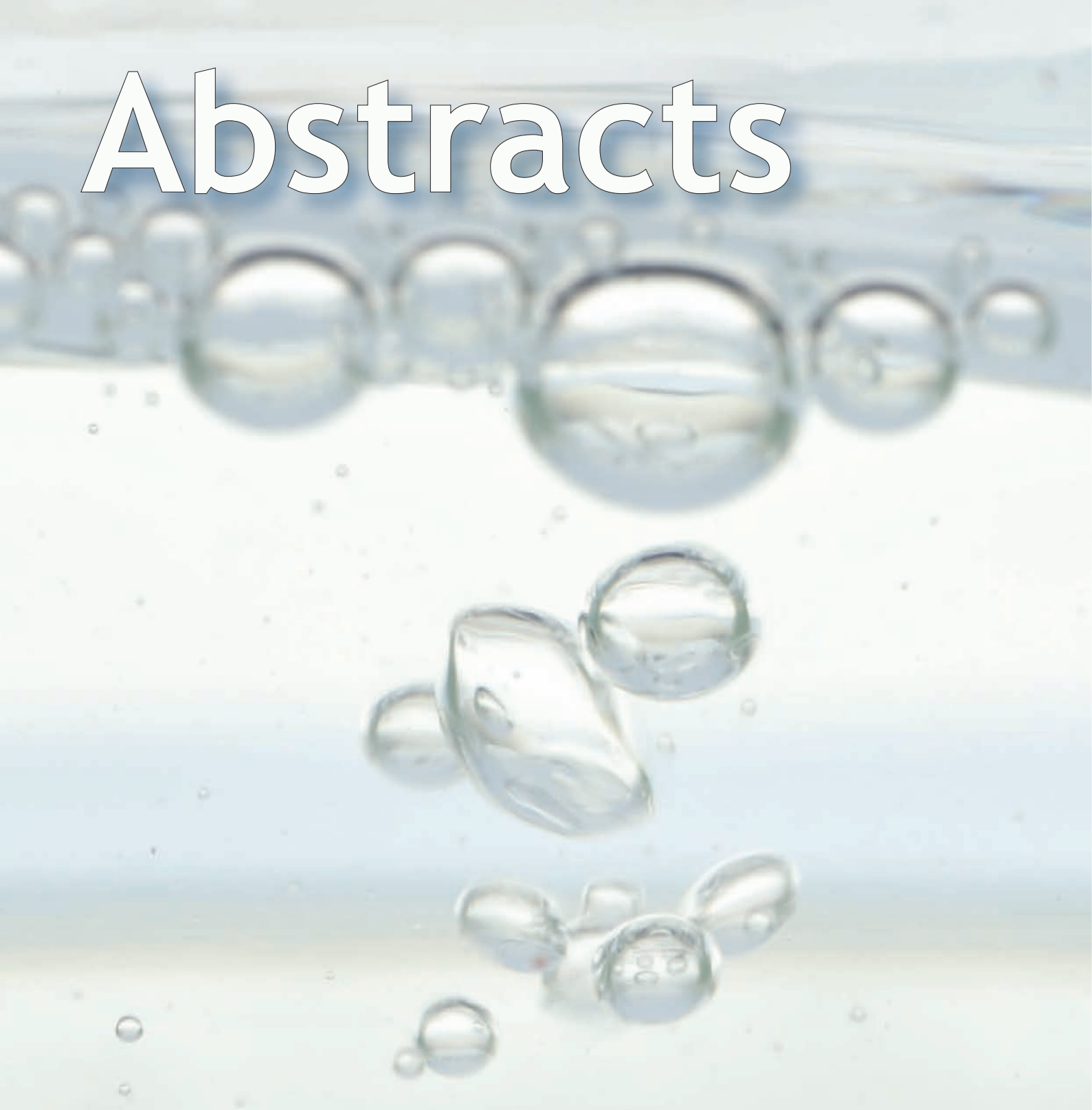
Abstracts



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Contents

Session 1: Groundwater

Optimisation of groundwater well field management

Henrik Madsen[1]

Abstract
Groundwater management at well fields includes a number of operation objectives, such as system reliability, operation and maintenance costs, energy consumption, environmental impacts, and water quality. Numerical modelling of well-fields can be used to analyse different operation strategies to provide more cost-effective water withdrawal and pump scheduling schemes while at the same time minimising the adverse impacts.

An integrated, dynamically coupled hydrological and hydraulic well-field modelling system has been developed for modelling the flow of water in the groundwater aquifer, through the wells and pipe system to the waterworks. The model combines a groundwater model (MIKE SHE), a well model (based on the multi-node well model in MODFLOW) and a pipe network model (EPANET). The integrated modelling approach allows a detailed simulation of the abstraction from the different wells in the well field, which depends on the hydraulic properties in the aquifer, wells, pumps and pipe network.

For optimization and control of well field operation the numerical model is coupled with an optimization algorithm. The integrated simulation-optimization system can be used as a planning tool to optimize well field designs and pump configurations. In addition, optimization can be used on-line for real-time control to provide optimal pump scheduling according to given demands. The real-time control system allows the simulation-optimization system to continuously adapt to both short-term and long-term dynamic changes in the well field.

Acknowledgements
This work is partly funded by the Danish Strategic Research Council, Sustainable Energy and Environment Programme and the Danish Water and Waste Water Association, Research Programme on Energy Savings. For more information visit http://wellfield.dhigroup.com/.

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The impacts of microbial processes and hydrogeological parameters on chemical gradients in porous groundwater systems

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Abstract
Groundwater resources are of global significance for drinking water. In many countries groundwater delivers more than 50% of current potable water and is indispensable for both agriculture and industries. However, groundwater is threatened by local point or diffuse pollution through leaching of pesticides and nitrate. In this study we coupled groundwater age dating, stable isotopes in groundwater nitrate ($\delta^{15}N$, $\delta^{18}O$), sulphate ($\delta^{34}S$, $\delta^{18}O$) and water chemistry data obtained from a high resolution multi-level well to interpret chemical gradients in a heterogeneous porous groundwater system.

Generally, chemical gradients are indicators of redox boundaries caused by active microbial degradation processes. Via modelling results using a dispersion model coupled to a long tritium record and stable isotopes in nitrate we demonstrate that biogeochemical gradients observed in the upper part of the aquifer are formed by mixing of old and young groundwater, with the latter affected by high anthropogenic N input.

Furthermore we found some evidence by the application of environmental tracers that the long mean transit times in the groundwater system are regulated by the thickness of the unsaturated zone and not by local aquifer heterogeneity.

On the other hand, our approach also provides multiple lines of evidence that chemical gradients in the deeper part of the groundwater system are regulated by microbial processes. Furthermore, the multiple isotope approach shows that anoxic pyrite oxidation may represent the electron donor for denitrification in a carbonate buffered groundwater system. This study demonstrates the importance of incorporating both hydrogeological and biogeochemical analyses in a complex porous groundwater system to understand groundwater ecosystem functioning.

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Groundwater Salinity in Greve, Denmark – Modelling and Management of the Municipality's Groundwater Resource

Paul Thorn[1]

Abstract
Elevated salinity (chloride levels greater than 250mg/l) in groundwater wells near the Municipality of Greve's coastline has been observed since the 1970's. Due to the proximity of the wells to the coast, it was traditionally thought that the salinity observed in the wells resulted from seawater intruding into the aquifer from the Baltic Sea. However, a recently released study by GEUS has indicated that the observed salinity could be via diffusion of saline connate pore waters in the chalk aquifer. This has a significant impact for the management of the groundwater, as if the source is from connate formational waters, the slow rate of the diffusion of the salts will not allow the salinity to rise. In contrast, if the salinity is from seawater intrusion, levels could significantly increase, polluting the wells. This study uses historical groundwater quality data (from 1970-2008) from bulk-water samples, combined with a geological model of the municipality in order to produce a conceptual model for the source of salinity observed in Greve.

The geochemical data from the wells suggest that there are two distinct groundwater types within four kilometres from the coastline. Thus the groundwater can be divided up into two separate districts, a northern and southern district. In the northern district, the geochemical data show bicarbonate and sodium rich groundwater. In addition, the sodium to chloride ratio is close to or over one. This suggests that the waters are undergoing freshening. The southern district has relatively chloride and calcium rich groundwater, as well as sodium to chloride ratios at or below 0.7. This suggests that seawater is intruding into the aquifer. The observed temporal changes in salinity also illustrate. The wells from the northern district show no temporal trend in salinity – the salinity remains at the same level from when the well was drilled to the present. In addition, the wells closer to the shoreline do not show a higher salinity level. In the southern district, the wells show a tendency for increased salinity over time, with the wells closest to the coast showing increasing salinity first, and have the highest levels (with one well increasing from 50mg/l Cl to 2200mg/l Cl over a 5-year period). Thus, it is apparent that the groundwater in the southern district is experiencing seawater intrusion, where as the salinity from the northern district is from the connate formational water.

The geology of the area provides an explanation as to why there is a difference between the two groundwater districts. In Greve, the primary groundwater aquifer is fractured Maastrictian chalk overlain by 5m-25m of glacial deposits. In the northern district, the glacial deposits are primarily clayey tills, with thicknesses of over 20m along the coastline. The clayey till acts as an aquiclude, preventing seawater from intruding into the aquifer. In the southern district, there is a thick lens of glacial outwash sands and gravels extending to the coast. This lens provides a conduit for saltwater to intrude into the aquifer.

The results have significant impact for the management of the groundwater in the municipality. As the elevated salinity in the northern district is from connate formational waters, these levels will not increase with the continuation or even increase in groundwater abstraction. However, in the southern district, there is a significant threat for saltwater intrusion into the aquifer. Thus, abstraction wells need to be monitored, and abstraction rates need to be reduced if seawater intrusion intensifies or moves further inland. In addition, new wells should not be located in this area.

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3D regional scale hydrostratigraphic modeling based on sequence stratigraphic methods: a case study of the Miocene succession in Denmark

Peter Scharling[1]

Abstract

A sound hydrogeological model is the heart of every well performing groundwater model. A sequence tratigraphic approach has been tested, which has been widely used in the petroleum industry since the 1980s for the construction of three-dimensional (3D) hydrogeological models for sedimentary basins. The sequence stratigraphical interpretation has been established for the Miocene succession in western Denmark based on seismic profiles, gamma-ray logs, sediment descriptions and palynological analysis of borehole samples. The up to 400 m thick Miocene succession consists of deposits originating from deep marine to terrestrial depositional environments. The succession is subdivided into six sequences, corresponding system tracts and distinct lithofacies covering the period from late Oligocene to latest late Miocene. The final model is converted into a binary 3D model that shows the location, geometry and thicknesses of potential deep aquifers, and is prepared for groundwater flow modeling. The model provides a qualified geological description of the connectivity between deep sand formations and the ground surface. By comparison to a traditional lithofacies model based on sediment descriptions of borehole samples, it is shown that the new method gives a more sound geological understanding, which is essential when flow paths and the vulnerability of deep aquifers are evaluated.

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Session 2: Water and Climate

Design practice for urban drainage including climate change impacts

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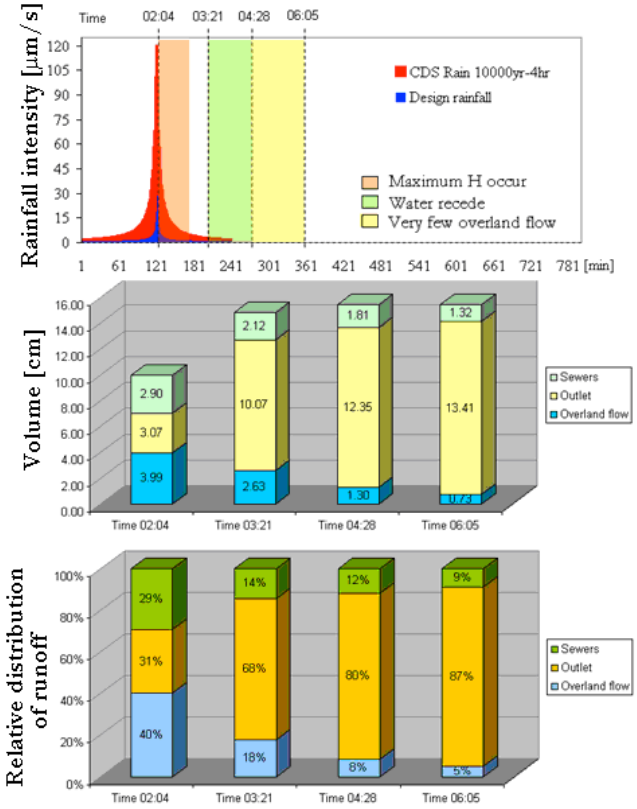
Abstract
An increase in precipitation intensities has been observed in Northern Europe, most likely due to the climate change. Incorporating the anticipated climate change impacts into design of urban drainage has been a big challenge for engineers and will have substantial impact on the overall cost of urban drainage in terms of investments and/or damage.

The presentation will focus on preliminary work on the increased risk of flooding, i.e. exceeding the design criteria. Analyses of flood risk are performed by a combination of hazard and vulnerability assessment of the physical impacts and economic losses. A simplified conceptual catchment is carried out in Mike Urban to model flooding impacts with linkage to hazard indicators, such as water extent, depth and velocity. The generation of flooding on a regular catchment due to extreme rainfall events is described in relation to catchment parameters, such as size, slope, roughness, drainage capacity, local pressures, etc. The vulnerability assessment is mainly with respect to the quantification of the monetary losses and intangible effects induced by flooding. The methodologies of quantifying environmental service flows and intangible goods are studied and incorporated in the cost function. The objective is to derive flood damage cost function that links to the catchment characteristics to provide economic background for further evaluation and adaptation tools.



Mass balance analysis of the distribution between runoff in sewage and overland flow depending on time

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Impact of alternative bias corrections on climate projections and predicted pesticide leaching

Torben O. Sonnenborg[1] and Peter van der Keur[1]

Global climate models are often downscaled using regional climate models to obtain a better description of the physical parameters and processes. The results from the regional climate models are, however, not accurate enough to be used as direct input to hydrological impact models. Therefore, bias correction of the climate model results is needed. In this study four different bias correction methods have been tested on results from regional climate model. In two methods the scenario climate is based on the historical climate whereas for the other two methods the results from the climate model is used as baseline for the scenarios data. The methods are based on data from 1961-1990 and validated on data from the period 1991-2006. The difference between the four methods for the scenario period 2071-2100 is quantified by statistical means. The impact of bias correction method is tested with respect to simulated pesticide leaching from the root zone for two different locations, one dominated by sandy soils and the other by clayey soils. Especially for the clayey soil dominated by macro-pore transport the choice of bias-correction is found to be important.

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Three Points Approach for urban flood risk management: adapting to climate change through transdisciplinarity and multi-functionality

C. Fratini[1+4], G.D. Geldof[2+4], J. Kluck[3] and P.S. Mikkelsen[4]

Abstract

Urban flood risk is increasing as a consequence of climate change and growing impervious surfaces. Increasing complexity of the urban context, gradual loss of tacit knowledge and decreasing social awareness are leading to inadequate maintenance of urban infrastructures. The European Flood Directive sets clear requirements and emphasises the need for a paradigm change in favour of non-structural measures aimed at urban resilience and social preparedness. The Three Points Approach (3PA) provides a structure that facilitates the organization of the decision making process dealing with urban flood risk management (UFRM) by enhancing the use of transdisciplinarity and accepting the complexity of the urban context. The 3PA introduces three domains where the decision makers may act (1) *technical optimization*, dealing with standards and guidelines; (2) *spatial planning*, to make the urban area more resilient to future changing conditions; (3) *day to day values*, to enhance support and awareness among the stakeholders. This study demonstrates the validity of the 3PA and describes how it can be used in practical UFRM. A multilevel approach to knowledge was employed to understand the mechanisms driving complex adaptive systems, like nature and society, characterizing the urban area and thus apply the 3PA in practice. Two case studies were analysed in the Netherlands and in Denmark with the 3PA. This analysis demonstrates the validity of the 3PA for UFRM and highlights the differences between the two countries in approaching the decision making process, drawing attention to the importance of culture in projects. We conclude that the 3PA offers decision makers an innovative perspective on UFRM and is ready to be used to organize strategy plans for urban adaptation to climate change.

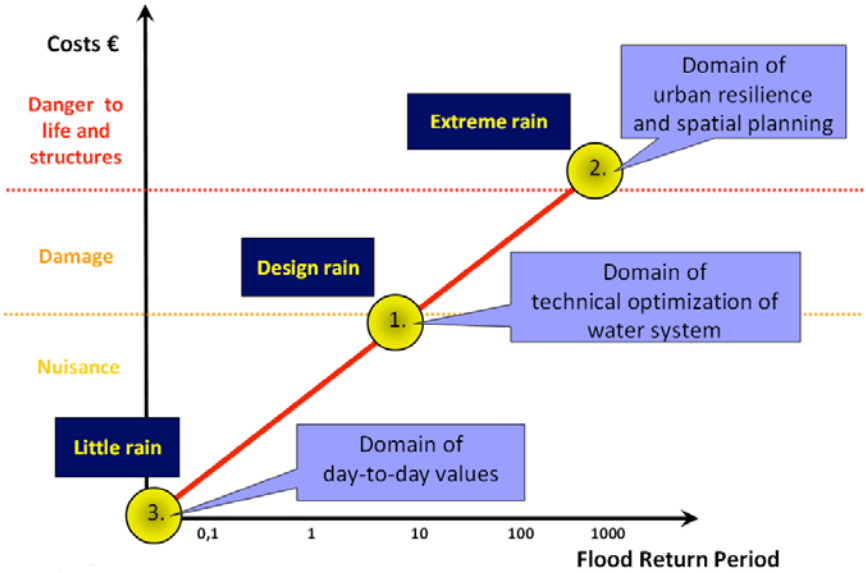

Figure 1. The Three Points Approach scheme. Both the axes are on a logarithmic scale. The horizontal axis represents the return period and the vertical axis represents the size of the flooding in terms of the cost of the nuisance/damage/-danger caused to the urban area and its inhabitants.

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Session 3: Water resources

How to assess groundwater abstraction impact on in-stream physical habitat conditions in small lowland streams

M. Olsen[1], E. Boegh[1], J.C. Conallin[1], H.J. Henriksen[2], J.C. Refsgaard[2], L. Troldborg[2]

Abstract
After inventory of the sustainable Danish groundwater resource in 2003 one of the conclusions was that consideration of minimum flow requirements in streams was most limiting for the size of the groundwater resource. This revealed special challenges in regard to impact assessment from hydrological conditions e.g. groundwater abstraction on in-stream ecological conditions. Groundwater abstraction affects low flows critical to in-stream ecological conditions in particular and it is well known that large scale water resources models often are developed with a focus on simulation of annual water balance and hydrograph shape rather than low flow.
The objective of this study was to assess if it was feasible to combine in-stream environmental flow criteria with an integrated surface-groundwater model (in this case the Danish national water resources model, DK-model) to quantify groundwater abstraction impacts on in-stream physical habitat conditions.
The island of Zealand, Denmark, was used as case area and brown trout (*Salmo trutta*) as indicator of in-stream habitat conditions. The brown trout was chosen since it is often used as environmental indicator in streams and recently there has been a huge advance in the knowledge on brown trout in-stream habitat requirements in Danish streams. A calendar of "Ecological Critical Flows" (ECF) was established for streams on Zealand using local expert knowledge. For each month the ECF-calendar indicates if high or low flow is critical for brown trout habitat conditions. Simulated and observed stream flow from 49 flow gauging stations included in the DK-model was used to assess flow simulation error and in-stream flow criteria; critical low flow criteria (Q_{low}), optimal flow criteria (Q_{opt}) and critical high flow criteria (Q_{high}). One Q_{low} and one Q_{opt} was assessed by combining general hydraulic geometry functions for water depth (D) and water velocity (V) in streams on Zealand with brown trout D and V requirements.

The ECF-calendar divides the year into 3 periods; April-June where high flow is critical for brown trout, July-October where low flow is critical and November-March where flow most often is not critical. Flow simulation error and bias is relatively largest for the lowest flows and is most pronounced in the July-October period where low flow is critical for in-stream habitat conditions. Simulation of Q_{low} is associated with large uncertainty and bias since all estimated Q_{low} is in the flow range where the DK-model overestimates flow by more than 100%. The DK-model is better at simulating Q_{opt} than Q_{low} since estimated Q_{opt}-values are in the flow range where overestimation is less than 100%.

The study revealed that low flow criteria and the DK-model at present are not suited for each other due to different focus. The finding emphasises that stream ecologists and hydrologist typically focus on different aspects of the hydrological regime. In-stream environmental flow criteria for use in water management should be ecologically relevant and easily understandable for both stream ecologists and hydrologists in order to bridge the gap between the two disciplines and achieve true integrated water management. In our opinion a tool like the ECF-calendar is a useful base for positive interaction between stream ecologists, hydrologists and modellers to establish and improve integrated water resource managements tools. Furthermore different approaches are needed at different spatial scales, i.e. flow criteria that are used at large scale should be adapted to large scale water resources model, while flow criteria and hydrological models should be improved and validated for local scale investigations in order to better simulate ecologically relevant flows. When targeting flows from the ECF-calender in hydrological model calibration high quality observation data representing low flow from flow gauging stations collected at the local scale and improved water balance input data are required.

This study was part of the research project "Groundwater abstraction and climate change impacts on ecological conditions in streams" (www.ecohydrology.ruc.dk) which is financed by the Danish Research Council for Technology and Production, 2007-2009.

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A new DK-model concept for nutrient loading calculations (DK-NP)

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Abstract
A new model concept has been developed that enables a harmonised calculation of monthly total nitrogen (N) and total phosphorus (P) loadings of surface waters (lakes and coastal waters). The model concept utilises data from a network of downstream monitoring stations in Danish streams established back in 1989 (coastal loading network). Today it consists of 113 monitoring stations covering 49% of the Danish land area. The remaining of the land area is unmonitored and hitherto different methods have been utilised to estimate N and P loadings. A NOVANA project running from 2006-2009 where also runoff from ungauged areas were modelled (DKQ model), has made it possible to develop a new model concept that can be utilised all over the country. We have recently finished the recalculation of monthly N and P loadings to coastal waters around Denmark for the period 1990-2008 utilising the new DK-NP model concept.

The core of the model concept is two statistical models predicting discharge weighted concentrations of N and P from diffuse sources (mainly agriculture) being developed based on ongoing monitoring results from 80 catchments for N and 24 catchments for P, the latter having water sampling done continuously with automatic samplers for a 8-year period. The statistical models has been utilised to estimate the diffuse loadings to freshwater from a series of 25 km^2 catchments in the unmonitored parts of Denmark by multiplying the modelled concentrations with DKQ modelled runoff values. For validation reasons the N model has been applied to the monitored areas as well and deviations between monitored and model estimated N loadings has been evaluated in different Georegions and for specific monitored catchments. The model concept also includes new procedures for estimating retention of N and P in streams, rivers, wetlands and lakes. In the case of 611 larger lakes the lake specific N retentions have been modelled chaining all lakes and catchments within a watershed and modelling incoming water and N for use in a N-retention model. Stream, river and wetland retention is modelled utilising simple reduction rates for the different types after having depicted and assessed the individual water bodies with algorithms embedded in GIS.

The newly recalculated nutrient loadings can be compared with loadings calculated with methods formerly used. Methods used in earlier calculations of nutrient loading were not strictly standardised but partly based on varying assumptions and methods used and reported by the former counties. For the period 1990-2005 recalculated mean nitrogen loading is 6.6% less than previously reported with annual deviations ranging from 0 to -15%. Contrary for phosphorus recalculated mean loading (1990-2005) is 6% higher than previously reported with annual deviations ranging from -10% to 15%. On a regional and local scale these deviations obviously can be marked higher than the ones for the national loadings.

We intend in the future to further develop and validate the new model concept improving the different retention models and create tighter linkages to the model calculated Nitrate leaching from the root zone on agricultural and non-agricultural land.

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Valuation of water quality improvements in the Water Framework Directive: valuation results, benefit transfers and the practical use in WFD implementation

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Abstract
The aim of this study is to test benefit transfer related to the implementation of the Water Framework Directive in Denmark. By benefit transfer we mean transfers of benefit results from one study site to policy sites, and hereby make use of the often costly results in policy assessments in other sites. The notion benefits are used for the environmental improvements of the WFD, by valuation studies these benefits are expressed in monetary terms. Because valuation studies are so expensive to conduct benefit transfer can be a cost-effective alternative as compared to primary valuation studies of the aquatic environment, but this only hold if the benefit transfers can be done without to large transfer errors.
The results from a stated preference study in Odense Fjord and Roskilde Fjord is used for the test of unit benefit values as well as benefit functions between these two Danish fjords. In both areas a similar questionnaire has been submitted to a representative number of households at Funen/Southern Denmark and Zealand, respectively. The questionnaire contains questions on the use of the fjords as recreational area - where they go most frequently, the frequency and what they most often do-, the households' address (both home address and second home address), socio economic variables such as age, gender, income and educational level in addition to valuation questions. Both studies contain two types of valuation questions (a contingent valuation question and a so-called choice experiment) but in this benefit transfer we only present the contingent valuation results. The improvements of the ecological conditions in the fjords from bad and moderate conditions to good ecological conditions are presented using a generic water quality ladder, developed for use in the EU-project AQUAMONEY (Bateman et al, 2009; Hasler et al 2009).

For both fjords benefit functions are estimated, and the parameters in the benefit functions are compared. Comparison of the parameters, i.e. the preferences for the two areas, are done by testing the hypothesis H_0: $b_1 = b_2$ and H_1: $b_1 \neq b_2$, where b_1 and b_2 are the estimated model parameters for the two fjords. If H_o is accepted and H_1 is rejected this is an indication of that the results/benefit functions are suitable for benefit transfer to other areas in e.g. Denmark.

The results indicate that the benefit transfers between the two fjords results in very low transfer errors, and this result is promising for use in the WFD implementation.

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Bateman I. et al (2009) Testing water quality benefit transfer. Paper presented at the EARE conference, Amsterdam, June 2009.
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Nitrate reduction in geologically heterogeneous catchments (NICA)

Jens Christian Refsgaard[1] and Britt SB Christensen[2]

Abstract
The nitrate load from agricultural land to lakes and coastal water in Denmark has during the past 20 years been reduced by about 50% by government regulations imposed on agricultural practice. The EU Water Framework Directive (WFD) requires that good ecological status be achieved for all water bodies by 2015 and prescribes that surface water and groundwater resources are managed in an integrated context. This will require an additional reduction of nitrate load by 50%, which economically will be very painful for the agricultural sector. The regulations imposed until now have been general, i.e. the same restrictions for all areas independent on the subsurface conditions. Studies have shown that on a national basis about 2/3 of the

nitrate leaching from the root zone is reduced naturally in the subsurface before reaching the streams. This implies that if a general agricultural regulation reduces nitrate leaching by 100 kg N, the nitrate load to surface water will only be reduced by 33 kg N. Therefore it is much more cost-effective to identify robust areas, where nitrate leaching through the root zone is reduced in the saturated zone before reaching the streams, and vulnerable areas, where no subsurface reduction takes place, and then only impose restrictions on the vulnerable areas.

Distributed hydrological models can make predictions at grid scale, i.e. at much smaller scale than the full catchment. Hence these models have a potential for being able to differentiate between robust and vulnerable areas. However, in all previous studies we have seen, distributed models do not have predictive capability at scales much smaller than catchment scale. A constraint in this respect is that distributed models often do not include local scale hydrogeological heterogeneities that are known to be important for reactive transport.

NICA (Nitrate reduction in geologically heterogeneous catchments) is a new research project that will develop tools for assessing nitrate reduction in the subsurface between the root zone and the streams and methodologies for assessing at which spatial scales such tools have predictive capabilities (see the enclosed figure). A new instrument will be developed for airborne geophysical measurements, MiniSkyTEM, dedicated for identifying geological structures and heterogeneities in the upper 30 m. State-of-the-art hydrological models (DAISY, MIKE SHE/MIKE11, HydroGeoSphere, RWHET) will be applied and the effect of geological heterogeneity will be analysed by use of stochastic geological realisations such as TProGS. A new concept, Representative Elementary Scale (RES), will be developed for assessing the minimum scale at which models, with a given data input, potentially have predictive capabilities. The studies will be conducted in a 10 km^2, densely instrumented catchment and tested in a 101 km^2 catchment, where farmers and authorities will be actively involved in evaluating possible measures for reducing the nitrate load to surface water in a cost-effective manner. The economic gain from a cost efficient location of the measures will be evaluated.

The talk will present the project idea.

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Session 4: Urban water

The hydrological possibilities and consequences of using sustainable urban drainage systems in Copenhagen

Jan Jeppesen[1,2] and Steen Christensen[2]

Research project: Black, Blue & Green – Integrated infrastructure planning as key to sustainable urban water systems (www.2BG.dk).

Abstract
The research project *Black, Blue & Green – Integrated infrastructure planning as key to sustainable urban water systems (2BG)* explores the possibility for a paradigm shift within urban water systems towards local storm water management.

In order to significantly reduce the contribution of storm water to existing sewer systems, massive storm water infiltration to the groundwater system might be a key solution. Whether or not this is possible depends on the levels and dynamics of groundwater. A product of the 2BG project is therefore an urban hydrological model capable of quantifying the total urban water cycle with emphasis on interactions regarding the groundwater system on catchment scale. The urban water cycle is described in terms of root zone water balance, water supply, waste water, storm water, groundwater flow between geological layers, sustainable urban drainage systems (SUDS), and the interactions between these systems. Application of the model (without SUDS) is demonstrated for the Copenhagen area for the period 1850-2003, whereby the complete history of groundwater abstraction and major city development in the region is covered. Observations of historical hydraulic head data, stream discharge, and inflow to sewage works are used to calibrate and validate the model.

Furthermore the urban hydrological model, including the SUDS utilities, is demonstrated thoroughly for the 2BG joint-case area (16 km^2 of the Harrestrup Å catchment in Copenhagen). For this area it is estimated that 60 % of the storm runoff must be disconnected the sewers in order to fulfill the objective of reducing the number of combined sewer overflows to Harrestrup Å to less than one each year. This 60 % disconnection forms the basis for a SUDS-drainage scenario which is simulated for the period 1991-2003. In the scenario the disconnected storm runoff is directed to infiltration areas (36 %), swale-trench systems (26 %), soak-aways (8 %), rain tanks (6 %), green roofs (10 %), and to streams (14 %), respectively.

Although it is attempted to direct the majority of the disconnected storm runoff to “green” SUDS (which include evapotranspiration) more than 50 % of the total input to the SUDS infiltrates to the groundwater system. As a result the groundwater recharge increases with 56 % compared to the reference situation without SUDS. The consequence is a dramatic rise in the groundwater table and a need for significant near-surface groundwater drainage. The main reason for this is the presence of a low-permeable capping layer of till and the close proximity to the sea.

Based on the model scenario it is recommended to only apply controlled storm water infiltration through green SUDS in the case area. Controlled storm water infiltration can be achieved by: (1) minimizing the storm water input to infiltration-based SUDS or (2) applying drains to the underground SUDS-structures whereby the position of the groundwater table is controlled. The latter may be a promising solution to both reduce / delay storm water and to drain ground water (which may rise anyway due to climate changes). In selecting the optimum SUDS drainage strategy the model has proven to provide excellent decision support.

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Monitoring of gas bubbles in rapid sand filters

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Abstract
Air bubble formation in rapid sand filters can decrease drinking water treatment efficiency. Recently there has been increased interest in formation of air bubbles during rapid sand filtration due to dissolved gas supersaturation in the inlet water. Air bubbles reduce water saturation in the filter bed, contribute to head loss, decrease residence time, and increase turbidity measured at the outlet. To address this problem, waterworks rely on backwashing to periodically remove built up gases.

This study aims to develop a new diagnostic tool to be used in waterworks to characterize and quantify the amount of air bubbles trapped in rapid sand filters. This new method employs reactive sodium sulfite tracer that can be injected and monitored in the filter. It is developed and tested in laboratory column experiments.

The experimental set up was designed to reproduce the formation of bubbles in the porous media during rapid sand filtration. In this set of experiments, particle and soluble contaminant filtration was neglected and distilled water was used as inlet water. To simplify the analysis of bubble formation, inlet water was saturated with oxygen and the concentration of other gases was negligible. Experiments were conducted in a 63x63x313 mm3 transparent column packed with 1 mm diameter glass beads. The water flowed downward in the column. The decrease in water content in the column was monitored by weighing the column continuously using an electronic balance. The column was periodically backwashed to remove built up gas bubbles. Tracer tests were performed during the experiment. A volume of 2 ml of a solution of 60g/l of sodium sulphite was injected into the column. Because sodium sulfite is a salt, an oxygen scavenger and a base, three breakthrough curves could be obtained after each pulse injection of the tracer: conductivity, dissolved oxygen and pH. The column was digitally photographed every 30 min for the duration of the experiment using a digital camera.

As the experiment proceeded and the amount of trapped gas increased, the breakthrough curves evolved. The value of longitudinal dispersivity of the conductivity curves increased with filtration time suggesting that bubble formation produced changes in the flow structure. The changes in the breakthrough curves could be related qualitatively to the increasing amount of oxygen present in the column using column mass and photographic data.

The new tracer method developed in this paper is useful to monitor the development of oxygen bubbles in the column. It could therefore be an innovative and valuable tool for investigating the presence of air bubbles in the filter bed of rapid sand filters at waterworks.

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Model based prediction of micropollutants fluxes in stormwater treatment systems

L.Vezzaro, E. Eriksson, A. Ledin, P.S. Mikkelsen[1]

Abstract
Stormwater treatment facilities are becoming essential elements in the strategies for reducing water pollution from urban areas. When elaborating pollution control strategies, urban water managers should be able to assess, compare and select the most appropriate treatment option (also called Best Management Practice - BMP) according to the specific condition of their system. However, when dealing with micropollutants (MPs), this assessment is affected by a general lack of information regarding BMPs performances.

The dynamic Stormwater Treatment Unit model for MPs (STUMP) was developed to simulate MP fluxes in stormwater BMPs based on the substance's inherent properties. An existing stormwater retention pond in

Stockholm (Sweden) was simulated. The STUMP results (e.g. Figure 1, left) were compared with other commonly applied multimedia models, which can be applied to estimate MP fluxes in BMPs. Two metals (Cu and Zn), and four intrinsically different organic micropollutants were selected and simulated: iodopropynyl butylcarbamate (IPBC, CAS number 85045-09-6) as "average" substance, benzene (CAS no. 71-73-2) as volatile substance, glyphosate (CAS no. 1071-83-6) as biodegradable substance and pyrene (CAS no. 129-00-0) as strongly sorbing. The STUMP can be easily adapted to simulate the investigated system and provides dynamic results that are useful to evaluate the behaviour of the BMP during rain events.

The results of global sensitivity analysis suggested that the processes driving the removal of total suspended solids (TSS) were the most sensitive for the estimation of MP fluxes in the analyzed system. Therefore the calibration of TSS parameters can reduce the uncertainty of estimated MP fluxes when no MP measurements are available. The uncertainty of the STUMP simulated fluxes for copper and zinc were estimated by applying the Generalized Likelihood Uncertainty Estimation method for the available measurements. The pond removal rate calculated by the parameter sets covering 50% of the measured concentration (Figure 1 – right) showed good agreement with the measured removal.

The STUMP model provides reliable prediction of the MP fluxes in stormwater treatment systems, enabling the quantification of the potential MP removal. As data often represent an obstacle in the simulation of MPs, the STUMP model requires a limited amount of information that is usually available (TSS measurements) or can be retrieved from literature (MP inherent properties). The STUMP model can thus be an important tool for urban water managers in the assessment of strategies for the reduction of stormwater pollutant emissions.

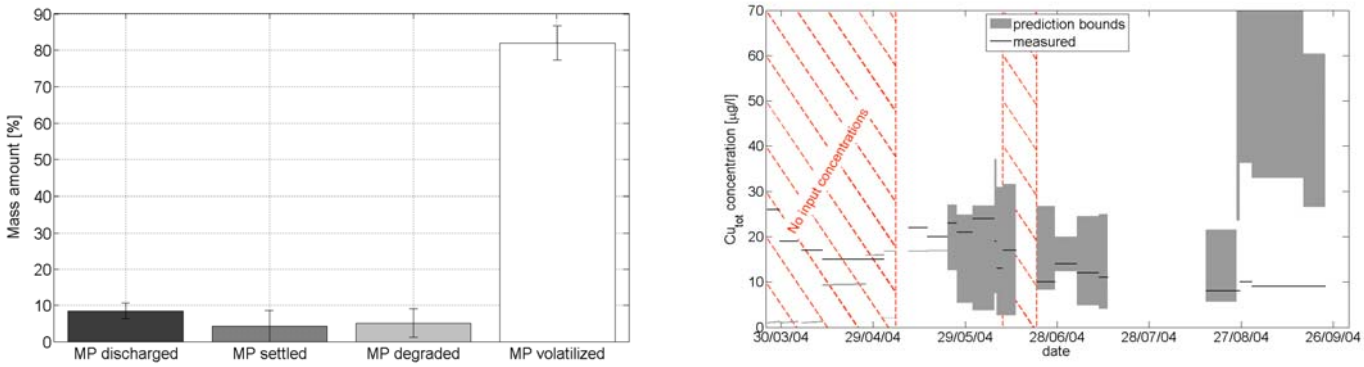

Figure 1. Estimated MP fluxes for benzene (on the left) and prediction bounds for copper concentration in the pond outlet (on the right)

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Confronting the problem of implementing sustainable urban drainage systems - An interdisciplinary case study project in Copenhagen

Ole Fryd and Antje Backhaus[1]

Abstract
Climate change will lead to more intensive rain events in Northern Europe (IPCC 2007) and conventional sewer based solutions are reaching their technical and economical limits. Complementing strategies are necessary.

The purpose of this paper is to present a multi-level and trans-disciplinary approach to the planning and implementation of sustainable urban drainage system (SUDS) retrofits in existing urban areas. Applicability and implications of the approach were discussed based on a case study that was carried out in 2009 in an area covering approximately 1/6 of Copenhagen municipality. A team of 8 PhD students in landscape

architecture, hydrology, environmental chemistry, economy and urban planning collaborated on the design research project with end-users from the City of Copenhagen and the water utility Copenhagen Energy Ltd.

Data screening and the analysis of existing municipal planning goals in combination with a first groundwater simulation resulted in an initial catchment level strategy. Based on this strategy a number of representative focus areas were identified for further detailing at site and neighbourhood level. At the single sites additional landscape architectural and hydraulic investigations showed chances and challenges for the work with SUDS. These evaluations at site level led back to a qualification and adaptation of the overall catchment strategy. Parallel to this iterative working process, aspects of environmental chemistry, economy and stakeholder involvement were examined.

Map of the catchment strategy

This interdisciplinary working process finally led to a number of recommendations for Copenhagen municipality and to a possible SUDS implementation strategy of “combined disconnections” for the city.
Core of the catchment strategy are three different area types where different measures for SUDS implementation are recommended (see map). In the most northern part of the area (area type 1), on-site infiltration and an intensive collaboration with the single house owners for the promotion of rain gardens, infiltration trenches etc. are recommended. The single point measures on private ground should be combined by public linear overflow structures.

In the areas where the municipality aims to develop green links between existing green areas (area type 2), green “park-ways” that also handle stormwater run-off are recommended.

In areas that slope towards green areas and open water ways (area type 3) a strategy that focuses on delay and transport is recommended. Existing streets should be transformed to transport the water to the recipients e.g. by the implementation of open gutters or rain beds.

This differentiated strategy could help to release the existing sewer system, reduce the risk of soil saturation and at the same time improve the overall green appearance of the city.

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Session 5: Detection and Sensor Systems

Characterization of a cantilever based detection system for a BAM pesticide assay

Michael Bache[1]

Abstract
A BAM (2,6 dichlorbenzamide) pesticide residue assay has been performed using a cantilever based detection system. The stress induced by the bonding of Anti-BAM antibody to BAM molecules immobilized on a cantilever surface is measured using a built in piezo element in the cantilever that changes its resistance under deformation. A series of successful experiments have been conducted successfully and the assay is currently being improved and characterized.

During the last 10 years an increasing number of water wells in Denmark has been polluted by pesticides or its break down products. Pesticide analysis of drinking water is currently being done by manual sampling and laboratory analysis. This means weeks in between sampling and the analysis result. An in-line sensor will therefore be beneficial for water quality monitoring. The project is a part of the SENSOWAQ (sensors for monitoring and The project is a part of the SENSOWAQ (sensors for monitoring and control of water quality) and is done in collaboration with GEUS (The Geological Survey of Denmark and Greenland) DHI and other private and government collaborators.

The detection of BAM is done by a competitive immunological reaction. The BAM molecules from the water sample compete with BAM attached to the surface of a cantilever for the binding to a BAM antibody. Binding of a BAM antibody to the surface of the cantilever will change the surface stress, causing the cantilever to bend, the bending is then detected by a change in resistance in the piezoelectric layer of the cantilever. The detection mechanism is in principle label free, but the antibodies have been marked to subsequently verify the bonding on the cantilever surface. The Schematic drawing and actual pictures of the cantilever sensor can be seen in the left pictures.

The BAM assay has given repeated positive measurements on a cantilever system. Fluorescent labelling of the antibodies has verified the attachment of antibodies on the cantilever surface. The picture on the bottom left shows a change in signal from the attachment of BAM antibodies to a cantilever coated with BAM molecules.

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Immunoassay based electrochemical sensor for quantitative detection of BAM in ground water

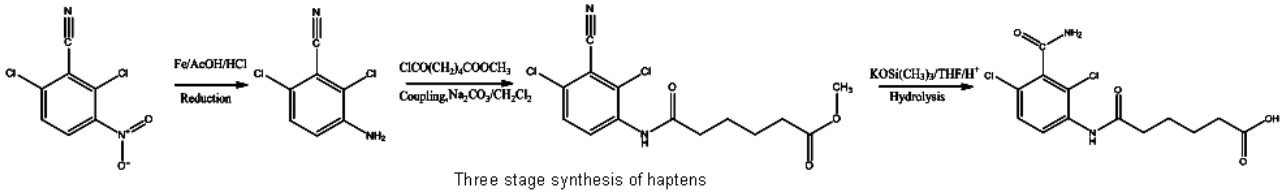
Basil Uthuppu[1] *and Mogens Havsteen Jakobsen*[2]

Abstract
2,6-Dichlorobenzamide (BAM) is a degradation product of the herbicide, Dichlobenil that has been used extensively in Denmark in the past. BAM is not degradable anymore and is soluble in water. Studies show that this potential ground water pollutant exceeds its allowed maximum limit of 0,1 µg/L in 7,9 % samples collected in Denmark.

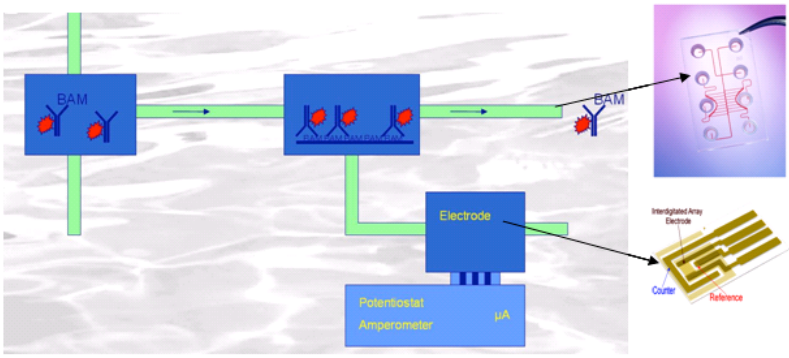
This project aims to develop a biosensor that works on a competitive immunoassay between immobilized BAM and BAM present in the sample with anti-BAM monoclonal antibody. Here the pre-incubated mixture of sample and HRP-labelled anti-BAM monoclonal antibody is passed through the BAM-OA-AQ coated surface and the bound antibody-HRP conjugate is detected by passing TMB substrate into the system

through redox reactions with the help of a screen printed electrode array. Conventional Spectrophotometric method also is used as a bench mark. This interdisciplinary project involves the following main tasks.

- Optimization and regeneration of the polymeric surface that develops a hapten library in a three stage organic synthesis
- Designing a flow system in which the biosensor is incorporated and that can be used for online monitoring of BAM in wells
- Designing an electrochemical detection system with high signal to noise ratio



Three stage synthesis of haptens



Schematic diagram of the sensor

This project is co supervised by Jens Aamand, Senior Research Microbiologist, Dept. of Geochemistry, GEUS and Claus Jørgensen, Senior Biologist, Dept. of Environmental Risk Assessment, DHI

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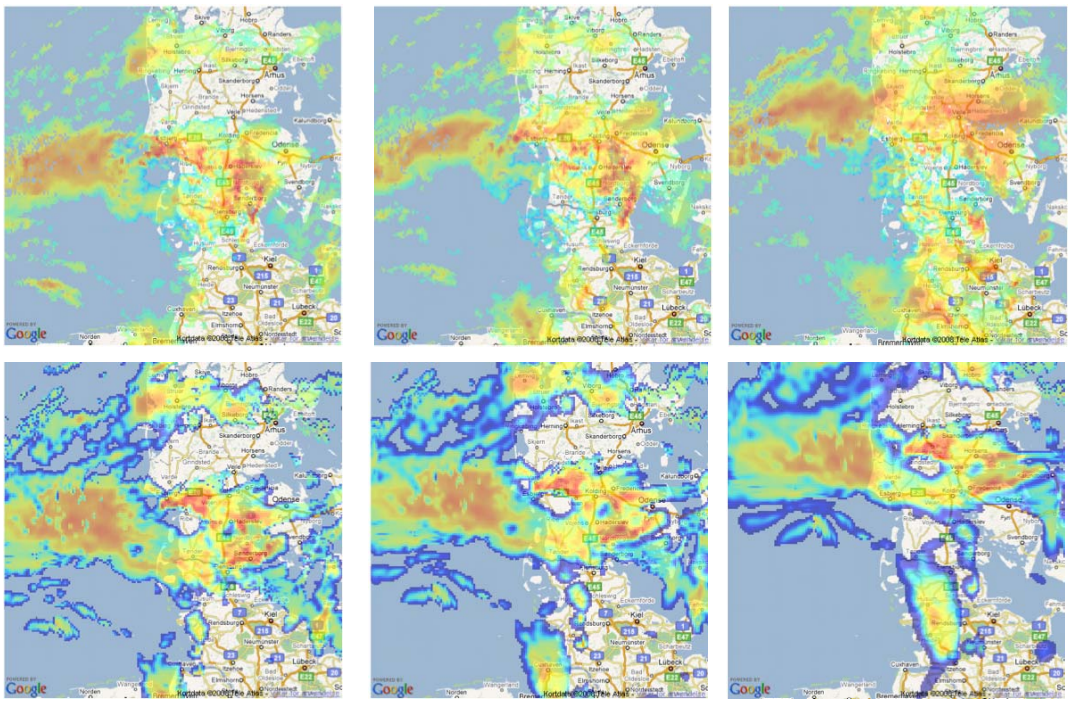
Application of X-band and C-band weather radar technology for forecasting precipitation over urban areas.

Michael R. Rasmussen[1] and Søren Thorndahl[2]

Abstract
As a part of the Storm- and Wastewater Informatics (SWI) project funded by the strategic research council, an integrated forecast system is developed to predict precipitation over urban areas. The overall aims of the SWI project are to close the knowledge gaps within prediction and control of current and future conditions in integrated urban wastewater systems. The major outputs of the project are components of an intelligent real-time decision support system, following a drop of water from the cloud, throughout the sewer–wastewater treatment system and into the receiving waters. A precise estimate of precipitation is necessary in order to model runoff in storm drainage systems. Knowing the precipitation intensity and distribution with a certain lead time, is also a key prerequisite for real-time control. The research presented here is focused on the radar based prediction of precipitation using long range C-bands radars combined with short range – high resolution X-band radars.



Example of COTREC prediction algorithm based on C-band radar

The objective is to analyse the movement and dynamics of precipitation and use that to do a forecast with a lead time of up to 2 hours. However, before this is possible, an adjustment of the radars is necessary. Experience from operational use of the system indicates that a dynamic adjustment strategy is required in order to achieve accurate results. An online system is now available and under test.

Information on weather radar research will be available from January 2010 on: www.vejrradar.dk

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Taste of drinking water as a function of aquifer geochemistry and land use.

Helle Marcussen[1], Wender L.P. Bredie[2], Sandra S. Nielsen[2], Walter Brüsch[3], Peter E. Holm and Hans Chr. B. Hansen[1]

Abstract
Water with a high sensory quality has been considered as water free from off-flavours. Much of the research in the area of water quality has therefore mainly been concerned with understanding and solving problems related to off-flavours. The relationships between chemical composition and sensory properties, however, have been difficult to establish. Non-scientific tasting guides suggest mouthfeel as the most important factor when selecting a bottled water and taste which is related to the content of minerals as the second most important (Mascha, 2006). Previous studies have mainly focussed on the profiling of the chemical composition of water and to a much lesser degree the sensory characterisation. The taste of water has been found to decrease with increasing total dissolved solids (TDS) with 450 mg/l as the limit for good tasting water (Bruvold and Daniels, 1990).

To investigate the taste of drinking water as a function of aquifer geochemistry and land use, drinking water samples were collected at 20 waterworks distributed over Denmark (Figure 1). The samples represented water extracted from acid to calcitic reservoirs, from sandy reservoirs, to reservoirs under thick clay deposits in costal or inland areas with land use ranging from heather, bog, forest or agriculture. A trained 11-membered sensory panel performed a descriptive analysis of the water samples including descriptors for tastes, odours and oral tactile sensations. The sensory analysis was carried out in sensory booths and included four replicate assessments for each sample using a balanced presentation design. The chemical analysis included pH, conductivity, total hardness, total dissolved solids and non-volatile organic carbon. The total content of Na, Mg, Al, P, K, Ca, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Cd, Cs, Ba and Pb was determined by inductively coupled plasma mass spectroscopy (ICP-MS). The content of Cl^-, F^-, NO_3^-, NO_2^- and SO_4^{2-} were determined by ion chromatography. The total content of solutes was negatively correlated to the perceived freshness, bitter and sour tastes, and positively correlated to salty taste. Salty taste was related to the Na^+ and Cl^- content possibly due to marine leakage into the costal reservoirs. The sensory differentiation between the inland reservoirs was shown to be relatively small, however, many of them provided water with a high freshness and relatively low intensity of tastes.

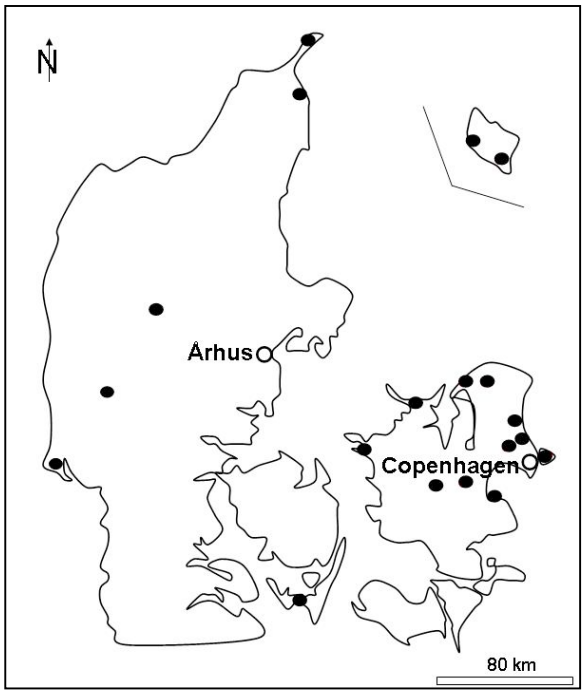

Figure 1. Map over Denmark with sampling sites.

References:
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Session 6: Water and Agriculture

Leaching of pathogens from manure to drainage water – assayed using classic and DNA/mRNA based methods

L. Fredslund[1], T.B. Bech[1], A. Forslund[2], R. Garcia[1,4] M. Amin[3], J. Baelum[1], J. Kjaer[1], , O. Popovic[2], T. X. Bui[5], D.D. Bang[5], S. Pedersen[3], L.S. Jensen[2], M. Laegdsmand[3], P. Santorum[4], & A. Dalsgaard[2] & C.S. Jacobsen[1&2]

Abstract

The usual practice of addition of animal manure to soil can provide opportunity for contamination of soil and drainage waters. In a large multidisciplinary project involving many institutions the spread of different pathogens in agricultural soils has been assayed. In this study, we examined different pathogens using different techniques to evaluate the survival of the organism in soils: Plate/plaque counting, direct quantification of mRNA and DNA-based qPCR.

In one experiment of the survival of *Salmonella* spp., three different factors were tested: temperature, soil type and manure treatment. A tetracycline-resistant *Salmonella typhimurium* culture was inoculated to yield 10^7 cfu/g into agricultural topsoil (with or without applied manure) or soil from the B horizon (below plough layer). Soils were stored at 5, 15 and 25ºC simulating seasonal temperature exposure. The survival of *Salmonella* spp. assayed by plating techniques showed a superior survival at low temperatures, but a general decay was found in all samples. A high number of protozoa was found in the manure amended soil corresponding to a fast decay of inoculated *Salmonella* spp. Quantification of mRNA and DNA directly in the soil and manure samples showed that mRNA was degraded fast in soils at high temperature while mRNA was more stable at 5°C.

In a field experiment strings of manure were added into agricultural soil. During a period of two months, the sections of soils with different distance to the manure string were assayed to obtain information on survival and spread of virus (bacteriophage), faecal indicators (*Enterococci*, *Bacterioides*, *E. coli*) and tetracycline-resistant bacteria. The die-off of the different organisms was quantified showing an extended survival close to the manure-string. Genomic DNA from 400 tetracycline-resistant bacteria was isolated and their phylogenetic relationship was established using 16SrRNA gene sequencing showing that the main tetracycline-resistant bacterial species is *E. coli*.

Drainage water from the field was collected weekly from spring 2008. During the samplings in 2008, no tetracycline-resistant bacteria were found, but after manure applications in the autumn 2009 tetracycline-resistant bacteria were recovered. Again, a suite of different organisms were quantified, and in the first drainage water sample after manure application we found approximately 100 tetracycline-resistant cfu ml^{-1}. The total number of tetracycline-resistant bacteria in the manure was $1x10^4$ cfu ml^{-1}.

In conclusion, the survival and environmental spread of pathogens and indicator organisms shows that not only the upper soil are impacted by the microorganisms originating from non-processed manure, but also drainage water can contain quite high numbers of the organisms. The results also show that DNA-based quantification of *Salmonella* spp. yields higher numbers than quantification based on mRNA indicating that mRNA will form a very conservative choice for pathogen quantification in environmental samples.

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New water saving deficit irrigation guidelines for potatoes and tomatoes based on root signalling.

Christian R. Jensen[1], Fulai Liu[1], Yaosheng Wang[1], Sven-Erik Jacobsen[1], Finn Plauborg[2], Mathias N. Andersen[2]

Abstract

Agriculture is a big spender of fresh water in competition with other sectors of the society. Within the EU-project SAFIR (www.safir4eu.org) new water saving irrigation strategies was developed based on pot, semi-field and field experiments with potatoes, fresh tomatoes and processing tomatoes as model plants. The field irrigation guidelines was developed under temperate, Mediterranean (Greece, Italy) and Continental (Serbia, China) climatic conditions during summer. The field investigations on processing tomatoes were undertaken only in the Po valley (North Italy) on fine textured soil. The guidelines are developed under the assumption that drought adaptation mechanisms of crop plants can be utilised for optimizing water saving irrigation scheduling. The investigations showed that gradual and partial soil drying implemented by deficit irrigation (DI) or partial root zone drying (PRD) induced hydraulic and chemical signals from the root system resulting in partial stomatal closure, increase in photosynthetic water use efficiency, slight reduction in top vegetative growth. Further PRD irrigation increased N-mineralization causing a stay green effect late in the growing season. In potatoes and tomatoes the water saving irrigation strategies DI and PRD were able to save about 20-30% of the water used in fully irrigated plants. PRD irrigation increased marketable yield in potatoes significantly by 15% due to improved size distribution. PRD increased antioxidant content significantly c. 10% in both potatoes and fresh tomatoes. Under high temperature regime fully irrigation should be undertaken as clear from field observations in tomatoes. For tomatoes fully irrigation for cooling effects should be undertaken when night/day average temperature >26.5 ^{0}C or when air temperature > 40 ^{o}C to avoid flower dropping. The temperature threshold for potatoes is not clear. From three year field experiments drip irrigation experiments we found that under the phase of establishment both potatoes and tomatoes should be fully irrigated; however, during the later phases without causing significant yield reduction deficit irrigation might be applied for:

- Potatoes
  - From after end of tuber initiation DI or PRD irrigation is applied as 70% of FI. During the last 14 days of the growth period DI or PRD is applied at 50% of FI.
- Fresh tomatoes
  - From 1st truce is developed for two weeks DI is applied as 85-80 % of FI. In the middle period DI or PRD is applied at 70 % of FI. During the last 14 days of growth period DI or PRD is applied at 50% of FI.
- Processing tomatoes
  - From transplanting to fruit setting at 4-5th cluster PRD and DI irrigation threshold for re-irrigation is when available soil water content, ASWC=0.7 (soil water potential, Ψ_{soil} =-90 kPa). During the late fruit development/ripening stage, from 10% of red fruits, threshold for re-irrigation is for DI when ASWC= 0.5 (Ψ_{soil} = -185 kPa) and for PRD irrigation when ASWC (dry side) = 0.4 ($\Psi_{soil,\ dry\ side}$ = -270 kPa).

Conclusion: From glass house, semi-field and field experiments using sub-surface drip irrigation the following conclusions were drawn: Water saving irrigation treatments can be undertaken without yield decrease in the range from 20-50% of FI during the growing season. Guidelines for potatoes, fresh tomatoes and processing tomatoes are given for the initial, middle and late growth phases. The findings during the SAFIR project might be used for implementing water saving deficit irrigation guidelines for further adaptation to local soil and climatic conditions.

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Alternate partial root-zone drying irrigation – a novel irrigation strategy improves resources use efficiency and product quality

Fulai Liu[1,], Yaosheng Wang[1], Sven-Erik Jacobsen[1], Christian R. Jensen[1], Mathias N. Andersen[2], Finn Plauborg[2]*

Abstract

Worldwide shortage of freshwater resources has stimulated research into water-saving irrigation strategies in order to increase crop water use efficiency (WUE). At the same time, global energy crisis and environmental degradation call for more efficient use of nitrogen (N) fertilizers in crop production due to its high energy consumption and potential risk to environmental pollution. Alternate partial root-zone drying irrigation (PRD) is a novel water-saving irrigation strategy being intensively researched in many courtiers. The principle behind PRD is to alternately let one part of the root system be exposed to soil drying, while the other part is irrigated, in order to keep the leaves hydrated. The drying roots trigger hormonal signals mainly abscisic acid (ABA) that induces partially closing of stomata and modifying growth and thereby improving WUE. PRD irrigation has shown great potential in saving irrigation water in several crop species. Our own studies at Danish conditions found that, compared with the fully irrigated controls (FI), PRD could save 30% water without yield reduction in potatoes. Most interestingly, the irrigation technique could enhance crop nitrogen uptake and improve tuber quality in terms of increased yield of marketable tubers (15%) and antioxidants content (10%) in the tubers. In tomatoes, we also observed that, compared to FI and common deficit irrigation (DI) treatments, PRD irrigation could increase WUE (20%), nitrogen uptake (15%), and fruit quality (e.g. higher antioxidants contents (7%), soluble solids content (10%), and total reducing sugars content (12%)). By using ^{15}N isotope labelling technique, we have recently demonstrated that the improved nitrogen uptake under PRD irrigation was due mainly to an enhanced soil mineralisation rate leading to greater nitrogen availability to the plants. Conclusively, PRD is a promising irrigation strategy that may simultaneously improve water and N use efficiency as well as product quality in crop plants.

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Session 7: Public-private RTD cooperation

The Innovation Consortium "Danish Membrane Bioreactor Technology - MEMBIO"

P.E. Jørgensen[1] and G.H. Kristensen

Abstract
Within the Innovation Consortium MEMBIO, work has been done since the beginning of 2008 on the development of innovative solutions to some of the challenges that still limit the use of so-called MBR technology for wastewater treatment. The consortium has participation from suppliers and users of waste-water technology as well as from research and GTS environments. Financing of the consortium comes in part from The Danish Agency for Science, Technology and Innovation and in part from the participating industrial partners and the GTS institutes.

Membrane Bio-Reactor (MBR) technology represents a technological leap over traditional biological water treatment technologies. The technology combines microbiological processes with a separation of dissolved and suspended components through a membrane barrier. MBR technology results in extremely compact design compared to traditional technology, combined with a markedly improved effluent quality – both with respect to pollutants of environmental and potential health concern, and with respect to hygienic quality. The treated water thus represents a potential resource for water reuse for a wide variety of applications in both urban an industrial contexts. The market for MBR technology solutions to urban and industrial wastewater treatment is increasing rapidly, and in light of the many advantages when applying the technology, it is expected that the technology in the not distant future becomes dominant regarding microbiological-based environmental technology solutions.

Internationally, there has in recent years been invested massively in the development of MBR technology, and a number of MBR installations are established both for the treatment of municipal and industrial wastewater. There are however a number of process technical barriers to be dealt with before the MBR technology is likely to really take hold as the dominant technology for wastewater treatment. Among the most significant is the tendency of the membrane to clog ("foule"), as well as increased energy consumption and higher investment costs as compared to conventional wastewater treatment plants. Despite the fact that Denmark is traditionally strong in the individual disciplines that needs to be integrated to develop technological solutions based on the MBR concept, activities in the MBR area has so far been modest.

In this context the overall purpose of the consortium is to support, that the traditionally strong position that Denmark has had within wastewater technology is continued within the MBR field, so that the MBR technology is established and anchored at Danish suppliers and users of wastewater technology as well as in research and GTS environments. The above objectives are ensured by conducting relevant themed tech-nology projects, where the partners in cooperation, and together with the planned research, build up skills and develop products for the research, GTS and industrial levels.

The different approaches to the current topic represented by the participating universities, GTS institutes and commercial enterprises, is a great strength for the consortium's work. As the knowledge and skills of the partners complement each other, the consortium can manage the entire development process from identification of basic mechanisms to application of technical solutions. The fact that the consortium is working across different cultures and with background in various incentives, can also be challenging, for example in relation to intellectual property rights and confidentiality. Innovation Consortia, however, con-stitutes a flexible and non-bureaucratic cooperation framework, in which the parties themselves to a very large extent determine the agreements on cooperation, including the confidentiality of information exchanged between the parties.

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DNA-baserede værktøjer til problemløsning i vandbranchen

Aaron Saunders[1]

DNA-baserede værktøjer åbner nye muligheder for at løse problemer og optimere biologiske processer. Disse teknologier er indtil for nylig kun blevet brugt på universiteterne, men Teknologisk Instituts Center for Kemi- og Bioteknik samarbejder nu med industrien om at få dem anvendt i praksis. To cases skal præsenteres: "Forbedret sporing af kilder til fækal forurening" og "Forbedret diagnostik af problemer med jordsmag i dambrugsfisk". DNA-baseret kildesporing af fækal forurening måler på bakterier, der er specifikke for afføring fra bestemte dyregrupper – fx. mennesker, kvæg og fugle – som ellers ikke kan måles med traditionelle metoder. Dette gør det muligt at hurtigt indkredse mulige kilder til forureningen og metoden er blevet brugt i en række sager i Danmark. DNA-baserede analyser bruges også til at identificere kilden til jordsmag i dambrugsfisk. Resultaterne viser at jordsmag bliver dannet i biofilteret af hidtil ukendte bakterier, som ikke kunne måles med traditionelle metoder.

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Opgradering af våde regnvandsbassiner for videregående rensning

J. Vollertsen [1] *og M.C. Juul* [2]

Abstract
Regnvandet fra by og vej indeholder almindeligvis højere koncentrationer af tungmetal end spildevand og er ligeledes en væsentlig kilde til bl.a. PAH'er og visse miljøfremmede stoffer. Endvidere udgør fosfor fra separat regnvand ofte et væsentligt bidrag til eutrofiering af søer og kystnære vande. Tilsammen betyder dette, at udledning af separat regnvand er en betydelig kilde for belastning af vandmiljøet. Gennem de seneste år har denne problemstilling ført til, at kommuner og vejmyndigheder har etableret anlæg, der renser regnvandet før udledning til recipient. Den gængse teknologi herfor er våde regnvandsbassiner – det vil sige små søer eller damme, hvor naturlige processer nedbringer regnvandets forureningsindhold før udledning. Rundt omkring i byerne og ved motorvejene ligger der i dag i Danmark hundredvis af sådanne rensebassiner.

Korrekt designet er disse systemer effektive overfor partikler og den forurening der er bundet hertil, mens det har vist sig at effektiviteten overfor forurening på opløst form er ringe. Dette betyder for eksempel at 20-50% af tungmetallerne fra by- og vejoverflader slipper ud i recipienten, mens effektiviteten overfor vandopløselige stoffer, som fx en række biocider, er endnu ringere. Hertil kommer at opløst stof generelt er mere mobilt i vandmiljøet, hvor vandlevende organismer eksponeres og risikerer at optage stoffet. Afhængig af det konkrete stofs egenskaber kan der være tale om akut toksisk påvirkning, eller stoffet kan optages i organismen og slutteligt ophobes i fødekæden. Alt andet lige er opløst forurening derfor – gram for gram – mere problematisk end partikelbundet forurening. For at sikre en god økologisk kvalitet i vandmiljøet er der derfor behov for ikke kun at nedbringe den partikelbundne forurening, men også regnvandets indhold af opløst forurening.

Projektet har til formål at udvikle metalsaltbaseret fældningsteknologi til opgradering af eksisterende regnvandsbassiner med henblik på at forbedre fjernelsen af opløst og kolloid forurening. Teknologien gør brug af metalsaltes evne til at binde, kompleksdanne og udfælde opløste og kolloide stoffer, efter principper der er velkendte fra såvel behandling af drikkevand som spildevandsrensning.

Projektet strækker sig over 3 år og er i sin første fase. Her etableres forsøgsudstyr og gennemføres indledende undersøgelser i felten og i laboratoriet. Projektets koncept og resultater af indledende undersøgelser vil bliver fremlagt.

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Detecting organic contamination in water by fluorescense technology

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Abstract
Even in industrialized countries, contamination of fresh water and marine water by sewage is widespread and microbial contamination of drinking water and swimming pool water also happens quite often. Generally, there is a need for early warning of wastewater/faecal pollution. Today's methods are slow (within several hours or days) whereas response times of seconds or minutes may be required. The Aqua Fingerprint project aims at developing the knowledge base for future development of fluorescent based sensors that can detect faecal contamination in "clean" water within seconds. The water types investigated are: drinking water, swimming pool water, surface water and rain water. Through the use of PARAFAC – parallel factor analysis – fluorescence spectra (see below) are decomposed into a number of fluorescent components, typically 3-5. This technology has allowed us to detect levels of raw wastewater in "clean" water of 0.1-0.2 %, corresponding to 25-50 µg wastewater C/l. The project has shown that there is a potential of detecting faecal contamination within characteristic times of seconds.

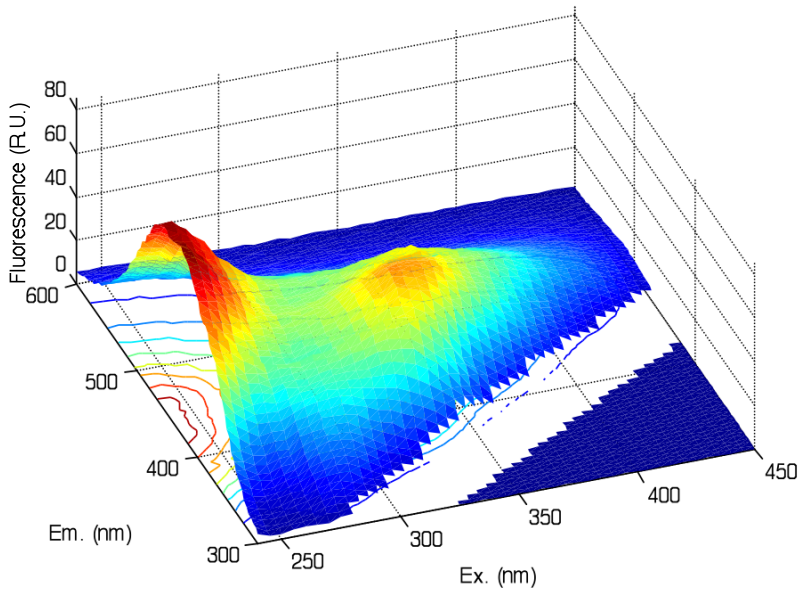

Figure. Fluorescense spectrum of a wastewater sample.

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Future urban water supply when the groundwater resource is under pressure

H.-J. Albrechtsen[1], M. Rygaard and P.J. Binning,

Abstract
Growing populations and urbanization challenge the limits of our conventional water resources in the developed world. Other more political drivers such as the EU water Framework Directive has with the recent

publication of the 'Vandplaner' put a tremendous pressure on the water supplies, especially in the Copenhagen area. At this background alternative water resources are considered to be exploited, and an outlook to solutions in other parts of the world shows a wide array of solutions with several options for increasing self-sufficiency. This includes use of unconventional water resources such as centralized wastewater reuse, desalination and local and central rainwater collection.

The scientific literature and the internet were searched for projects with increased self-sufficiency of an urban area, and a screening list of 113 cases was compiled including examples from around the world. The collection was intentionally restricted to represent possible solutions, and not every single project encountered, and e.g. many desalination projects were omitted, since they all represented variations of reverse osmosis membrane set-up.

Many solutions are already in use around in the world. However, introduction of alternative water resources raises several challenges: Energy requirements vary with more than an order of magnitude among the alternative techniques, wastewater reuse allows trace contaminants to reach the drinking water. Finally changes to the drinking water system can meet tough resistance from the public.

This work is based on a Public-Private-Partnership between KE and DTU Environment.

Rygaard, M., Binning, P.J. & H.-J. Albrechtsen. (2009) Alternative water management and self-sufficient water supplies, IWA Publishing,

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Collaboration between Infarm and Danish universities and knowledge institutions

Jesper Lorenzen [1]

Abstract
Infarm is a vendor of environmental technology for intensive animal production. As such, the company operates in a strictly regulated market, where claims constantly need documentation to have credibility. This is led the company to collaborate with Danish universities and other knowledge institutions throughout it R&D history.

From the very early proof-of-concept to the latest complex studies of lifecycle assessment, Infarm has opened its books for researchers to question, investigate and comment. Ultimately, the result is unequalled documentation level of the technology's performance and environmental effect as well as excellent relationships with Danish experts.

All in all, close RTD collaboration requires precise project formulation as well as strict internal and external project management to create valuable knowledge. When carried out successfully, research collaboration is a fantastic fruitful experience; when not, it is utterly frustrating.

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Poster session

The ScorePP approach to predict releases of priority pollutants from urban sources

H.-C. Holten Lützhøft[1], E. Eriksson[1], E. Donner[2], T. Wickman[3], P. Banovec[4], P.S. Mikkelsen[1], A. Ledin[1]

Abstract
The priority substances included in the EU Water Framework Directive shall in the course of 20 years obey environmental quality standards set for EU watercourses. The substances classified as hazardous substances shall furthermore be phased out of discharges. The aim of this study was to compile knowledge about the releases from point, diffuse and accidental sources to urban pollution of these priority pollutants (PPs) to be able to reduce or cease the emissions of said PPs. The Emission String (ES) concept was developed, which identifies an emission source by the particular pollutant being emitted (CAS #), the (economic) activity resulting in the emission (NACE), and the specific emission process (NOSE) during which the pollutant release takes place, all of which are connected to an Urban Structure descriptor, a Release Pattern descriptor and a Release Factor.
This classification approach was tested on a range of PPs listed in the WFD. Not a wealth of release factors connected to these sources could be found in the open literature, thus data like emission loads were also compiled. Of the 902 ESs established only 154 ESs were associated with release factors. No data were found for 578 ESs. Data on loads were established for 118 ESs, leaving 54 ESs assigned various information. In relation to the urban structure descriptor the majority of the ESs are related to manufacturing or production facilities, but other large source categories are households, waste disposal activities, transport, construction and agriculture, of which many can be classified as diffuse sources. Analysing the data on road transport it is seen that seven PPs are released due to vehicular combustion and wear and tear processes. Dependent on the substance and the activity or process, the releases account for between the low kg range for nickel and up to hundreds of tonnes for benzene.

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Coupling of numeric water quality models to quantitative microbial risk assessment - the future for assessment of the burden of disease caused by human contact with water.

Frank Leck Fotel[1], Mads Joakim Birkeland, Gerald Heinicke, Anders Erichsen, and Claus Jørgensen

Abstract
One of the most prevalent causes to human illness remains the exposure to faecal contamination via water. In developing countries, poor sanitation still causes a high mortality, especially among children. In developed countries, good sanitary conditions have been achieved through sewerage, but the population is still exposed to faecal contamination through drinking water, recreational water and through other contacts to contaminated surface water.

With climate change, a more frequent contact with contaminated water is expected because of more frequent flooding events. During a flooding event, the sewage system may not be able to hold the large volumes of water - the water will flood streets and basements. Additionally untreated water will enter recreational water bodies. Therefore, new routes of exposure to treated or untreated sewage appear and may cause severe illness. In this project we will model the risk of primary infection during flooding events by linking the

hydraulic models that predict the extent of the flooding to Quantitative Microbial Risk Assessment (QMRA). It is the intention that the QMRA shall be compatible with the Mike models in general in order to extend the applicability of the model.

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Spatial Externalities – The Implications for Optimal Design of Pollution Reduction Targets

Maria Theresia Hedegaard Konrad[1], Sisse Liv Brodersen, Kris Munch and Berit Hasler

Abstract
The discharge of nitrogen and phosphorous from several countries to the Baltic Sea causes serious water quality problems with respect to eutrophication and oxygen deficits. The Baltic Sea Action Plan (BSAP) proposed by HELCOM (2007) is an attempt to address this. It is common practice in environmental policies to set targets for reduction of emissions (Hart and Brady, 2002) often with a predefined allocation of reduction targets between relevant agents, such as countries. However, the environmental effects depend on the location of emissions and are not necessarily restricted to the area in which they are emitted. This paper addresses the implications for policy target-setting when such spatial externalities exist. Pollution reductions in the Baltic Sea are used as a case study.

Two different approaches to pollution reduction targets for the Baltic Sea are evaluated, i) targets set on the environmental quality in the individual sea-regions of the Baltic Sea, ii) targets set on nutrient load reduction targets for individual countries emitting pollutants into the Baltic Sea. The approaches are evaluated in terms of the total costs and environmental quality taking into account the spatial transfer of pollutants between sea regions.

A non-linear cost-minimization model for the Baltic Sea is set up, embracing all sea regions and countries around the sea. Data from all the riparian countries are used. The model is used to prescribe abatement activities to obtain the different reduction targets. Not only the nutrient discharges to the sea from land, but also the effect on environmental quality due to transportation of nutrients via sea flow between the sea-regions is accounted for. The results show that obtaining a good ecological quality in all sea-regions is much harder than immediately recognized, since some sea-regions are very exposed due to transportation of nutrients.

The research illustrates the importance of accounting for both economic and environmental heterogeneity in policy evaluations as the seemingly harmless difference between the two sets of targets has important implications for the spatial distribution of externalities. The results are compared and contrasted to the extensive literature on spatial externalities from airborne emissions, such as the literature on sulphur dioxide in the U.S. The case study suggests that this type of research has important implications for policy evaluations related to the Water Framework Directive and the Marine Strategy Directive.

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Freshwater discharge, 1990-2008.
- Assessment of freshwater discharge to coastal waters round Denmark using a meta DKQ-model combining measured and DK-model estimated discharge.

Jørgen Windolf [1], Brian Kronvang[1], Lars Troldborg [2], Hans Jørgen Henriksen [2]

Abstract
A new harmonised modelling tool (DKQ) has been developed for the estimation of monthly freshwater runoff to coastal waters around Denmark for the period 1990-2008.
DKQ is based on results from 179 gauging stations covering 57% of the ca. 43,100 km Danish land area in a combination with modelled runoff for ungauged coastal areas utilising the DK-model. For 99 of the gauging stations unbroken time series of measurements are available for the period 1990-2008. However, for 80 of the gauging stations there's no unbroken time series of daily discharge measurements. Hence, at technique for both interpolation and extrapolation has been developed to generate estimated station specific monthly runoff in periods with no measurements. This technique use a combination of measured monthly runoff from reference gauging stations in coastal catchments and modelled monthly runoff for specific catchments lacking an unbroken time series of measurements. The modelled runoff is derived from the MIKE SHE model (DK-model), where results from 1 km×1 km grid's has been available at the time of meta model development. The modelled runoff was shown to have general station specific bias as well as seasonal bias when comparing model estimates with measurements. Station specific model corrections for these bias's have been made and the adjusted modelled runoff has then been used for periods with no measurements from the 80 stations. For periods with no modelled runoff available (2006-2008), results from a set of reference gauging stations holding full time series of measurement have been used in the inter- and extrapolation procedures.

For land areas being ungauged areas in the period 1990-2008 (43% of the Danish land area) the DKQ meta-model utilises monthly empirical relationships developed between a set of reference gauging stations and the DK-modelled monthly runoff for 320 smaller ungauged coastal watersheds. Hence, within each of nine major Georegions bias correction factors have been calculated as the average ratio between observed monthly runoff at the gauging stations and the monthly runoff simulated with the DK-model for the same gauging stations. These bias correction factors have been applied for the ungauged coastal watersheds lying within each Georegion. For periods with no modelled runoff (period 2006-2008) results from a set of reference gauging stations holding full time series of measurement have been used for extrapolation. Hence, each coastal watershed is linked to one or several reference gauging stations and empirical monthly relationships between simulated and bias corrected monthly runoff as calculated with the DK-model for the ungauged area within the coastal watershed and the reference station(s) have been developed. These monthly relationships are then utilised to calculate the runoff from the ungauged part of the coastal watershed after having accessed to the monthly runoff data from the reference station.

The DKQ meta model described above has been developed in a NOVANA project collaboration between the National Geological Survey of Denmark (GEUS) and the National Environmental Research Institute (NERI), Århus University. Experiences gained will be used in the ongoing updating of the hydrological DK-model (www.vandmodel.dk). The discharges estimated by the procedure described have been used in the reporting of results from the national environmental monitoring programme including calculations of nutrient loadings to coastal waters.

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Nitrogen retention
- Assessment of nitrogen retention of nitrogen leached from soil towards the coastal waters, 1990-2008. National end regional figures and trends.

Jørgen Windolf[1], Gitte Blicher-Mathiesen & Brian Kronvang

Abstract
Although landbased Nitrogen loadings to the coastal waters have been markedly reduced since the 1990'ies these loadings still impacts the environmental quality of the Danish fjords and near coastal waters. The main source of this loading is nitrate leaching from the root-zone below the grown fields. Other minor sources are nitrate leaching from unfarmed areas and nitrogen outlets of sewage to freshwaters or directly to the coastal waters.

However, during the hydrological cycle a substantial part of these nitrogen outlets are retained. Thus, mean annual Nitrogen leaching from the rootzone can be estimated to 212.000 t N (1990-2008). However, mean diffuse Nitrogen loading to coastal waters was only 67.300 t N during the same period. Hence, Nitrogen retention – by difference – was 145.000 t N or 68% of the estimated leaching. 121.000 t N of this retention is estimated to be due to nitrate reduction in ground waters - the remaining 24.000 t N being retained in surface waters. The major sinks for nitrogen in surface waters are assumed to be lakes (8.400 t N) and the streams themselves (15.100 t N).

The geographical variation in Nitrogen retention is substantial and proper assessment of these varying retentions in different catchments is important when estimating the effect of measures applied to reduce the nitrate leaching.
On a national scale a GIS based map of the varying retention is available for estimating the local/regional effects of changes in nitrogen leaching. For catchment with measured figures for Nitrogen load in streams the retention is calculated by difference between Nitrogen leaching and measured Nitrogen loading in the stream. However for catchment with no measured N load in streams, estimation of Nitrogen retention is performed using a retention model. This model is regionally validated on results from 19 streams on the island of Fyn by comparing the simulated and measured nitrogen load in the stream. For these streams regional empirical models has previously been developed linking the annual nitrogen leaching from the root zone and the nitrogen loading in the streams by a simple nitrogen reduction model. Furthermore, a new model for estimating nitrogen concentrations in streams has recently been developed (DK_NP). One of the driving forces (variables) in this model is the annual surplus of nitrogen in Danish agriculture and the development in this surplus. For the national figures there are a strong relationship between this surplus and the Nitrogen leaching from the agricultural land. The goodness of fit of these 3 models will be evaluated and the implications discussed.

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Comparison of statistical downscaling procedures for assessing climate change impacts on water resources at catchment scale

Henrik Madsen[1], Keiko Yamagata, Maria A. Sunyer, Torsten V. Jacobsen

Abstract
It is well known that climate projections from global circulation models (GCM) are biased and cannot adequately reproduce the variability in climate variables that are present at the local scale. Thus, there is a need for downscaling climate projections from GCMs in order to make reliable impact assessments at the local scale. Regional climate models (RCM) that are set up for a particular region and nested within a GCM are able to resolve the atmospheric processes on a finer scale and better account for complex topographical features and land cover heterogeneities. However, RCM inherits the biases and other deficiencies of the GCM, and hence further downscaling is often needed for RCM projections.

Statistical downscaling has been introduced to relate the climate projections at larger scale (from GCMs or RCMs) to climate variables at the local scale. In this paper downscaling of RCM projections is considered for water resources impact assessment at catchment scale. Different downscaling procedures based on a general change factor methodology are applied and compared. The basic concept in change factor methods is that climate model simulations are used to extract changes in different statistical characteristics of climate variables from the present to the future climate (denoted change factors). These changes are then superimposed on the statistical characteristics of the climate variable representing the local scale, which are subsequently used for the impact assessment.

The paper considers climate change impacts on the water resources in the North-Eastern part of Sealand, Denmark. Climate simulations from the HIRHAM RCM for the period 1950-2100 based on the IPCC SRES scenario A1B are used in the analysis. Three different downscaling procedures are applied to downscale precipitation, temperature and potential evapotranspiration. These include: (i) mean correction (often referred to as the delta change method), (ii) mean and variance correction, and (iii) a stochastic weather generator based on the Neyman-Scott rectangular pulse model. The downscaled climate data are used as forcing to a MIKE SHE integrated hydrological model of the region for analysing the impacts of climate change in relation to (i) regional and sub-catchment water balance components, (ii) droughts and low flow conditions, and (iii) high flows and flooding.

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