Annual Report 2018

Section Sanitary Engineering

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For up-to-date information about education and research of the section Sanitary Engineering visit our website: *www.sanitaryengineering.tudelft.nl*

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Introduction

Welcome to the annual report of the Section Sanitary Engineering of the Department of Water Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology. Research and education activities of the section are centred on the so-called "Urban Water Cycle" and include extraction, treatment and supply of drinking water, the collection, conveyance and treatment of used urban waters including urban drainage, and the make-up of industrial process water as well as treatment of industrial residual streams. Our main research focus is on advanced treatment of compounds and organisms of emerging concern, recovery of valuable compounds, water and energy from used waters, monitoring and asset management of urban water infrastructures. The section consists of 11 full-time, and 5 part-time scientific staff members, about 10 (visiting) post-doctoral researchers and 50 PhD students, and 5 staff members for managerial and laboratory support.

One of the major highlights of 2018 was the research assessment the Department underwent. The committee, consisting of international top scientists, assessed our Department Water Management as world leading, and gave "excellent" marks for all categories: scientific quality, societal relevance and viability .

Our research activities resulted in the graduation of 4 PhD students in the past year, next to the publication of 68 peer reviewed papers in highly ranked journals. Amongst others, we developed methods to coat ceramic membranes for application in brine treatment, to adsorb compounds of emerging concern from wastewater treatment plant effluent and to remove arsenic in conventional sand filtration plants. We were also able to extract ammonium from liquid streams for electricity production in solid oxide fuel cells and treat saline phenolic waste streams efficiently using anaerobic membrane bioreactors. Furthermore, we succeeded to strengthen our research for the poor by developing the Delft Global Drinking Water programme. With several donations it was possible to stimulate high quality, but low cost, research for and in Developing Countries. In this way we e.g. managed to set-up a pilot plant for arsenic removal in Nicaragua.

In 2018 our master tracks Environmental Engineering and Water Management of the Civil Engineering Master programme attracted over 110 new MSc studenten . This overwhelming number demonstrates that the Netherlands in general, and the TU Delft in particular, has a great reputation in these fields and that students from all over the world are motivated to benefit from our knowledge. In 2018 we continued our on-line education by launching the second edition of the specialised 'ProfEd' on 'Membrane Technology' and running our well-known MOOCs on Drinking Water Treatment and Urban Sewage Treatment. New is the start of a PDEng programme (Professional Doctorate of Engineering), a two years post-master programme that we developed together with the sector. It is meant to further strengthen the engineering & design capacity in the sector and consists, apart from coursework, of an individual thesis on a complex, integrated topic relevant for the sector. During the first batch three students started on water related subjects.

Finally, we can proudly announce that a new full professor on Urban Water Infrastructures was selected, an emerging field in both research and education, with an envisaged huge societal impact in the years to come. Prof. Dr. Zoran Kapelan came over from Exeter University and started on 1 September 2018 at TU Delft to build his group. In the coming years we expect to recruit more (junior) scientific staff members in this field. In addition, a new tenure track position on "adsorption processes in water treatment" was filled in by Dr. Frederik Zietschmann and Dr. ir. Doris van Halem was promoted to associate professor Groundwater Treatment.

We wish you a lot of pleasure reading our annual report and hope that this inspires you to start or to continue the cooperation with our section Sanitary Engineering.

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Research

Research and Education Strategy Section Sanitary Engineering

From urban water chain to urban water cycle

While more than 50% of humanity lives in urban areas, cities and water are closely linked to each other. A well-functioning water network is essential for a city. Everybody has the right to be supplied by clean and riskless drinking water, proper sanitary services, safe and reliable collection and treatment of the used urban waters, and protection of surface water and groundwater bodies. Fresh and clean water, however, is scarce and for several cities the limiting factors for economic growth.

Sanitary engineering typically takes place within the urban water cycle, which in itself is part of the greater hydrological cycle. Drinking water is obtained from groundwater or surface water. The water is treated and subsequently transported to the users, i.e. households and industries, by means of an extensive distribution network. Hereafter, the used waters, previously called wastewaters, are collected, often together with the drainage water, again via an extensive sewerage system. Subsequently, the collected sewage is conveyed to the sewage treatment plant, where the water is relieved from unwanted pollutants. After treatment, the purified water is discharged into open surface waters, after which it is again part of the natural hydrologic cycle.

Given the worldwide increasing water scarcity and/or costs involved in importing fresh waters from large distances, a growing interest exists in making shortcuts in the urban water cycle, creating possibilities for multiple water use or even partly transforming the urban water chain into an urban water cycle. As such, water is more and more regarded as a valuable commodity, whereas its polluting constituents are more and more recognized as recoverable resources. Intervening technologies are being developed for upgrading water qualities and concomitantly recovering contaminants as resources, turning negatively valued urban streams into positively valued assets. Traditional conveyance systems for sewage and urban drainage are critically evaluated and made fit for the modern urban water cycle approach, anticipating

on current societal demands and possible climate changes. Forecasted increase in flood events will put additional demands on adequate urban drainage designs. Obviously, reliability, cost-effectiveness, and resource efficiency are keywords in present research in sanitary engineering and water treatment technologies. In order to take all benefits from the used urban waters, profound knowledge is required on physical-chemical and biological treatment technologies needed to upgrade these waters to agreed standards for subsequent use or discharge.

Mission statement

The mission of the Sanitary Engineering Section programme is formulated as "Performing innovative research and (advanced) education in urban water cycles related to societal relevant themes".

Ambition in research and education

Research and education of the Sanitary Engineering Section is of high societal relevance and technical excellence. It serves the current needs of the Dutch Water sector and outlines present developments and future strategies in close cooperation with the sector. In addition, international developments and our increasing participation in the "international water arena" increasingly include research projects of global concern. Our philosophy results in a balanced combination of societal and industrial pull and scientific push. We strongly believe that this is in the best interest of our MSc and PhD students serving both science and industry. Delft University of Technology and partners not only benefit from the scientific and professional publications and PhD dissertations, but also from patents, practical applications, and knowledge transfer in open course ware lectures and massive open on-line courses (MOOCs) via the internetInternet. At present, about 50 students carry out their PhD research and yearly about 20-30 students finalise their MSc specialisation in Urban Water Engineering or Environmental Engineering.

Education

Apart from two introductory courses in the BSc, specialised courses are given in the MSc-tracks Water Management and Environmental Engineering of the Civil Engineering Programme. The education is focussed on the learning-by-doing, involving students, where possible, with practical assignments (activated learning). In addition, students are stimulated to have an internship abroad, in order to broaden their horizon. In addition, the section is active in on-line education. Current Massive Open On-line Courses (MOOCs) from our group are: "Introduction to Drinking Water Treatment", "Introduction to Urban Sewage Treatment", and "Introduction to Water and Climate". On the EdX platform these MOOCs are indicated as the WaterX-series of TU Delft. Internet based thematic ProfEd courses present detailed information in specific technologies and highlight the expertise of our group. Courses are bi-directional and charge an inscription fee. The ProfEd "Membrane Technology" is already online, whereas the courses "Aerobic Granular Sludge" and "Anaerobic High-rate Treatment" will be launched in 2019. The section Sanitary Engineering is front-runner in online education, and the MOOC "Introduction to Water Treatment" was the first one of TU Delft.

Research themes and approach

Dutch drinking water is characterized by a very high quality, owing to the high technical standards in Dutch water companies, resulting in the continuous supply of safe drinking water at an acceptable price. No chlorine is used during drinking water production, which is made possible by applying a multiple barrier treatment approach, producing biologically stable water. Moreover, the drinking water is soft, has a pleasant taste and colour and pipeline leakages are virtually zero. Water losses in our network do not go beyond 2-3%. As a result of this, the trust in the drinking water quality is high. The Dutch drink water from the tap and they do not feel the need for using bottled water or point-of-use filters. Continuation of the high quality standards in the water sector requires research on presence and fate of priority pollutants, biological growth (e.g. Legionella) and water quality deterioration in the distribution system.

Municipalities are responsible for collecting and transporting used waters and managing the rainwater and groundwater in urban areas. At present and in the near future they are facing several challenges, e.g. climate change, (de)urbanisation, more stringent legislation, required costs reduction, required drop in fossil fuels usage, maximised energy recovery, resource effectiveness, implementation of sensor networks for process control. These challenges are to be faced in the light of a more

Research and Education Strategy

intense cooperation with other stakeholders, ultimately leading to an increasing need for knowledge of the involved processes and sound engineering solutions.

Water boards, ultimately responsible for the upgrading of the used urban waters, are challenged by increasingly stringent effluent criteria and societal concerns on priority pollutants and hygienic quality of the produced effluents. Moreover, foreseen shortcuts in the water chain, creating urban water cycles, require effluent qualities meeting the demands of the subsequent user, that are often much more stringent than the emission standards. On the other hand, the proposed shortcuts may facilitate full emission control as all pollution will then be scavenged at the treatment plants for industrial water provision. The foreseen developments logically result in improved operation of sewage treatment plants, introduction of new treatment technologies, interactions between sewerage and separation of rainwater from the sewer system. In addition, the water authorities are emphasizing the potentials of recovery of resources, such as nutrients, bio-plastics, cellulose fibres, and energy from sewage streams.

To be able to address the research needs of the water sector, our MSc and PhD research is clustered in 4 thematic research themes:

1. "Water Quality: Science & Technology" includes solutions for emerging threats, increasing standards, optimized treatment, as well as for subsurface processes, where water quality relates to the geo-chemical conditions.
2. "Reclamation of Water, Energy, Resources" deals with technologies for the closing of material cycles in the urban-industrial water cycle.
3. "Distribution and Discharge Networks" investigates the water quality and hydraulic aspects in distribution and drainage systems.
4. "Global Sanitation, Safe Drinking Water & Health" focuses on health related aspects in the urban water cycle, with emphasis on improving drinking water supply and sanitation in developing countries.

Each of the staff members has its own specialisation to develop research in one or more of the above mentioned research themes. These specialisations include (anaerobic) membrane bioreactors, (ceramic) membrane filtration, metallic surfaces in water, characterisation of natural organic matter, soft sensors in water treatment, monitoring in sewer systems, emerging pathogens and technology selection in relation to water quality.

Our research agenda includes a mixture of desk-top research, laboratory experiments, pilot-plant experiments and full-scale field research. Computer modelling enables us to understand the complex reality and limit the number of experiments to achieve an optimal result. Where laboratory experiments test our initial hypothesis under defined conditions, pilot plant and field research includes the specific water quality and reactor operational aspects that cannot be simulated in the lab. Moreover, full-scale investigations at treatment plants and piped/sewerage networks are required in order to study the effects of large-scale hydraulics. As such, our research can be characterised as a mixture of water quality, process technology, hydraulics and applied mathematics. A thorough understanding of physical, chemical and biological processes is required to improve the water matrix to the required level. Combined with a thorough insight in hydraulic aspects, such as turbulence, mixing, and uneven flow patterns, this will ensure the feasibility of the technology in large-scale settings. Based on our experience, these mixtures of scales and sciences provide a total view on sound sanitary engineering that stimulates new ideas and approaches.

The professors in our group have a down-to-earth approach and practice 'management by participation'
They stimulate discussions between PhD students, staff members and experts from science and industry. Moreover, they frequently participate in national and international meetings on the research agenda for the water sector, such as the International Water Association and KNW, providing additional stimuli to the research. The processes of improvement and innovation function primarily through the interaction with the experts from science and industry. Frequent external visitors are invited to participate in meetings and colloquia.

Our international network includes a vast number of foreign universities, such as in Leuven, Gent, Sheffield, New South Wales, Bradford, Johannesburg, Boulder, Waterloo, Trondheim, Dresden, Poitiers, Rennes, Toulouse, Zürich, Valencia, Santiago de Compostela, Cali, Sao Paulo, Belo Horizonte, Singapore, Harbin, Beijing, Shanghai, and Xiamen. Research projects are performed in cooperation with NWO, Commercial partners, TKI, AMS, and the European Union. Special agreements for research collaboration are made with Waternet, Dunea, HWL, Vewin and Rioned. Next to papers and reports, our research is communicated through a newsletter. In addition, many ideas are disseminated at our annual 'Vakantiecursus', which is acknowledged as the leading Dutch conference on Sanitary Engineering being annually first, just after New Years' eve.

Theme 1: Water Quality: Science & Technology

Theme leaders: Bas Heijman, Boris van Breukelen, Frederik Zietzschmann, Jan Peter van der Hoek & Henri Spanjers

Water resources are increasingly threatened by the presence of micro-pollutants coming from household, industrial and/or agricultural activities. Traces of these compounds, such as endocrine disrupters, polar pesticides and pharmaceuticals, are even found in Dutch drinking water. Only a few of these emerging substances are known and measured in (standardized) routine analyses in our drinking water. Since conventional treatment systems have a (very) limited capacity to eliminate these compounds, advanced water treatment is required. Similar concerns have risen towards the presence of different kinds of (resistant) pathogenic organisms in surface waters, which may find their way to the drinking water supply if not properly dealt with. Improvement of wastewater treatment effluents is well articulated in the European Water Framework Directive (WFD), which is adopted by its member states. Fortunately, in recent years we have seen major breakthroughs in new technologies such as membrane filtration, adsorption processes and disinfection/oxidation with ozone/UV/ H2O2. These technologies are investigated and currently being implemented in both the drinking water sector and the wastewater sector. In fact, an integrated approach needs to be developed.

Our research in Theme 1 is focused on optimal water quality control by developing new treatment techniques to upgrade wastewater treatment plant effluents, source water for drinking water preparation, and pre-treated industrial water prior to discharge. In addition, the subsurface water quality is monitored and assessed using geo-chemical models. In technology development, the determination of the practical feasibility is of high importance and aspects such as efficiency, costs, and operational complexity are addressed. In addition, sustainability issues such as fossil fuel consumption, use of chemicals, formation of by-products, and the possibilities for re-use of liquid/solid side streams (see Theme 2) are of increasing importance. Several PhD projects address the effectiveness of the different treatment techniques/ treatment combinations in removing both common and emerging polluting substances. In addition, a modelling approach is developed to predict the removal of new emerging substances and to assess the plant performance towards organic micro pollutants. Computer models are also used to control the water quality leaving the treatment plant, while delivering the required flow and quality.

Research projects

Understanding Iron and arsenic removal	*David de Ridder*
Ceramic nanofiltration as the key step for sustainable wastewater treatment with reclamation of water, energy and nutrients / Zeolites as novel adsorbent in water treatment	*Ran Shang*
Bromate biodegradation during managed aquifer recharge	*Fei Fei Wang*
Microbial dynamics in Drinking water distribution system (DWDS) during and after Thermal Energy Recovery	*Jawairia Imtiaz Ahmad*
Online fouling control in Anaerobic Membrane Bioreactors	*Magela Arbiza*
Physical removal mechanisms of suspended solids from wastewater in Aerobic Granular Sludge installations	*Lenno van den Berg*
Natural Organic Matter removal from surface waters: Separation of Dissolved Organic Carbon and ions from Ion Exchange brine using Ceramic Nano Filtration	*Irene Caltran*
Managing chemicals of emerging concern in the water cycle	*Astrid Fischer*
Treatment of phenolic wastewater in AnMBR under extreme conditions: BioXtreme-following up	*Victor Garcia Rea*
Broadening and renewal of the Dutch drinking water benchmark	*Marieke de Goede*
Understanding arsenic mobility for smart fixation during drinking water treatment	*Jink Gude*
The application of high-silica zeolite pellets for the adsorption of organic micro-pollutants in columns	*Nan Jiang*

Theme 1: Water Quality: Science & Technology

Theme leaders: Bas Heijman, Boris van Breukelen, Frederik Zietzschmann, Jan Peter van der Hoek & Henri Spanjers

Research projects

DIPool: Dutch Innovative Pool Advanced UV-based technology for pool water treatment	*Maarten Keuten*
Improving the effectiveness of assetmanagement of the drinking water process	*Rian Kloosterman*
Application of flocculants in todays sewage treatment plant	*Guido Kooijman*
Ceramic nanofiltration as the key step for sustainable wastewater treatment with	*Franca Kramer*
reclamation of water, energy and nutrients	*Onno Kramer*
Hydraulic modelling of liquid-solid fluidisation in drinking water treatment processes	*Julian Munoz Sierra*
BioXtreme – Anaerobic wastewater treatment under extreme conditions	
Development and application of Multiplex qPCR for Antibiotic Resistance Genes	*Gabriela Karina Paulus*
in the Water Cycle	*Sara Toja Ortega*
Removal of suspended solids using Aerobic Granular Sludge	*Feifei Wang*
The Fate of hydrogen peroxide and bromate as by-products of AOP within MAR	*Liangfu Wei*
Fluoride removal from groundwater by low-cost mineral-based adsorbents	*Mostafa Zahmatkesh*
Bioremediation of Humic compounds from water using fungi	
AdOx – a next generation adsorption-oxidation process for removal of CECs	*Yasmina Bennani*
from municipal wastewater	*Sonja Vidojković*
Magnetite surface properties in the various conditions of power plant water steam cycle	*Sajad Fathi*
Modelling of Subsurface Iron Removal (SIR) - Case study on Corle Pumping Station (The Netherlands)	
Origination, Stabilization and De-stabilization of Microbial Ecology in Drinking Water	*Lihua Chen*
Distribution Systems (DWDSs): Quantity, Community, Target Bacteria	
Ceramic membranes modified by Chemical Vapor Deposition or Atomic Layer Deposition	*Mingliang Chen*
for oil/water emulsion separation	*Mingyan Fu*
Regeneration of granular zeolites saturated with organic micropollutants	*Bin Lin*
Alleviation of organic fouling of ceramic membranes by oxidation	*Steef de Valk*
Passive waste water treatment using mineral wool based bio filters	
AdOx – a next generation adsorption process for removal of Organic MicroPollutants	*Marij Zwart*
from municipal wastewater	

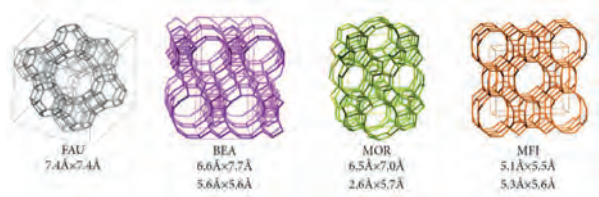


Figure 1. The name and pore opening size of 4 tested zeolite frameworks (From the database of International Zeolite Association). Project of Nan Jiang.

Figure 2. Zeolite powders. Project of Nan Jiang.

Theme 2: Reclamation of Water, Energy, Resources

Theme leaders: Jules van Lier, Merle de Kreuk, Ralph Lindeboom & Luuk Rietveld

Our current and future legislation sets the boundary conditions for the functionalities and efficiencies of our (waste)water treatment systems. However, increasing attention is paid to the fact that wastewater treatment effluents and (waste)water treatment (side)products are also potential resources for domestic, industrial and agricultural processes. Valorisation and (re)use of these resources contribute to an increased sustainability of the water sector as well as to the foreseen future circular economy as opposed to our current consumptive linear economy. In Theme 2, research projects are being formulated that are focused on the recovery of both substances, such as water, nutrients, metals, and energy in the form of biogas, heat, electricity from waste streams and drinking water production. In this development, efficient treatment at acceptable costs plays a crucial role. Overarching institutes, such as the union of the water authorities and the association of drinking water companies have come to several agreements with the government to actually start implementing technologies focussed on the recovery and reuse of these resources. Examples are the 'Green Deal' and the reduction in 'Fossil Fuel Consumption' at municipal sewage treatment plants. At present, energy recovery in the from of biogas is being maximised, after which the energy is used in the treatment plant it self heading to energy neutrality, or biogas is being upgraded to 'green gas' for gas grid injection or production of automotive fuel. In addition to the conventional approach, novel decentralised sanitation systems are being scrutinised in which waste streams are separated in black water (faeces), yellow water (urine), grey water (bathing and kitchen) and rainwater. The feasibility of these systems is not fully clear, but the separated streams may facilitate the recovery of specific resources in an economic manner. For instance, in the past 10 years it became clear that the depleting phosphorus mines would force us to develop technologies that are specifically targeted to extract phosphorus from the waste streams. Finally, the water of the effluent of a wastewater treatment plant is increasingly regarded as a valuable resource for industry and agriculture. In the Netherlands, the largest share of our fresh water consumption is directed to the industry. Realising that sewage treatment plant effluents are a reliable water source, the production of industry water from sewage is receiving increasing interest. Moreover, sewage water reclamation for reuse will prevent the diffuse pollution of our surface waters, whereas competitive claims on fresh water sources are dealt with. Next to sewage treatment plant effluents, the direct extraction of fresh water from sewage in the so-called 'sewer mining approach' is being researched. Our current research is focused on technology development to make reclamation and recovery feasible, not only in the Dutch/Western context but also in the context of developing countries.

Research projects

Mixing Characterisation for Enhanced Biomass Conversion Using CFD Modelling in Gas-mixed Anaerobic Digester	*Peng Wei*
Maximisation of energy recovery from sewage sludge with an innovative digestion process	*Adrian Gonzalez*
Re-designing the vaalue and supply chain of water/minerals: a circular economy approach for the recovery of resources from saline impaired effluent (brine) generated by process industries - ZEROBRINE	*Amir Haidairi*
Cascade system concept to enhance hydrolysis rate in anaerobic digestion of waste activated sludge	*Hongxiao Guo*
Bio-methane production from urban organic matter (BeWaMet)	*Maria Lousada Ferreira*
Microbial community analysis of anaerobic bioreactors treating extreme wastewater	*Marjet Oosterkamp*
Steering Product Formation in High-Pressure Digestion Systems	*Pamela Ceron Chafla*
Agriculture & Managed Aquifer Recharge (AGRIMAR): Drainage Water Recycling for Irrigation and Surface Water Quality Protection	*Emiel Kruisdijk*
From pollutant to power	*Niels van Linden*
Reclamation of nutrients from digestate after green biogas production: Development of as solid/liquid separation process	*Manuel Garcia Garcia*

Theme 2: Reclamation of Water, Energy, Resources

Theme leaders: Jules van Lier, Merle de Kreuk, Ralph Lindeboom & Luuk Rietveld

Research projects

Integrated Hyperthermal Anaerobic Fermentation of Empty Fruit Bunch and Palm Oil Mill Effluent to Enhance the Production of Biomethane and High-Value Chemicals (People Project)	*Saqr Al-Muraissy*
Wastewater suspended solids in Aerobic Granular Sludge	*Lenno van den Berg*
Energy recovery from nitrogen-laden industrial wastewater using anaerobic technology	*Zhe Deng*
Biogas-Solid Oxide Fuel Cell (SOFC) Energy System For Rural Energy Supply	*Henry Wassaija*

Figure 1. Fresh fruit bunch - palm oil

Figure 2. Empty fruit bunch - palm oil

Figure 3. Palm oil mill

Figure 4. Palm oil mill effluent ponding

Palm oil

A huge industry like palm oil is widespread in South-East Asia and Africa covering hundreds of thousands of hectares. In addition to creating jobs and improving national economies, it also generates enormous amounts of organic waste. Empty Fruit Bunch (Figure 2) is often burnt in the open air producing considerable greenhouse gas emissions (like methane) and its climate impact as a consequence. Apart from that, palm oil mill effluent (Figure 4), which is discharged to open ponds then to rivers, pollutes soil and river systems, adding to the methane emission and heat loss upon discharging and cooling. However, recently, there is a move towards making the industry more sustainable which is the heart of this project. Project of Saqr Al-Muraissy.

Theme 3: Distribution & Discharge Networks

Theme leaders: Zoran Kapelan, Francois Clemens, Jeroen Langeveld, Lisa Scholten & Jan Peter van der Hoek

Water infrastructures are a vital support of urban societal development: they supply clean drinking water and evacuate polluted wastewaters to protect public health and they drain storm waters to prevent flood damage and economic and societal disruption. Quality of service provided by water infrastructures is under threat as ageing processes degrade structural and hydraulic conditions. Leakages, blockage, pipe blockage, water quality deterioration are but a few of the detrimental effects ageing processes can generate. Developing better understanding of ageing processes is a prerequisite to be able to predict and prevent harmful effects. Early detection and warning is another essential strategy to cope with failures and to increase understanding of failure conditions. The focus of this research theme is on monitoring, detection and prediction of failures in water infrastructures by a combination of experimental research and probabilistic methods in support of quantitative risk analysis. We use urban labs to collect experimental data from real-life conditions and use data mining techniques linking multiple data sources to predict failures in support of risk analysis and prevention. Our aim is to provide society with effective techniques and strategies to use ageing water infrastructures while maintaining optimal functionality. In addition to the existing infrastructure, the group also researches novel sanitary systems to collect concentrated wastes with vacuum or pressurised systems, using small bore piping networks.

Research projects

Sewer Leak Detection, Quantification and Location	*Bram Stegeman*
Research on the mechanisms to prevent FOG layer formation in wastewater pump sumps	*Alex Duinmeijer*
Uncertainty propagation in water quality integrated catchment modeling	*Antonio Manuel Moreno Rodenas*
Adaptable and Robust Integrated Real Time Control of Urban Drainage Systems	*Job van der Werf*
Decision-making for integrated urban drainage systems: dealing with uncertainties stemming from a system in transition	*Eva Nieuwenhuis*
Sewer maintenance and hydraulic performance	*Marco van Bijnen*
FOULC: Fast Over-all scanning of Underground and Linear Constructions	*Mathieu Lepot*
Computational studies on the flow of domestic slurry	*Dhruv Mehta*
Household water safety plan : A comprehensive approach in improving water quality at household level	*Daniel Sihombing*
Solids in sewer systems	*Matthijs Rietveld*
D-SHiT: Domestic Slurry Hydraulics in Transport systems	*Adithya Thota Radhakrishnan*
Quantifying Uncertainty in Integrated Catchment Studies (QUICS)	*Franz Tscheikner*
The urban water cycle as enabler for circular cities: New Urban Water Transport Systems	*Ljiljana Zlatanovic*
Critical sewers and drinking water pipes	*Didrik Meijer*
Integration of Water, energy and material flows to achieve sustainable urban solutions	*Ka Leung Lam*
DASH of Water - DAta-driven Stochastic Hydraulic models of Water distribution systems	*David Steffelbauer*
Integrated urban water risk-based asset management	*Hala Alhamed*
Residual lifetime of plastic sewer pipes	*Konstantinos Makris*
Criticality of urban water networks	*Didrik Meijer*
Formation and impact of recalcitrant and/or toxic compounds generated in Thermal Pressure Hydrolysis (TPH) of waste activate sludge	*Javier Pavez Jara*

Theme 3: Distribution & Discharge Networks

Theme leaders: Zoran Kapelan, Francois Clemens, Jeroen Langeveld, Lisa Scholten & Jan Peter van der Hoek

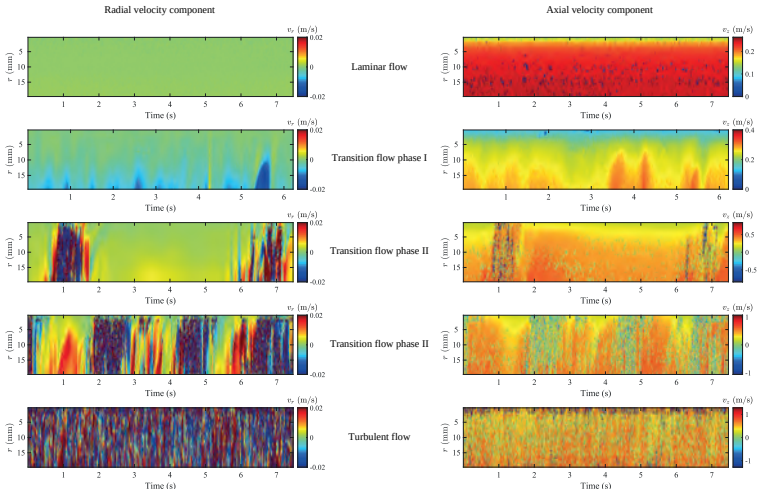


Figure 1. Schematic representation of a sanitation system according to decentralized sanitation and recover concept (novel sanitation). Project of Adithya Thota Radhakrishnan.

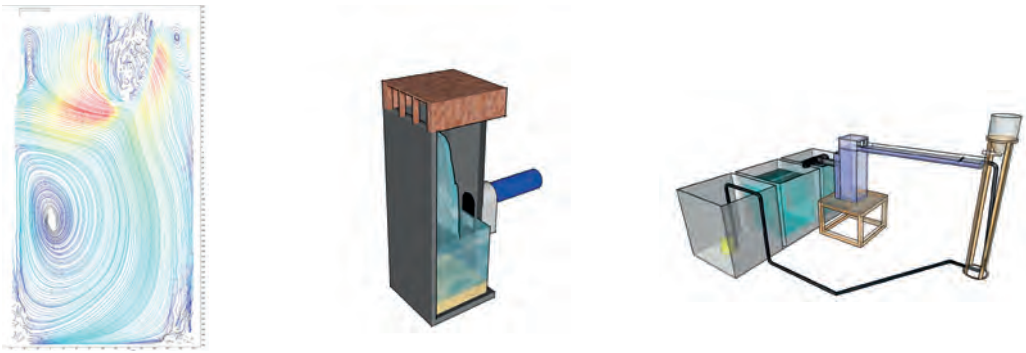


Figure 2/3/4. A gully pot links streets with sewer systems to transport run off out of residential areas. This runoff does also contain solids which can be retained in the gully pot. The retention capacity of solids depends a.o. on the flow pattern. This flow pattern has been visualised in the lab in the setup below with particle image velocimetry (PIV) which can be seen in the figure right. Project of Matthijs Rietveld.

Theme 4: Global Sanitation, Safe Drinking Water & Health

Theme leaders: Doris van Halem, Ralph Lindeboom, Gertjan Medema

Safe water is essential to our society. Water systems should be designed, operated and maintained so they protect society against the spread of infectious disease agents, antimicrobial resistance and toxic chemicals. New issues emerge (antimicrobial resistance) and old issues continue to re-emerge in emergency settings (cholera). They emphasize the vulnerability of our densely populated society to infectious diseases and highlight the importance of knowledge about pathogens and antimicrobial resistance, their sources, fate and transport in water and effective treatment and management. In our rapidly urbanizing society, the water system is loaded with pathogens and resistant bacteria and we are need the water system for food production, supply of drinking water and recreation, so the pathways of exposure are many. The conventional exposure through drinking water is well under control, but other water uses (such as bathing or irrigation) are not. Moreover, we are inventing new concepts for dealing with water in our society (wastewater reuse, water in cities, etc.). These provide new niches for pathogens and new routes of exposure to pathogens.

In developing countries, the occurrence of water-borne diseases is still a major cause for the high mortality of infants. In fact, safe drinking water and improved sanitation are at present not available for every human being on earth. The Sustainable Development Agenda of the United Nations includes a goal (#6) to ensure access to water and sanitation for all. However, current knowledge on low-cost drinking water treatment and sanitation is often insufficient to provide safe water in remote or densely populated areas; either, because solutions do not fit within the targeted environment, or a scientific approach is not at hand. Therefore, the research focus lies on the development of novel treatment technologies for the rural and urban poor, explicitly taking into account the socio-economic conditions of the targeted environments. Specific topics of interest include stand-alone NF/RO membranes, arsenic removal, improved sanitation, multiple water use in mega-cities and energy/resource recovery coupled to sanitary service provision. Research projects with developing countries are designed and executed in close collaboration with local partners, such as the University of South Africa, Dhaka University (Bangladesh), Indian Institute of Technology (India), Ndejje University (Uganda) to stimulate co-creation and uptake of research output. This research theme has attracted a wide range of funders, including NUFFIC (NICHE, NFP), NWO WOTRO and Delft Global | Initiative, leading to an active group of PhD and postdoctoral researchers. In addition, a large number of BSc and MSc students travel abroad each year to support this research theme with their thesis work.

Research projects

Enhanced low-cost ceramic membrane filters for drinking water treatment	*Mona Soliman*
As(III) removal by RSF system for small-scale piped water supply in arsenic-affected rural Bangladesh	*Md. (Kajol) Annaduzzaman*
Plant pathogen removal by managed aquifer recharge and quantitative microbial risk assessment	*Carina Eisfeld*
Water quality assessment of small-scale managed aquifer recharge systems for drinking water provision in coastal Bangladesh	*Muhammad Risalat Rafiq*
Cellular slime moulds as regulators of bacterial numbers in faecal droppings and soil	*Maja Taucer-Kapteijn*
Sustainable freshwater supply in urbanizing Maputo, Mozambique	*Andre Marques Arsenio*
Mobile crowd participation as innovative methodology for water research	*Annemarie Mink*
Arsenic Removal for Drinking Water Treatment in Nicaraguan Rural Communities	*Bayardo Jose Gonzalez Rodriguez*
Potentials of sewage water reclamation for industrial use in Maputo, Mozambique	*Noor Galamussen*
Suspended sediments in a highly turbid river: implications for infiltration capacity in simulated bank filtration	*Juan Pablo Guitierrez*
Water reclamation for irrigation in Maputo, Mozambique	*Celma Niquice Almerinda*

Theme 4: Global Sanitation, Safe Drinking Water & Health

Theme leaders: Doris van Halem, Ralph Lindeboom, Gert-Jan Medema

AD-DAF: Effects of microaerophilic condition on sludge rheology and biomass activity on Anaerobic Digestion	*Antonella Piaggio*
Development and application of Multiplex qPCR for Antibiotic Resistance Genes in the Water Cycle	*Gabriela Paulus*
Wastewater healthy reuse and antimicrobial resistance	*Bruno Bicudo*

AdOx – a next generation adsorption-oxidation process for removal of CECs from municipal wastewater

Current wastewater treatment plants are designed to remove macro pollutants and nutrients, and are not equipped for removal of contaminants of emerging concern (CECs). Over the last years, posttreatment to remove CECs from treated wastewater has gained much attention. Especially adsorption by activated carbon, oxidation by ozonation, biodegradation and the combination of these technologies have been investigated. However, the costs and the environmental impact of the combined use of ozonation – activated carbon adsorption are high caused by the use of activated carbon and the thermal reactivation of exhausted carbon. In addition, these technologies are not selective for the removal of CECs, as also background organic matter, present in high concentrations in treated wastewater, is removed and reduces the efficiency of CECs' removal. The objective of this project is to realize an innovative adsorption-oxidation process for CECs' removal from municipal wastewater based on the use of zeolites as adsorbent and the chemical regeneration of exhausted zeolites with ozone.

In this research two break-through innovations are introduced:

- Zeolites will be tailor-made to be effective and efficient for non-selective CEC removal from wastewater treatment plant effluent, avoiding the adsorption of background organic matter;
- Chemical regeneration of the exhausted adsorbent (zeolites) with the use of ozone will result in cost savings and a lower environmental impact compared to the thermal reactivation of activated carbon. As ozone can be made available at the wastewater treatment facility applying the AdOx process, regeneration may be carried out on-site, minimizing transportation costs and minimizing CO2 emissions. With chemical regeneration of zeolites the oxidant only reacts with the adsorbed organic substances. As the background organic matter is not adsorbed by the zeolites, this potentially results in a low chemical use.

The combination of these two innovations will lead to an innovative treatment concept that is small in size, because of the short contact times; can be regenerated frequently, because of on-site generation of ozone; and does not require continuous dosage of ozone, thus not reacting with background organic matter and CECs in the full stream, avoiding the formation of by-products and metabolites.

The project will thus result in a next generation adsorption-oxidation process for CECs removal from municipal wastewater, characterized by high removal efficiencies for CECs, low costs and a low environmental impact.

Project partners:	Waternet, Waterschap De Dommel, Hoogheemraadschap Rijnland, Hoogheemraadschap Delfland, Witteveen + Bos, Xylem Water Sollutions Nederland BV
Funded by:	Stowa, KWR, Topsector Water, STW Partnership
Project coordinator:	Luuk Rietveld, Jan Peter van der Hoek, Bas Heijman
Period:	2018-2021

DASH of Water
Data-driven Stochastic Hydraulic models of Water distribution systems

Worldwide, the ageing water infrastructure is challenged to become more efficient by rising drinking water demands. Even in Europe, as a matter of fact, nearly one quarter of treated water is lost in the distribution systems before reaching the customers. An increasing number of water utilities use hydraulic simulation software to design and operate water systems in a more efficient way. However, measurements in water distribution are scarce resulting in inaccurate computer models of real systems.

An innovative new way of combining hydraulic models and data from smart meters—recently available devices measuring and transmitting water usage of households in real-time—can help to reduce model uncertainties and, hence, increase water system's operational efficiency on a wide range of applications. For example, more accurate models enable faster detection and localisation of leaks in water pipes and, thus, minimise distribution losses.

This project aims to develop beyond state-of-the-art methods to simulate and optimise water distribution systems in a more realistic and accurate way by utilising the potential of recently available smart meter technology. First, data science algorithms will be developed and applied on real-world smart meters to retrieve relevant information for hydraulic modelling from the vast amount of data. Second, advanced data-driven stochastic hydraulic (DASH) models of drinking water systems will be developed by linking smart meter information, demand simulation software and hydraulic computer models. Finally, these advanced models will be employed and tested on a wide range of real-world applications for increasing the operational efficiency of drinking water systems. The DASH project will be inter- and multidisciplinary and mainly advancing the field of hydro-informatics, the intersection of water management and the computational sciences. The project is a collaboration between Delft University of Technology, Leiden Institute of Advanced Computer Science, KWR-Water Cycle Research Institute and Oasen. Besides scientific publications and direct industry adoption, the project results will be brought to the attention of a wider public through open-sourcing of developed algorithms and advertising the project through social media channels and blog posts.

PhD students are supervised by dr. Boris van Breukelen (daily supervisor of both PhD students), prof. dr. Gertjan Medema (promotor of Eisfeld), prof. dr. Pieter Stuyfzand (promotor of Kruisdijk), prof. dr. Jack Schijven (RIVM, Utrecht University; promotor of Eisfeld), and dr. Jan van der Wolf (DLO, Wageningen; expert in plant pathogens and supervisor of Eisfeld).

Project partners:	Delft University of Technology, Leiden university – Leiden Institute of Advanced Computer Science (LIACS), KWR, Oasen
Funded by:	The European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 707404 – LEaDing Fellows PostDoc Programme
Project coordinator:	David B. Steffelbauer, Edo Abraham and Luuk Rietveld
Period:	2018-2020

INTEGRATION OF WATER, ENERGY AND MATERIAL FLOWS TO ACHIEVE SUSTAINABLE URBAN SOLUTIONS

Research objectives

This project aims to improve our knowledge and develop decision support tools to help water utilities and government agencies make informed decisions about water, energy and material flow management and their integration in cities. The focus will be on the interactions of water cycles with energy and material flows in cities. This research has two specific aims: 1) to quantify the potential of water, energy and material flow management opportunities; 2) to develop decision support tools for prioritizing opportunities.

Project outline

Introduction

The urban water system has traditionally been designed to serve purposes of bringing in treated drinking water and removing wastewater generated. A similar linear view is common in other resource flows like energy and nutrient flows. The interlinkages between these flows and opportunities within cities have not been well acknowledged historically. Recent years has seen a growing interest in capitalizing on these opportunities because of growing pressures from water scarcity, urban population growth, resource depletion, increasing energy cost and climate change.

Approach

This project will focus on the urban systems of Amsterdam, where rich sources of data are available through the project collaborators. The developed potential evaluation frameworks and decision support tools are expected to be generally applicable for assessing and prioritizing opportunities in other global cities.

Results

The project results will help identifying more sustainable solutions for enhancing urban resource efficiency and reducing greenhouse gas (GHG) emissions.

Scientific relevance

Despite of a growing interest, there are still major knowledge gaps (e.g., which scale is most effective and the key influencing factors; regional impacts of large-scale implementation; life-cycle impacts; spatial and temporal impacts) and lack of tools for decision makers to identify the appropriate strategies in a given context (e.g., accounting for uncertainties; current tools focusing a lot on opportunities within water utilities instead of wider urban systems; trade-offs/interactions between opportunities; integrated assessment of opportunities).

Social relevance

Cities account for the majority of resources consumption of humanity (e.g., water, energy, food) and contribute 70 to 80% to global CO2 emissions . Water is by far the largest portion of this urban resource flow in term of shear mass.

Literature

Lam, K.L., Kenway, S.J., Lant, P.A., 2017. City-scale analysis of water-related energy identifies more cost-effective solutions. Water Research 109, 287-298

van der Hoek, J.P., Struker, A., de Danschutter, J.E.M., 2017. Amsterdam as a sustainable European metropolis: integration of water, energy and material flows. Urban Water Journal 14, 61-68.

Project partners:	Delft University of Technology, LEaDing Fellows Postdocs Programme, Waternet
Funded by:	LEaDing Fellows Postdocs Programme
Project coordinator:	Jan Peter van der Hoek
Period:	2019-2020

AdOX

Project partners: Xylem, Witteveen + Bos, Waternet, Hoogheemraadschap Rijnland, Hoogheemraadschap Delfland
Funded by: NWO, KWR, STOWA, TKI-Water technologie
TU coordinator: Luuk Rietveld
Period: 2018-2022

Agiculture & Managed Aquifer Recharge (AGRIMAR)

Project partners: Delft University of Technology, Utrecht University, Wageningen University & Research (DLO), CNRS (France); Acacia Water, Delphy, Broere Beregening; NVWA; STOWA; Water Boards: Hoogheemraadschap Hollands Noorderkwartier, Waterschap Hunze en Aa's, Wetterskip Fryslân, Waterschap Noorderzijlvest; NAO (Dutch potato organisation); LTO-Noord (agricultural and horticultural organisation the Netherlands); NAV (Dutch arable farmers union); KAVB (royal general bulb growers' association)
Funded by: NWO Topsector Water (Delta and Water Technology)
TU coordinator: Boris van Breukelen
Period: 2017-2021

Aspasia

Project partners: -
Funded by: NWO
TU coordinator: Merle de Kreuk
Period: 2016-2021

AMBR for water reclamation

Project partners: Biothane-Veolia
Funded by: Biothane-Veolia
TU coordinator: Jules van Lier
Period: 2015-2020

Biogas-SOFC for the rural poor

Project partners: 3Me, Simgas B.V.
Funded by: Delft Global Initiative
TU coordinator: Ralph Lindeboom/PV Aravind/Henri Spanjers/Jules van Lier
Period: 2018-2022

Ceramic nanofiltration as the key step for sustainable wastewater treatment with reuse of water, energy and nutrients

Project partners: TU Delft, Evides Industriewater, Logisticon
Funded by: STW-TKI
TU coordinator: Bas Heijman
Period: 2014-2018

Cracking barriers in sludge digestion

Project partners: RHDHV and STOWA
Funded by: STOWA
TU coordinator: Merle de Kreuk
Period: 2016-2021

Current research grants

DELTAP (an integrative approach for smart small-scale piped water supply in the Ganges-Brahmaputra-Meghna Delta)

Project partners: Studio Bereikbaar, Schlumberger, Evides, Precious Plastics, Dhaka University, AN College, EPRC, Max Foundation, UNICEF India, PRACTICA
Funded by: NWO WOTRO Urbanising Deltas of the World 2
TU coordinator: Doris van Halem
Period: 2016-2021

Domestic Slurry Transportability

Project partners: TU Delft, Deltares
Funded by: STW Watertech2013, Deltares, STOWA/Rioned, Waternet, Waterschap Zuiderzeeland, XYLEM BV Grontmij BV, Desah BV
TU coordinator: Jules van Lier
Period: 2014-2018

Enhanced low-cost ceramic membrane filters for drinking water treatment

Project partners: TU Delft's ChemE and Industrial Design Engineering. Research institutes, NGOs and the Ministry of Water in Nicaragua
Funded by: Delft Global Initiative
TU coordinator: Doris van Halem
Period: 2016-2020

FixAs

Project partners: Vitens, Brabant Water, Hatenboer Water, RH-DHV, Dunea, Pidpa, Evides, RIVM, TU Delft
Funded by: STWatertechnology
TU coordinator: Doris van Halem
Period: 2014-2019

Fungi - Increasing the utilization of organic waste and low value feeds with the help of lignin degrading fungi

Project partners: Wageningen University and Research Center
Funded by: STW - Waste to Resource
TU coordinator: Henri Spanjers
Period: 2012-2018

High-rate VFA production from industrial waste using the granular sludge process

Project partners: Paques, TU Delft
Funded by: STW, Partnership program: "Partnership Paques - The VFA Platform"
TU coordinator: Merle de Kreuk
Period: 2013-2017

Hydraulic modelling of liquid-solid fluidisation in drinking water treatment processes

Project partners: TU Delft, Waternet
Funded by: Waternet
TU coordinator: Jan Peter van der Hoek
Period: 2016-2020

Integration and optimization of water, energy and material flows to achieve sustainable urban solutions

Project partners: TU Delft, Amsterdam Intitute of Advanced Metropolitan Solutions (AMS)
Funded by: TU Delft, Amsterdam Intitute of Advanced Metropolitan Solutions (AMS)
TU coordinator: Jan Peter van der Hoek
Period: 2016–2018

LOTUS-HR

Project partners: Delft University of technology, UNESCO-IHE, NIOO-KNAW, Wageningen University, NEERI, TERI and IIT-Delhi, Nijhuis Industries, HWL, Drainblock, IPstar, Alterrra, RIKILT, Scholte holding B.V., JCI Industries, STOWA, LEAF, Kilian Water, Waste, Greenyard Horticulture Belgium NV
Funded by: NWO-STW (including in-cash cofounding by companies)
TU coordinator: Merle de Kreuk/Ralph Lindeboom
Period: 2017-2022

Magnetite surface properties in the various conditions of power plant water steam cycle

Project partners: TU Delft, Sonja Vidojkovic
Funded by: EU Horizon 2020 Marie Skłodowska-Curie Actions
TU coordinator: Henri Spanjers
Period: 2018-2020

Microbiologically safe drinking water

Project partners: RCEES (China), Oasen, TU Delft
Funded by: NWO
TU coordinator: Gertjan Medema
Period: 2014-2017

NICHE-KEN 212

Project partners: Pwani University Kenia, Q-point, K.I.Samen, DLV Dier, Egerton University
Funded by: Nuffic
TU coordinator: Bas Heijman
Period: 2015-2018

NUWTS – The new urban water transport infrastructure as enabler for resource recovery: New Urban Water Transport Systems

Project partners: Topsector Water & Maritiem TKI Watertechnology, Amsterdam Instritute of Advanced Metropolitan Solutions, Waternet, Brabant Water, Evides, Royal Haskoning DHV, Waterschap De Dommel, WML
Funded by: all project partners
TU coordinator: Jan Peter van der Hoek
Period: 2018-209

OLO-Micro

Project partners: VU, Deltares, STOWA
Funded by: STOWA, TKI-Watertechnologie
TU coordinator: Merle de Kreuk
Period: 2016-2021

Current research grants

PEOPLE

Project partners: Universiti Terengganu Malaysia
Funded by: Delft Global Initiative
TU coordinator: Ralph Lindeboom/Henri Spanjers/Jules van Lier
Period: 2018-2022

Pilot Research Themista-Ephyra combination at WWTP Nieuwgraaf

Project partners: RHDHV (penvoerder), Logisticon Water Treatment B.V., Waterschap Rijn en IJsel
Funded by: RVO - Hernieuwbare Energie
TU coordinator: Merle de Kreuk
Period: 2017-2019

Propopi - Towards Pro-Poor Private Investments in water supply in Kota Bandung

Project partners: Vitens-Evides-International (VEI), Simavi, PDAM-Bandung
Funded by: RVO
TU coordinator: Bas Heijman
Period: 2014-2019

PS Drink – Priority-setting System to assess emerging risks for safe Drinking water supply

Project partners: TU Delft, Universiteit Utrecht – Institute for Risk Assessment Sciences, RIVM – National Institute for Public Health and the Environment
Funded by: RIVM – National Institute for Public Health and the Environment
TU coordinator: Jan Peter van der Hoek
Period: 2016 - 2020

Quantifying Uncertainty in Integrated Catchment Studies (QUICS)

Project partners: University of Sheffield, University of Bristol, TU Delft, CH2M Hill, Wageningen University, Justus-Liebig-University of Giessen, University of Coimbra, Public Research Centre Henri Tudor, Eawag, Aquafin, Waterways srl, Ruhr-Universitat Bochum, Witteveen+Bos, Universite Laval, CTGA
Funded by: EU funded FP7 Marie Curie Initial Training Network (ITN)
TU coordinator: Jeroen Langeveld/Marie-Claire ten Veldhuis
Period: 2014-2018

SewerSense - Multi-sensor condition assessment for sewer asset management

Project partners: TU Delft, Leiden University
Funded by: Technologiestichting STW
TU coordinator: Lisa Scholten
Period: 2016-2020

Side reactions during Thermal Pressure Hydrolysis

Project partners: STOWA, Paques BV, Waterschappen De Dommel, Vechtstromen, Vallei & Veluwe, Waterbedrijf Limburg
Funded by: STOWA
TU coordinator: Merle de Kreuk
Period: 2017-2021

Super-W

Project partners: UGent, UPC (Barcelona), RWTH Aachen, UCT (Prague)
Funded by: Horizon 2020
TU coordinator: Jules van Lier/Ralph Lindeboom
Period: 2016-2019

Sustainable fresh water and energy production for the Island of Johnny Cay (Colombia)

Project partners: Solteq Energy, Lenntech, Coralina, TU Delft
Funded by: Transition Facility 2014, ODA subsidy, Education & Capacity building
TU coordinator: Bas Heijman
Period: 2014-2018

Sustainable fresh water supply in urbanizing Maputo, Mozambique

Project partners: TU Delft, UNESCO-IHE, Universidade Eduardo Mondlane, Vitens-Evides-International, FIPAG, Royal HaskoningDHV, Waterbedrijf Limburg, IRC
Funded by: NWO - WOTRO
TU coordinator: Luuk Rietveld
Period: 2014-2018

TAPES - Transnational Action Program on Emerging Substances

Project partners: TU Delft, Waternet, Waterschap De Dommel, KWR, DVGW, Erftverband, VMW, University of Edinburgh FNHW, VITO
Funded by: Interreg IVB NWE
TU coordinator: Jan Peter van der Hoek
Period: 2013-2019

Thermal Energy Recovery from Drinking Water

Project partners: TU Delft, Waternet
Funded by: Waternet, Topsector Water TKI Watertechnology
TU coordinator: Jan Peter van der Hoek
Period: 2015-2019

VEWIN - Improving and broadening of the Dutch drinking water benchmark

Project partners: Vewin, TU Delft (Faculty TBM), Dutch drinking water companies
Funded by: Vewin (Association of Dutch water companies), PWN, Oasen, Waternet
TU coordinator: Jan Peter van der Hoek
Period: 2013-2019

VIDI - Unravelling mechanisms underlying negative effects from complex contaminations in granular sludge

Project partners: RHDHV, TU Delft (AS-EBT)
Funded by: NWO
TU coordinator: Merle de Kreuk
Period: 2016-2021

Current research grants

Virus removal with low-cost ceramic membranes

Project partners: DGI
Funded by: Delft Global Initiative
TU coordinator: Doris van Halem
Period: 2016-2020

Zeolites as novel adsorbent in water treatment (Zeotreat)

Project partners: Oasen, Evides, PWN, HWL, TU Delft
Funded by: TKI Watertechnolgie
TU coordinator: Bas Heijman
Period: 2015-2018

ZERO BRINE – Recovery of resources from saline impaired effluent (brine) generated by process industries

Project partners: NTUA, CTM, Witteveen & Bos, UNIPA, SUT, FACSA, SEALEAU, WssTP, Revolve Media, UNIABDN, LENNECH, IVL, TYPSA, IQE, EVIDES, TUBITAK, HUNTSMAN, DLR, Europiren, ARVIA, ISPT
Funded by: Horizon H2020
TU coordinator: Henri Spanjers, Luuk Rietveld
Period: 2017-2021

Sewerage and urban drainage research program

The Dutch urban drainage sector will be facing a number of significant challenges in the next decade. The sector has to deal with new issues such as climate change and priority pollutants, whilst at the same time there is a societal pressure on cutting cost levels, reducing CO2 emissions and nutrient recovery. In addition, there is an increasing lack of highly qualified personnel. This urged the sector to decide to support the sewerage chair at Delft University of Technology, with the following objectives:

- an increase of the number of MSc students;
- an increase of the number of PhD students;
- fundamental research answering the observed challenges.

Research program

The research program comprises 4 themes, therewith covering the main challenges of the sewerage and urban drainage sector.

Theme 1 Asset management

In the Netherlands, each year € 600 million is spend on asset management or, more specifically, on sewer renovation and rehabilitation. Recent research has demonstrated visual sewer inspections to be associated with significant uncertainty and limited reproducibility. As these inspections are the main source of information used in sewer rehabilitation projects, these annual investments lack a profound basis. The research within this theme focuses on alternative sources of information (or ways of working) in order to organize the asset management in such a way that sewer system performance (serviceability) will be maintained at the desired level. Laser scanning and core sampling have been tested as alternative technology, verified by full scale testing of pipe strength. In addition, a serious game has been developed to analyse the role of information quality and the influence of interactions between stakeholders. Nikola Stanic M.Sc and ir. Wouter van Riel both successfully defended their PhD thesis in 2016. Their work is succeeded by Eva Nieuwenhuis since the beginning of 2017 and by Kostantinos Makris since may 2018 on ageing of plastic pipes.

Theme 2. Operation and maintenance

Operation and maintenance in sewer systems is driven by local criteria, e.g. gully pots are typically cleaned once a year, irrespective of the type of sewer system (combined or storm sewer) and irrespective of the impact on sewer system performance. The research projects within this theme will provide knowledge on the relation between the operation and maintenance strategy applied and overall system performance. The main focus will be on the front end of sewerage, being house connections and gully pots. This topic is dealt with by ir. Johan Post, who defended his PhD thesis in 2016. Matthijs Rietveld started November 1st, 2016 with follow up research on gully pot performance. In addition, in 2018, Marco van Bijnen successfully defended his PhD research on the relation between the condition of the sewer system in terms of root intrusion and sediment beds and hydraulic performance.

Theme 3. Dynamics of sewer systems

Continuous monitoring of hydraulics and wastewater quality is applied at a number of locations in the Netherlands. These data open an enormous opportunity to study the dynamics of sewer systems itself and in relation with wwtps and receiving waters and to enhance the knowledge on in sewer processes. Ir. Petra van Daal-Rombouts successfully defended her PhD thesis in 2017 on this topic, using the extensive database of Waterboard De Dommel and closely cooperating with the Waterboard. Job van der Wef continues this work. Antonio Moreno Rodenas is working on the uncertainties in integrated modelling.

Theme 4. Sustainable urban water cycle

Theme 4 focuses on research on new concepts for the urban water cycle enabling energy recovery and reuse of materials. The main issue left to be dealt with is the conveyance of black water. Adithya Thota Radhakrishnan, M.Sc is the Phd student working on this theme within the STW funded project Domestic Slurry Transport.

Organization

The research program is funded by partners from the Dutch urban drainage sector. Each contributor to the research program participates in this Program Committee. The Program Committee advises the sewerage chair on the composition of the research program. In addition, the members have the privilege to actively participate in the supervisory committees of the research projects within the program and to provide case studies.

The partners of the research program are (in alphabetical order): ARCADIS, Deltares, Gemeente Almere, Gemeente Arnhem, Gemeente Breda, Gemeente 's-Gravenhage, Gemeentewerken Rotterdam, Gemeente Utrecht, GMB Rioleringstechnieken, KWR, Royal HaskoningDHV, Stichting RIONED, STOWA, Sweco, Tauw, Vandervalk & De Groot, Vitens, Waterboard De Dommel, Waternet en Witteveen+Bos. The urban drainage research program started in 2010 with a 5-year budget. Given the success of the program, in 2015 all partners decided to prolonged their participation until 2020, thus creating a solid base for the further development of this challenging research field.

dr.ir. J.G. Langeveld (Jeroen)
Director Kennisprogramma Urban Drainage
Associated professor Sewerage and Urban Drainage

Research and Education group Industry Water

In 2011 a collaboration between the section Sanitary Engineering and Evides Industry Water (EIW) was initiated, which formed the first steps towards a new group at our section: Industry Water. Within this group, research and education was developed with focus on industrial water supply, use and treatment. This development fulfills a clear need as in many manufacturing industries, including power production, water plays a crucial role in almost all industrial operations and is the basis for sustainable resource management and environmental protection. Industry Water considers the dynamics and complexities of industrial production and integrates disciplines of industrial process engineering and water process engineering from the perspective of water reuse and resource recovery.

Currently within the group Industry Water research is being carried out on water quality aspects of (ultrapure) process water for steam boilers and cooling towers, projects are carried out that focus on the treatment of highly polluted industrial effluents, and opportunities are being explored to deploy treated municipal sewage for industrial use.

These activities have already resulted in an increased knowledge and expertise within the section, which creates an excellent basis for the development of a strong industrial water group. Keeping close ties with the municipal water cycle and its inherent disciplines drinking water production and supply, and sewage collection and treatment, the section provides a unique platform for developing such an industrial water group.
In 2018 a number of MSc thesis projects were carried out under the theme of industrial water including: Silica removal using silica gel beads, corrosion behavior of mild steel in soft alkaline cooling water, adsorption-desorption system for desalination based on residual heat, separation of monovalent and divalent ions in ion exchange regenerate by using nano-filtration, vacuum membrane stripping of industrial wastewater, use of bipolar membrane in electrodialysis for concentrating ammonia, silica scaling in closed-circuit desalination, recovery of sodium sulfate from RO concentrate of silica-industry wastewater.

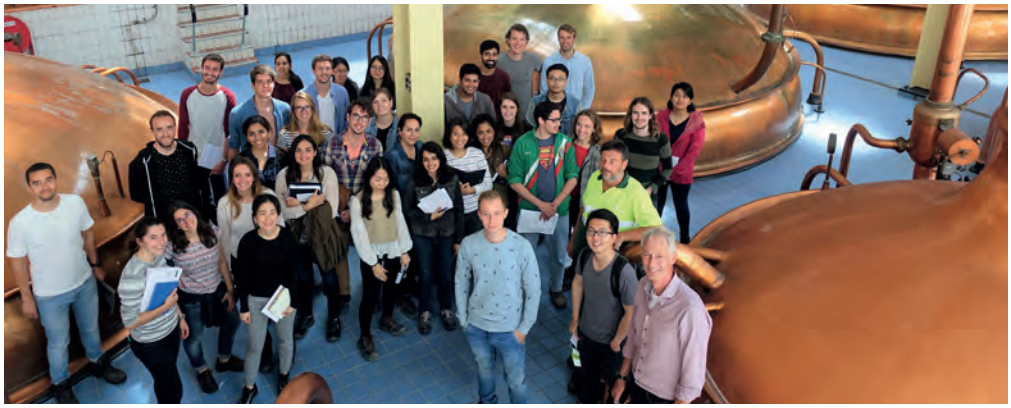
Current PhD thesis projects include: degradation of phenolic compounds in petrochemical wastewater by using anaerobic membrane bioreactor under extreme conditions (high toxicity, temperature and salinity), fouling control by flocculant addition based on measurement of online sludge filterability in anaerobic membrane bioreactors, development of an energy-positive system (based on a solid oxide fuel cell) for removing ammonia from low carbon/high nitrogen residual water, recovery of ammonia from anaerobic digestion of nitrogen-laden wastewaters, potentials of sewage reclamation for industrial use in Mozambique.

A two-year EU Marie Sklodowska-Curie project was started in 2018 with the purpose to study magnetite surface properties in the various conditions of power plant water steam cycle. The European Horizon 2020 Innovation Action Program project ZeroBrine entered its second year, where the focus of our group was mainly on the design and set-up of two pilot plants at the Evides Demi Water Plant in the Botlek industrial area.

In 2018 the Industry Water Group and the Network Group Industry Water, that consists of companies in the (petro) chemical sector, the food sector as well as energy and utility providers, and that is managed by KWR, held a joint workshop on industry water. The purpose of this workshop was to present our current MSc and PhD thesis research, and to discuss opportunities for collaborative research.
The group successfully delivered for the 3rd time in a row the newly developed MSc course "Industry Water". This course appeals water management and environmental engineering students who are interested to work with or in the industry, and is also useful to students with an industrial background, such as chemical engineering or industrial ecology, who want to learn about water processes in the industry.

The course allows students to develop understanding of the importance of water use in the industry, and to gain knowledge of water intensive production processes and their related water qualities. The course enables students to identify opportunities for water saving, reuse and resource recovery, and to apply best available technologies. The student are equipped with skills to take a unique position as a water professional in the industry, and they will be able to integrate disciplines of industrial process engineering and water process engineering. Ultimately the student will care about industrial water technology for a sustainable society. An exciting component of the course are three assignments at different industries (a paper mill, a chemical industry and a brewery) where real-life industrial water challenges will be tackled.

Henri Spanjers
Associate professor Industry Water



TISCA: Cooperation Programme *Technology Innovation for Sewer Condition Assessment*

Sewer systems and wastewater transport systems are vital parts of the urban wastewater infrastructure. In the Netherlands, like in many other countries in Europe, over 90 % of the population is served by the urban wastewater infrastructure. Managing these assets is one of the main challenges for the municipalities and water boards that own and operate these systems. In order to further develop and optimize asset management for urban wastewater infrastructures, it is essential to have sufficiently reliable information about the current status of the assets.

During the last decades, CCTV inspection has been the main source of information for the assessment of the status of gravity sewers. For rising mains, generally having less capabilities to enable easy access during operation, the development of dedicated (non-destructive) inspection techniques is still at an early stage of development.

Recent research at Delft University has demonstrated that the information obtained by CCTV inspections is associated with high uncertainties and that this information is by definition limited to failure mechanisms accompanied by visible damage within the pipe. In order to overcome these limitations, other methods, such as core sampling, laser profiling, tilt meters, have been tested as part of the 'Kennisprogramma Urban Drainage (KPUD) at Delft University of Technology. In order to speed up the process of technology development for sewer inspection, the KPUD, RIONED and STOWA have set up the TISCA programme in cooperation with STW.

The programme budget amounts to a maximum of € 3 million. The financial resources for this programme come from Technology Foundation STW (€ 1,5 million), KPUD (€ 0,75 million), RIONED (€ 0,5 million) and STOWA (€ 0,25 million).

The researchers in TISCA will cooperate very closely with the researchers in the KPUD. Part of the programme are monthly TISCA days, which will comprise colloquia to exchange ideas and results, working sessions on specific topics, (in-)formal meetings with fellow PhD students and meetings with the user groups and user committees.

The main focus of TISCA is on solutions for a coherent methodology for the (partly in-situ) condition assessment of sewers. Or, in other words, the next generation of sewer inspection technologies. In total 5 research projects have been granted as part of the TISCA program, two of which have been granted to Jeroen Langeveld and one to Lisa Scholten.

Lisa Scholten is responsible for the project SewerSense – Multi-sensor condition assessment for sewer asset management.

This project aims at four aspects of condition assessment: 1) data acquisition, 2) validation of inspection technology, 3) a framework to assess the impacts of assessed sewer condition and 4) prediction models. TU Delft and Leiden University will develop automated defect detection and classification diagnostics for CCTV and promising novel inspection techniques, such as laser profiling and stereo vision camera's. The framework will be adjusted to make a direct relation between condition assessment and expected remaining service life.

Jeroen Langeveld is responsible for the projects FOULC: Fast Over-all scanning of Underground and Linear Constructions and Geo-Electrical Sewer Leak Detection, Quantification and Location.

The FOULC project, performed by post-Doc Matthieu Lepot, aims at obtaining information on some of the main functionalities of a sewer using non-intrusive techniques. Several sensors will be positioned on a hoovercraft drone, that can move in partly filled pipes. Information can be gathered in-situ to quantify the actual hydraulic capacity, the presence and the amount of sediments and biofilm, detailed 3D information on the actual sewer geometry and information on the locations where and the amount of infiltrating groundwater. The development of this sensor platform is dedicated to sewer systems, but the application is not limited to sewers since it can also be applied for obtaining information on hydraulic capacity of and the presence of sediments in ditches and canals.

The leak detection project addresses leakage, which is one of main causes of failures of pressure mains and the nightmare of sewer operators in areas where ground water is used as a source for drinking water production. Leaks occur due to ageing of our underground wastewater infrastructure, leakage of sewers and pressure mains and

subsequent infiltration or exfiltration (I/E) is becoming an increasingly important issue. In order to be able to deal with leakage, sewer operators need to be able to detect, quantify and locate I/E. The project focusses on exploring the potential of geo-electrical monitoring: Self Potential monitoring and Electrical Resistivity Tomography in the soil and Focused Electrode Leak Location from within the sewer to detect, quantify and locate leaks. Bram Stegeman works on this project as part of his PhD.

dr.ir. J.G. Langeveld (Jeroen)
Director Kennisprogramma Urban Drainage
Associated professor Sewerage and Urban Drainage

Dunewater in the 21th century – Strategic cooperation Dunea Duin en Water – TUD in the field of drinking water research

On 9 October 2013 Dunea drinking water company and the Faculty of Civil Engineering and Geosciences signed a 4-year contract for strategic cooperation in the field of drinking water research. The cooperation covers the focuses on four specific subjects:

- The effect of advanced oxidation processes on managed aquifer recharge during the removal of organic micro pollutants from drinking water.
- Research into the effect of dune infiltration on the arsenic concentration, and research into methods to reduce the increase during dune infiltration and methods into removal of arsenic from drinking water.
- Research into the effect of flushing the drinking water distribution system, with and without the use of chlorine, on microbiological contamination.
- Preliminary research into the extension of the lifetime of the transport system “Afgedamde Maas”.

Dunea Duin en Water produces and distributes drinking water for over 1.2 million customers in the province Zuid-Holland. The dunes near Scheveningen, Katwijk and Monster are the centre of Dunea’s treatment process, which enable the production of safe and reliable drinking water. Surface water from the Afgedamde Maas is Dunea’s main water source. After pretreatment this water is transported to the dune area and infiltrated.

Strategic research collaboration HWL

TU Delft cooperates closely with Het Waterlaboratorium (an institute for water research). A partnership agreement was signed in March 2010. Het Waterlaboratorium makes funding available for innovative research into the detection and removal of organic micro-pollutants in the urban water cycle.

Cooperation brings benefits for both parties. Het Waterlaboratorium benefits from easier access to knowledge and research at the university, while TU Delft gains access to the expertise of Het Waterlaboratorium in the field of detecting and identifying organic micro-pollutants. Research themes include the presence and behaviour of priority substances and emerging substances within the urban water cycle, the behaviour and selective removal of natural organic material, and the quality of water in distribution networks. This research is carried out both by staff at Het Waterlaboratorium and by students, PhD researchers and postdoc researchers.

Het Waterlaboratorium specialises in high-quality advice and research relating to water. The laboratory's expertise is available for all those who want to achieve perfect water quality. Its customers are companies that supply drinking water, but also include hospitals and health institutions, the off-shore sector, municipal government, businesses and sports institutions.

Waternet and TU Delft investigate innovation in water cycle

In 2008 Waternet and the faculty of Civil Engineering and Geosciences of TU Delft signed a strategic collaboration contract. The collaboration focuses on research in innovation in the water cycle, particularly on the sectors drinking water, wastewater and water systems.

Waternet is the first water cycle company in the Netherlands. Waternet takes care of the entire water cycle: from drinking water, sewerage and treatment of waste water to discharge of waste water effluent into surface water. Furthermore, maintenance of ditches, lakes and ponds, advice during high ground water levels and dike supervision are part of the tasks of Waternet. Waternet has been assigned to perform these tasks by waterboard Amstel, Gooi en Vecht and the city of Amsterdam. With Waternet's ambition to shape the innovation in the water cycle and the expertise of TU Delft in the sectors of the water cycle, this collaboration is a logical next step.

The duration of the collaboration was, in first instance, four years and still continues. The collaboration consists of MSc work of TU Delft students at Waternet, PhD research, post doc, and the use of the pilot installation at Leiduin as a "water cycle laboratory". Prof.dr.ir. J.P. van der Hoek of Waternet is appointed as a part-time professor at TU Delft.

IWA Project Innovation Award: Bronze winner with “Thermal Energy Recovery from Drinking Water: Exploitation of a Renewable Energy Source”

At the IWA World Water Congress and Exhibition 2018 the project “Thermal Energy Recovery from Drinking Water: Exploitation of a Renewable Energy Source” carried out by Delft University of Technology, Waternet and Sanquin, was awarded with the bronze prize in the category “Performance Improvement and Operational Solutions”. The official ceremony took place 17 September 2018, in Tokyo – Japan. The IWA Project Innovation Award recognizes and promotes excellence and innovation in water management, research and innovation.

Cees Boeter award 2018

The Department of Water Management is proud to announce the winner of the Cees Boeter Award for the best BSc thesis written in the 2017-2018 academic year.

As each year, we have been able to select three nominees from a highly competitive group of young researchers and designers with a huge variety of topics.

Nominee 1 studied Water reclamation with ceramic membrane filtration for cooling water in industrial use. Daniel Donse studied the use of reclaimed water for industrial cooling in Maputo, especially the possibility to treat wastewater effluent in ceramic membrane filtration.

Our second nominee, Irene van der Veer, built a model to predict daily Leaf Area Index values. This Index is an important element of hydrological models, but a model to predict daily LAI values and is applicable on global scale does not exist.

The third nominee is Tess Wegman, who looked into the possibilities of implementing High Temperature Aquifer Thermal Energy Storage systems to store geothermal energy through injecting saline groundwater from deeper layers storage in other saline aquifers.

The three nominees show that our best BSc students are able to tackle important problems, are able to deal with complicated data sets, are able to analyse complex outcomes and can write a report as well.

But, as always, there can be only one winner. This year, that winner is the student that managed the complexities of data and mathematics, and wrote an impressive report. Our winner of the 2018 Cees Boeter Award is Irene van der Veer.

Awards

Prof. J.P. van der Hoek appointed as Principal Investigator at AMS -Postdoc position available for for a second two-years period

In September 2016 the board of the Amsterdam Institute for Advanced Metropolitan Solutions (AMS) has appointed Professor Jan Peter van der Hoek as Principal Investigator for a period of two years.
AMS is the institute in Amsterdam, founded in 2014 and supported by the City of Amsterdam, in which Technische Universiteit Delft, Wageningen University Research and Massachusetts Institute of Technology, together with partners from the public and private sector, work on three specific themes: Circular City – Vital City – Connected City.

Jaap van der Graaf award 2017/2018

The Jaap van der Graaf Award was presented to Alexander Hendriks MSc on 13 January 2017, during the 70th Drinking Water and Waste water Symposium ('Vakantiecursus') at Delft University of Technology. This annual prize is given in recognition of the best English-language article about waste water treatment, written by a student or researcher and published during the preceding year. The winning article was selected by an independent jury and our colleagues Hendriks and van Lier and the Kreuk came out on top. It was published in the journal 'Biotechnology Advances' under the title 'Growth media in anaerobic fermentative processes: The underestimated potential of thermophilic fermentation and anaerobic digestion'.

This year 28 articles focusing on the urban water cycle had been send from all groups in the country. This shows the productivity of the Dutch researchers in this field remains high. As each year the jurymembers, Arjen van Nieuwenhuizen, Cor Merks, Gertjan Medema, Ad de Man, Jasper Verberk, Jelle Roorda, Hardy Temmink and Jules van Lier ranked the articles based on 5 criteria: societal impact, innovation, applicability on the short/medium term, scientific quality and writing style.
The choice for the winning article was a very tough selection process. "The differences were very small, like in sports, tenths of a second", according to one of the jury members.
From the beginning it became clear, the winning article was highly appreciated by all jury members. The title doesn't seem to resemble the urban water cycle, but based on Alexander's literature review it became clear how trace elements (vitamins and minerals) play a critical role in the daily practice of anaerobic digestion. Their absence can cause a significant inhibition on a process that is applied on a full scale throughout the world.
The work shows that deficiencies can be detected by regular daily measurements, dosage of "vitamientjes" could improve digester performance. It appears that even the difference between mesophilic and thermophilic digestion should be questioned in order to advance science.
"Wanting to know the cause of the difference can lead to the remarkable conclusion that intrinsically there is no difference"

Gijs Oskam

Voor deze prijs komen jonge en/of aankomende academici in aanmerking die in 2016 of 2017 zijn afgestudeerd op het gebied van de Stedelijke Watercyclus. De aanmoedigingsprijs van 2500 euro moet jonge onderzoekers/ingenieurs een extra stimulans geven. De belangrijkste criteria voor het winnen van de prijs zijn belang, originaliteit en kwaliteit van het onderzoek in de Stedelijke Watercyclus.

De winnaars zijn geworden:

Abel Heinsbroek	1e prijs t.w.v. €1000
Evelien Martens	2e prijs
Maarten Keuten	2e prijs

Stories of Science

The webpage 'Stories of Science' keeps you informed of up to date scientific research within the Sanitary Engineering section. Here are some excerpts from the experts:

Leapfrogging towards sustainable palm oil

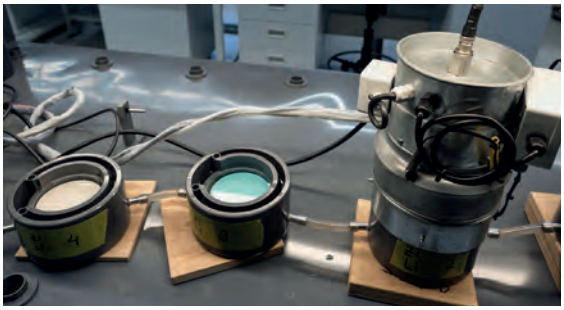
'With palm oil being the most widely used vegetable oil in the world, the industry is likely to stay with us for the foreseeable future, despite its controversial reputation of pollution, deforestation and ignoring the needs of local communities. "The palm oil industry is only expanding, so doing nothing is not going to solve the problem," says Dr Ralph Lindeboom of the department of Sanitary Engineering. Lindeboom aims to help make the industry more sustainable for both the environment and local people.'

Dr.ir. Ralph Lindeboom

A chlorine-free pool

'Pool water is usually disinfected using chlorine-based products, such as hypochlorite, to wipe out all micro-organisms. Unfortunately, hypochlorite also reacts with other pollutants in the water, such as sweat and urine, to release disinfection by-products. These by-products may be harmful to health and can cause skin irritation and red eyes. The DIPool project of Marjolein Peters and Maarten Keuten looks at how the formation of harmful disinfection by-products can be counteracted, either by reducing the contamination of the water or by using less or no hypochlorite. The ultimate goal is to develop a chlorine-free pool based on UV disinfection.'

Ir. Maarten Keuten



Drinking water quality after Thermal Energy Recovery

'Water companies are keen to use cold from drinking water as a source of energy for cooling purposes, such as cooling houses. This technique, called Thermal Energy Recovery, companies wish to operate climate friendly and turn water distribution networks into a renewable energy resource. But if the drinking water loses its chill, will it still be fit for human consumption? And what about the microbiological quality of the water? That is what PhD candidate Jawairia Imtiaz Ahmad is trying to find out at TU Delft's Waterlab.'

Ir. Jawairia Imtiaz Ahmad

Towards an effective reduction of arsenic levels in drinking water

Reliable tap water, proper waste water treatment, and dry feet. That's what people in the Netherlands expect and are accustomed to. However, flooded homes, sewer overflows and impassable roads occur with increasing frequency. The Randstad conurbation has suffered from severe water issues in recent months for instance. The KNMI [Royal Netherlands Meteorological Institute] has predicted that the number of extreme showers will further increase in the 21st century due to global warming. The water infrastructure in our urban areas isn't built to accommodate this, warns Professor Jules van Lier. He argues in favour of smarter solutions and a new paradigm for our Urban Water Infrastructure.

Ir. Jink Gude

Working together with worms

Getting the best out of nature is what drives biotechnology scientist Steef de Valk. In the Waterlab of TU Delft he is researching the way tubifex worms process sludge. Knowing more about how they manage to decompose the sludge so efficiently, can contribute to a better purification process in waste water treatment plants.

Ir. Steef de Valk

To find out more information please visit the following link: https://www.tudelft.nl/en/ceg/about-faculty/departments/watermanagement/research/stories-of-science/

Guest researchers

Hongbo Liu

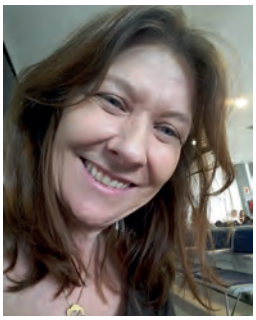
Hongbo Liu comes from Jiangnan University situated in Wuxi city, in China. He is an associate Professor focusing on sludge anaerobic fermentation for VFAs production, as well as biological wastewater treatment technologies. Since October 24th, 2017, he has worked in TUDelft as a visiting scholar. Under the supervisions of Prof. Jules van Lier and Prof. Merle de Kreuk, he has been investigating the influence of humic substances on Anammox during rejection water disposal.

Bensheng Su

I am Bensheng Su, I come from Beijing University of Chemical Technology, China. Main research: biological treatment technologies mainly including advance anaerobic technology and aerobic granular sludge in industrial sewage and municipal sewage.

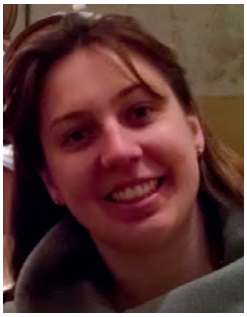
Currently, I am working at TUDelft as a visiting scholar from 9/12/2016 to 1/10/2018. My current project is focussing on anaerobic digestion of sludge, how to improve the hydrolysis rate and get more methane.

Paula Paulo



Paula comes from Brazil where she is associate professor at the Federal University of Mato Grosso do Sul (UFMS), located in Campo Grande-MS. Her project deals with risk assessment for the safe reuse of greywater, where she is proposing a semi-quantitative approach inspired by the WHO safety sanitation planning for both microbial and chemical risk assessment. The main objective is to build a conceptual a model, serving as a tool to assist in the decision making process for household/decentralised sanitation systems aiming at reuse.

Guest researchers



Karoline Richter

My name is Karoline Richter. I graduated in Civil Engineering from Federal University of Paraná (UFPR) in 2010 in Brazil. I started working as a Civil Engineering also at UFPR. Dissatisfied with the waste of materials in the construction, in 2012, I started my master's degree in the sustainability process area and it contributed with my engineering work. I completed my masters degree in 2014, yes, in Brazil we stay 5 years in under graduation and more 2 years in masters graduation. In 2015, I realized that I could contribute even more to the Brazilian society if I could help them to have access to water and sanitation supply systems through a scientific contribution. So, in 2016, I started my PhD studies in UFPR at the Postgraduate Program of Water Resources and Environmental Engineering where I am researching on design a model of decision-making process for alternatives of integrated drainage and sanitation systems in urban areas (peri-urban areas; areas with lack of drainage and sanitation). My supervisor here at TU Delft is Professor Francois Clemens and I am also thankful for the Assistant Professor Lisa Scholten support. I'm very happy for being received as a guest researcher here at the university.

Marc Arpad Boncz

Graduated as a chemist (VU, Amsterdam), I obtained a PhD in Environmental Technology (Wageningen) and am now working as an assistant professor at the UFMS (Federal University of Mato Grosso do Sul) in Campo Grande-MS (Brazil). My main research interest is processing of wastewater for materials recovery and bioenergy production, and for this I work with anaerobic and algae based processes, as well as some physical-chemical methods.

During my 15-month stay at TU Delft I have and will be working on several topics. First, modeling the processes studied in Brazil and writing papers, but I am also participating in the Zero-Brine project coordinated by Henri Spanjers, in which chemical precipitation of inorganic materials is being studied and modelled, with the objective of recovery of Calcium and Magnesium salts. After return to Brazil I will return to giving classes again and of course I will be happy to receive anyone from Delft wanting to gain some experience abroad.

Guest researchers

Mario Takayuki Kato

Mario is a Civil Engineer with M.Sc in Hydraulics and Sanitation at University of São Paulo (USP) and Ph.D in Environmental Technology at Wageningen University (WUR). He is from Recife, Brazil, working at the Federal University of Pernambuco (UFPE) as full professor in Sanitary and Environmental Engineering. He has been working mainly with low-cost sanitation, diluted wastewater, reuse and value-added products recovery. During his one-year period at TU Delft, he will focus in strengthening the studies on such subjects in collaboration and support of Prof. Jules van Lier.

Lourdinha Florencio

I come from Recife, Brazil, where I graduated in Civil Engineering at Federal University of Pernambuco (UFPE). I obtained the M.Sc in Hydraulics and Sanitary Engineering at University of São Paulo (USP), working with activated sludge process and the Ph.D in Environmental Technology at Wageningen University (WRU), studying the degradation of methanol in anaerobic bioreactor. Since 2010 I am a full Professor at UPFE. My main research interest is aerobic and anaerobic wastewater treatment under tropical condition, nutrient recovery, water reuse and bioenergy production from glycerol and algae based processes. The objective of my one-year stay here in TU Delft is to write papers based on the studies done in Brazil and to learn more about those subjects in collaboration with Prof Jules van Lier.

Individual projects

Jawairia Imtiaz Ahmad

Microbial dynamics in Drinking water distribution system (DWDS) during and after Thermal Energy Recovery

Research objectives

The aim of the current research is to determine the impacts of thermal energy recovery on microbiological drinking water quality and microbial dynamics inside drinking water distribution network. The study will also focus on assessing the impact of increasing temperature after cold recovery on biofilm formation and development on pipe surface. And comparing different temperature ranges after cold recovery, to determine the maximum allowable temperature change without compromising the microbiological water quality after thermal energy recovery (TER).

Project outline

Introduction

Climate Change is happening and it results into temperature changes globally and also at regional and local levels. It is also impacting the water bodies, as reported in the IPCC AR5. It is strongly agreed that fresh water resources will be negatively impacted by climate change, resulting in reduced water quality. These risks will occur due to increased temperature, sediment and nutrient load due to heavy rainfalls, which cause malfunctioning of treatment plants (Cisneros et al. 2014). But every threat comes with an opportunity. In the same manner, the water sector has a huge potential to contribute in lessening the impacts of climate change by reducing CO2 emissions from its processes. Because water contains a lot of energy, both thermal and chemical, recovery of this energy and using it as an alternative for fossil fuel will reduce carbon footprints of the processes used to treat water for drinking purposes (Van der Hoek 2012). But the changes in water temperature, especially increased temperature after recovering cold, may effect the microbiological, physical and chemical properties of water during distribution (McNeill & Edward, 2002). It was highly observed that frequency abundance of many dominant phyla in DWDS's increased in summer and in extreme winter conditions. Apart from this, some opportunistic pathogens do exist in DWDS's under favourable temperature conditions above or around 25oC (Pinto et al. 2014; Chakhtoura et al. 2015; Hammes et al. 2010).

Approach

Hence, the current study is planned to carried out both at pilot and full scale thermal energy recovery systems to evaluate the impacts of TER on microbiological water quality under different temperatures and from different source waters (both surface and surface/ground).

Scientific relevance

The thermal energy recovery might make the distribution systems favorable for growth of certain microbial communities or suppress the growth of those who cannot compete at high temperatures. This is one of the questions to be solved: TER will either enhance the growth of microbial communities in the system or it will increase the microbial quality of drinking water in DWDS's downstream in the network, by working as a hot spot to consume all the nutrients at one point in the system (inside heat exchanger). The current study is trying to fill this knowledge gap in field of drinking water supplies and microbiological quality of water.

Social relevance

Reducing carbon emissions is the social responsibility to save this planet from the effects of climate change. The supply of safe drinking water to masses of population is also the core responsibility of drinking water utilities. This research is trying to correlate/link both goals by recovering cold from DWDS's under the condition/temperature limit which cannot compromise microbiological quality of the drinking water afterwards.

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Pictures: Cold Recovery pilot installations at waternet, drinking water treatment plant facility at Leiduin, The Netherlands.

Jawairia Imtiaz Ahmad

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Start date project: May 2015
Expected end date: May 2019

Key words:
Thermal energy recovery, Drinking water distribution network, Biostability, Microbial water quality

Cooperation with other institutes:
Waternet, TKI

Saqr Al-Muraisy

Integrated Hyperthermal Anaerobic Fermentation of Empty Fruit Bunch and Palm Oil Mill Effluent to Enhance the Production of Biomethane and High-Value Chemicals (People Project)

Research objectives

The main goal of this project is to develop an efficient process to produce biogas and high-value bulk chemicals using undefined mixed cultures from palm oil mill waste. Suitable high temperature technology will be implemented in the process design. As a secondary goal, the novel process design will be integrated into a holistic water reuse approach.

Project outline

Introduction

There has been an increasing demand on fossil fuel which is depleting causing numerous challenges to global economic growth. This has encouraged industry and academia to find alternative resources which are sustainable and environmental friendly (Chandel, Antunes et al. 2012, Dutta, De et al. 2013). Palm empty fruit bunch and palm oil mill effluent are promising options to produce biofuel sustainably (Ahmad, Buang et al. 2016).

Malaysia is the second largest producer of palm oil worldwide. Malaysia Palm Oil Board (MPOB) reported that a total of 17.86 million tonnes of crude palm oil was produced in Malaysia in 2009, resulting in the production of 100 million dry tonnes of dry biomass, of this, around 38 million tonnes was empty fruit bunch (EFB) (Chin, Chia et al. 2015). These numbers increased by 35% in 2017 (MPOB 2017). For every 1 kg of crude palm oil (CPO) produced, approximately 4 kg of dry biomass is generated, in which one third of the biomass is oil palm empty fruit bunch (EFB) (Geng 2013, Chin, Chia et al. 2015). Moreover, 2.5 kg of palm oil mill effluent (POME) is produced for every 1 kg of crude palm oil (CPO). Therefore, It is necessary to find suitable treatment techniques for EFB and POME to relieve the pressure of pollution in the environment which is a huge issue in palm oil producing countries such as Malaysia and Indonesia.

Approach

This project can be divided into six promising steps which cover the process of EFB and POME treatment. First, palm oil mills site visits where the current status of the palm oil mills is assessed and potential solutions to the issues of the waste produced are identified. Second, various EFB pretreatment techniques are investigated in terms of lignin degradation to improve accessibility to cellulosic matter in the fibre. The objective is be to evaluate various innovative pretreatment techniques based on lignin degradation and polysaccharides accessibility. Third, hyperthermophilic anaerobic co-digestion of EFB and POME integrated process design that will be developed to treat both EFB and POME to produce biogas and high-value chemicals at elevated temperature to utilize the heat produced from palm oil mills with POME at 80-90 degrees C. Fourth, process optimization and modelling of the optimal environmental conditions within the digester will be investigated. In addition, models could be built based on the process characteristics and kinetics to predict the outcome and the result would be validated from the measured values. Useful modelling techniques include anaerobic digestion models No. 1 (ADM1), PhreeqC, Artificial Neural Network, etc. Fifth, energy analysis and Life Cycle Assessment (LCA) where it will be carried out to evaluate the environmental impacts and gives more focus on energy analysis of biogas production and value-added chemicals through the digestion of EFB and POME. Lastly, pilot plant set up and on-site demonstration which will be installed in the project location in Malaysia. Process will be run under real environmental conditions of the location/site to evaluate its performance and efficiency. Figure 1 depicts the flow scheme of the project.

Scientific and social relevance

Most of empty fruit bunch (EFB) is currently burnt in the open air emitting green gas; while a small amount was used as a biofertilizer for new palm oil plants (Garcia-Nunez, Ramirez-Contreras et al. 2016). Finding innovative techniques to treat EFB recalcitrance would be valuable to improve its fiber utilization resulting in less waste disposed to the environment. Moreover, EFB treatment will contribute to the production of biofuel which is a sustainable source of energy.

Rivers of Malaysia is one of the most polluted rivers in the world which affects water distribution systems to residential areas, daily human-river interaction and aquaculture diversity as palm oil mill effluent (POME)

is directly discharged to the river. Thus, this project aims to have a small portion of contribution to relieve the pressure of pollution in the Malaysian rivers by treating POME from organic pollutants and reuse it in other activities such as irrigation, in the upstream processes of the palm oil mill and/or in EFB pretreatment process.

Figure 1. People Project Approach

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Key words:
Resource Recovery, Palm Oil, Empty Fruit Bunch, Palm Oil Mill Effluent, Biofuel

Cooperation with other institutes:
Universiti Malaysia Terengganu (UMT)

Md Annaduzzaman Kajol

As(III) removal by RSF system for small-scale piped water supply in arsenic-affected rural Bangladesh

Research objectives

This study aims to investigate biological As(III) oxidation and subsequent adsorptive removal in aeration-filtration systems for the treatment of As-contaminated anaerobic groundwater for safe drinking water production in rural Bangladesh.

Project outline

Introduction

Large parts of the Ganges-Brahmaputra-Meghna Delta (GBM Delta) are densely populated, with megacities Dhaka and Patna as pillars of the region. Urbanization of deltas puts a severe stress on the availability of clean, safe drinking water and therefore threatens the lives of millions, mostly affecting the poorest. Arsenic-contaminated groundwater causes a widespread, serious health risk exposing millions of people worldwide (Smith et al., 2002; Chowdhury, 2010). In the GBM Delta in India and Bangladesh this contamination was recognized over twenty years ago (Acharyya and Shah, 2006); however, to date, arsenic mitigation strategies have collectively disappointed, due to the financial, institutional, environmental, technical and social (FIETS) complexity of the arsenic problem. Water supply in the GBM Delta is predominantly organized through the use of scattered household hand-pumps, where the water safety is un-controlled, leading to contaminant exposure, particularly for the poorest. Among many available treatment technologies, the conventional groundwater treatment for drinking water production consists of aeration and rapid sand filtration (RSF). Aeration and RSF are commonly used for dissolving iron (Fe), manganese (Mn), and ammonium (NH4) ,phosphate (PO4) and partially arsenic (As) when present in source water (Lytle et al., 2007; Gude et al., 2018). It has widely been proven that As(III) oxidizes rapidly in the top layer of a rapid sand filter, caused by accumulation of As(III) oxidizing bacteria (AsOB). It is the aim of this study to utilise this knowledge towards the development of decentralised As removal technology for rural Bangladesh, with specific emphasis on low-cost design, high temperature climate and intermittent operation.

Approach

- Pilot-scale investigation on the effect of AsOB to enhance arsenic removal in RSF in Rajshahi, Bangladesh, based on locally available materials.
- As(III) oxidation will be tested with different water quality settings in the laboratory as well as in pilot scale with the individual and combined effect of Fe, Mn, NH4, and PO4 on As(III) oxidation. Additionally, experiments with naturally As(III)-containing groundwater will be done to find the influence of the natural groundwater matrix on the AsOB.

Figure 1. Rapid sand filtration based arsenic removal pilot-scale experimentation in rural Bangladesh.

Scientific relevance

So far biotic As(III) oxidation in rapid sand filters (RSF) has predominantly been studied for low As levels (≤20 µg/L) but not for high level (>100 µg/L). Although AsOB are found in rapid sand filters, it is, far less researched whether these bacteria are responsible for As(III) oxidation independent of co-occurring chemical and biological processes. The oxidation of As(III) by AsOB is of

great interest for As(III) removal because the resulting As(V) formation is imperative for subsequent adsorption onto Hydrus ferric oxide (HFO) in the filters.

Social relevance

This study is of direct interest to exposed consumers, NGOs and governmental agencies in Bangladesh as it will develop solutions for the As safe drinking water production based on locally available materials, simple and affordable in design and operation in these arsenic-affected areas. The solutions are developed in close collaboration with local educational institutes, design engineers and personnel, aiming at a close link to end-user desires and needs for improved health through safer drinking water.

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Key words:
Arsenic, Drinking water, RSF, Biotic oxidation, Treatment

Cooperation with other institutes:
EPRC, Dhaka University, RUET, Rajshahi University, Bangladesh

Magela Odriozola Arbiza

Online fouling control in Anaerobic Membrane Bioreactors

Research objectives

The purpose of this project is to develop a control system based on online filterability measurement coupled with chemical dosage to stabilize and enhance flux in Anaerobic Membrane Bioreactors (AnMBRs).

Project outline

Introduction

AnMBR is an innovative technology for municipal wastewater treatment and an established technology for industrial wastewater. However, the main bottleneck of the AnMBR is the much lower fluxes than those reported for aerobic membrane bioreactor technology 1. The decline in permeate flux is caused by 'fouling', this is the deposition and accumulation of particles on the surface and in the membrane.

The causes and mitigation of membrane fouling have been widely studied in both aerobic and anaerobic membrane bioreactors. Research on membrane fouling mitigation strategies focuses on optimization of operational conditions, mechanical cleaning and chemical cleaning. Although fouling mitigation actions are usually suitable in a stable operation of the membrane system, they may not be adequate or enough when the fouling problems are caused by sludge with high fouling potential 2. The application of flux enhancers (FEs) for fouling control has been extensively researched. However, in AnMBRs research has focused in short-term lab scale tests. Feasibility of continuous addition of FEs during long-term operation in pilot AnMBRs is still uncertain therefore it should be further studied 3.

Quantifying the sludge fouling potential, independently of membrane operational conditions, is crucial for allowing successful control actions on the sludge. Different indicators, such as critical flux and filterability, were defined aiming at quantifying fouling potential of activated sludge. These were mainly applied to characterize and monitor fouling and not for control purposes.

This research project focuses on developing an advanced control strategy based on online sludge filterability measurements coupled with FEs addition to optimize the membrane filtration process in a pilot AnMBR allowing to stabilize and enhance the operational flux.

Approach

The research is performed within the framework of the European project BioWaMet that proposes AnMBR as an innovative technology for municipal wastewater treatment. A pilot AnMBR for blackwater treatment at room temperature was constructed in Spain by the project leader Aqualia. The effect of FEs on reactor performance and sludge characteristics was studied.

The experimental data will be used to develop an online control strategy to stabilize and enhance flux based on sludge filterability measurements coupled with FEs addition.

Results

The effect of adding KD451 to a pilot Anaerobic Membrane Bioreactor (AnMBR) treating blackwater was studied. The optimal dosage of KD451 was estimated with short-term filterability tests of a sludge sample with different dosages of FE. The optimal dosage was 0.05 g L^{-1}, it was selected to maximize filterability using the minimum amount of FE. This dosage was added to the pilot and the effect on reactor performance and sludge characteristics was studied. The reactor performance was assessed in terms of mean Transmembrane Pressure (TMP_{ave}), flux, organic matter removal and quality of the permeate. The sludge characteristics measured were suspended solids, colloidal Chemical Oxygen Demand (COD) and Particle Size Distribution (PSD). Additionally, the Sludge Filterability (SF) was measured using the Delft Filtration Characterization (DFC) installation connected online to the pilot AnMBR. Results show that the addition of FE increased particle size, decreased colloidal particles concentration and improved SF; thus, decreasing the TMP_{ave} from 245 to 154 mbar and increasing the operational flux from 9.3 to 10.3 L m^2 h^{-1}. No effect of the FE on solids concentration and permeate quality was observed. The effect of the FE was stable during the 3 weeks measuring period.

Scientific relevance

Poor sludge filterability is one the possible factors of high membrane fouling, leading to lower fluxes. This is the main factor determining the economic feasibility and applicability of AnMBR technology. Lower fluxes translate into higher membrane surface requirements,

and membranes represent a significant cost in AnMBR systems. The development of an online fouling control strategies to stabilize and enhance flux will contribute to position the AnMBR as an economically feasible technology.

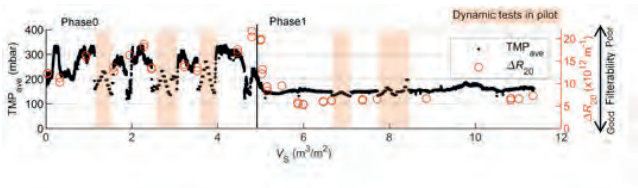

Figure 1. Evolution of mean TMP during a filtration cycle (TMPave) and sludge filterability measurements (inversely related with anaerobic ΔR_{20}) before (Phase 0) and after (Phase 1) flocculant addition to the pilot AnMBR. Vs is the volume of permeate produced per square meter of membrane. The "Dynamic tests in pilot" highlighted in the plot correspond to flux-step and gas flow-step tests performed in the pilot AnMBR, this periods were not considered for comparison of both phases.

Social relevance

Water scarcity is a severe worldwide problem that rises the interest in sustainable wastewater treatment to produce reclaimed water, reduce energy and environmental impacts while recovering resources. AnMBR technology couples the widely proved advantages of the anaerobic digestion process, namely biogas production and low sludge production, with disinfection by membrane filtration. The biogas can be used to generate calorific energy and/or electric power. Additionally, anaerobic digestion does not require oxygen supply and consequently the energy consumption is significantly reduced. Therefore, AnMBR is a promising technology for sustainable wastewater treatment.

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Key words:
AnMBR, Flux enhancer, Fouling control, Sludge filterability

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Aqualia Spain, University of Southampton UK

Lenno van den Berg

Wastewater suspended solids in Aerobic Granular Sludge

Research objectives

The aim of this project is to understand the fate of complex contaminants (e.g. suspended solids and colloids) in aerobic granular sludge (AGS) installations, the effect of these contaminants on granule characteristics, and the mass transfer processes that play a role in this.

Project outline

Introduction

Aerobic granular sludge is a recent innovation in which microorganisms are selected to grow in aggregates rather than flocs. The technology enables combined carbon, nitrogen and phosphorus removal, can reduce space requirements of the installations by ±80% and is cost-effective compared to activated sludge technology (De Bruin et al, 2004). The granules are a form of biofilm, in which no support or carrier material is used (so-called auto-immobilization).

Development of the AGS technology was primarily based on laboratory studies with soluble and readily biodegradable substrates. The soluble fraction of the organic matter in wastewater however, is typically less than 50% (Roeleveld and Van Loosdrecht, 2002). So-called particulate substrates or suspended solids form the majority of organic matter in the influent of a sewage treatment plant. It has been shown in laboratory studies that particulate COD can be removed effectively by granular sludge, but that the biomass tends to form irregular structures and filaments appear on their surface. An excess of filamentous structures can lead to a reduced settleability, scum layer formation and potentially complete process failure (De Kreuk et al, 2010; Wagner et al, 2015). A proper fundamental understanding of the fate of complex contaminants in AGS installations is essential in better controlling the negative effects associated with these contaminants.

Wastewater enters the reactor during the anaerobic feeding phase, in which the fresh wastewater flows upward through the granule bed. Soluble contaminants, such as volatile fatty acids, can diffuse into the granule and are consumed and stored anaerobically. Particulate contaminants can attach to granules or even enter the pores of granules, depending on their physical characteristics. Hydrolysis may break up the particulates in smaller pieces and fermentation can yield volatile fatty acids. However, since the anaerobic phase is non-mixed, these processes are very difficult to monitor. Advanced methods are required to study them and to determine to what extent they play a role in AGS formation and the sewage treatment efficiency.

Approach

1) Characterization of the complex contaminants in wastewater regarding physical characteristics such as size, shape and charge;
2) Characterization of diffusional properties and granule structure of granular sludge from different treatment plants with nuclear magnetic resonance (NMR);
3) Analysis of exchange and timescale of exchange between influent wastewater and granule bed with NMR and MRI;
4) Analysis of attachment and incorporation of particulates into the granule with magnetic resonance imaging (MRI).

Scientific relevance

This research will provide a better understanding of the interaction between suspended solids and granular sludge. The obtained knowledge might be applicable to other granular sludge systems, such as anaerobic granular sludge and Anammox.

Social relevance

A fundamental understanding of the fate of complex contaminants and involved mass transfer processes can aid in the further optimization of existing AGS plants and provide an additional stimulus for the construction of new AGS plants. This will lead to reduced energy use for the treatment of wastewater (less greenhouse gas emissions) and reduced treatment cost.

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Key words:
Suspended solids, granular sludge

Cooperation with other institutes:
Royal HaskoningDHV

Bruno Bicudo

Wastewater healthy reuse and antimicrobial resistance

Research objectives

This PhD project is part of the LOTUSHR project and its objective is to evaluate the health risks associated with the healthy reuse of waste water in New Delhi, with a special emphasis on the analysis of pathogens and emerging bacterial threats. Prospective reuse possibilities will include (but not limit to) drinking water reuse, unrestricted irrigation, construction, industrial process water, etc.

Project outline

Introduction

Wastewater reuse is an important adaptation option for mitigating water stress in rapidly growing urban centers. It provides an all year round available water source, which is particularly useful for irrigation practices. Although potentially advantageous, irrigating with reclaimed wastewater does not come free of risks. According to Christou et al., 2017, irrigating crops with reclaimed wastewater increases their exposure to elements such as antibiotics, ARB and ARG and affects the soil micro-organism balance.

The first and most important concern about safe wastewater reuse comes from the microbiological point of view. Indian wastewaters have been found to contain significant amounts of very diverse pathogenic organisms, many of which have acquired resistance to multiple antibiotics. The spread and increase of antibiotic resistance and antibiotic resistance genes (ARG) has been highlighted both by the WHO and CDC as serious threats for public health on a global scale. At the current rate of dissemination, recent estimates indicate that by 2050, AMR will be responsible for approximately 10 million deaths every year, even surpassing deaths by cancer.

In New Delhi, studies have been conducted in the Yamuna River, in several STP and in Hospital effluents, indicating that antibiotic resistant organisms are already present in the Yamuna before it even reaches New Delhi, and some actually increase their numbers and resistance in the wastewater treatment plants and hospital environments. Tetracycline antibiotic resistance genes for example, have been found in New Delhi's drinking and recycled water.

Together with ARB and ARG, reclaimed water will be screened for the prevalence of pathogens, particularly those associated with cases of severe diarrhea, responsible of 13% of children (under 5 years old) mortality in India, taking the lives of over 300.000 Indian infants on an yearly basis. Other contaminants of relevance such as heavy metals and organic micro pollutants

Approach

After pre-treatment in Anaerobic membrane bioreactors (AnMBR) and nutrient removal in constructed wetlands and algae Photobioreactors, produced water will be subject to a suitable tertiary treatment in order to further improve its quality and increase the water reuse potential. Technologies will be selected on the grounds of scientific evidence regarding their potential for the removal of antimicrobial resistant bacteria and genes, pathogens,

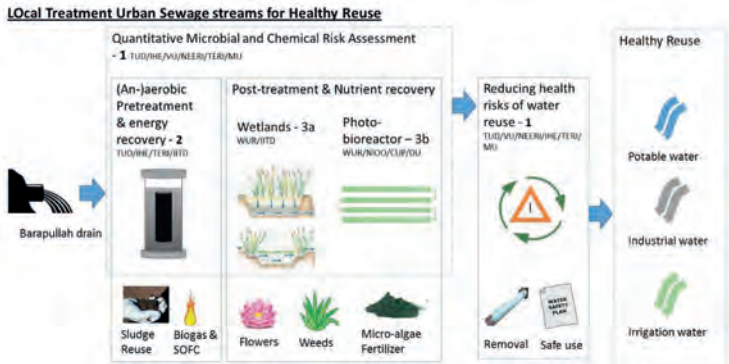
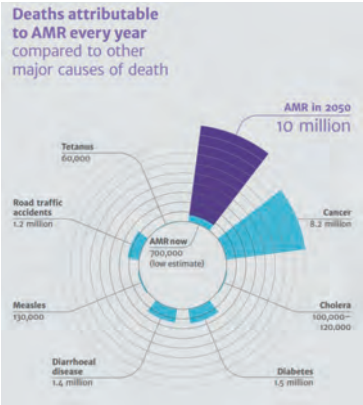


Figure: LOTUSHR treatment configuration.

OMPs, HMs, and organics. For this purpose, two tertiary technologies were pre-selected, namely O_3+GAC and Electrocoagulation, while some novel technologies are still under consideration.

Scientific relevance

Conventional WWTP have been found to be considerably incapable of dealing with emerging contaminants such as antibiotic resistant bacteria and genes. The consequences on human health of ARB and ARGs being discharged in the environment is not fully understood, yet evidence suggests that due to a process of gene exchange, environmental bacteria are also becoming resistant to antibiotics, acting as active reservoirs for resistance genes. Finding feasible ways to upgrade wastewater treatment in order to cope with this growing threat will be paramount for this research project.



Source: "Antimicrobial Resistance: Tackling a crisis for the health and wealth of nations"

Social relevance

The successful conclusion of this research will give water stressed cities like New Delhi the means to produce a valuable, all-year round source of safe reuse water, particularly during the summer high demand periods.

Literature

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Key words:
Wastewater Reuse, Health Impact Assessment, Antimicrobial resistance

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Irene Caltran

Natural Organic Matter removal from surface waters: Separation of Dissolved Organic Carbon and ions from Ion Exchange brine using Ceramic Nano Filtration

Research objectives

This research aims to:

- make a case study of the state of the art for Natural Organic Matter removal from drinking water, focusing on experiences with ion exchange in the North Sea region;
- test and upscale Nano Filtration ceramic membranes in order to treat Natural Organic Matter-rich brine. We focus in on separation mechanisms between NOM and salts, and separation between monovalent and multivalent anions

Project outline

Introduction

Natural Organic Matter (NOM) is usually present in surface water. NOM is not only the cause of odor and color problems in drinking water. It is also responsible for the majority of the demand for coagulants and disinfectants, the competition with removal of other compounds, membrane fouling, biological instability and bacterial growth and formation of disinfection by-products (DBPs) (Matilainen and Sillanpää, 2010).

In locations where fresh ground water is scarce, the removal of NOM from surface waters is one of the main challenges of drinking water companies. Therefore, many companies are performing experimental work about this subject. DOC2C's is a joint project of different West European drinking water companies and universities and has the aim to improve the NOM removal processes with research and mutual collaboration.

One of the technologies used for NOM removal is Ion Exchange (IEX). The resin used during IEX has to be periodically regenerated. From the regeneration process, there is production of brine containing salts, NOM and other ions. The disposal and the treatment of the brine can be a limiting factor for the use of IEX at a large scale (Verdickt, 2012).

Several approaches are studied in order to reduce the amount of brine to be disposed and in order to recover resources present in the IEX brine, such as water, salt and NOM.TU Delft is developing selective Ceramic Nano Filtration membranes (CNF), coated by TiO2 Atomic Layer Deposition (ALD).

The membranes will be studied in order to be applied to the IEX brine with the objective to:

- Separate the regeneration salt (e.g. NaCl) from NOM and the other ions (e.g. NO_3-, SO_4^{2}-), in order to reuse the recovered salty water in the regeneration process.
- Separate salts from NOM, in order to recover the NOM concentrate for other uses, for instance for agricultural purposes

Approach

The current techniques for NOM removal and their combinations are being inventoried, with particular attention to the drinking water companies in the European Two Channels region. The inventory includes the approach used by different water companies and their experienced challenges. Both literature research and questionnaires are used for this purpose.

IEX is a promising NOM removal technique, but the disposal of the produced brine is challenging its use. To address this problem, we investigate separation between ions (Cl- , NO3- and SO42-) and NOM by Ceramic Nano Filtration. Because of the high ionic strength of brines, we expect that steric rejection is the key for separation. Therefore, we focus on membrane pore size. For this reason, we aim to modify commercial ceramic membranes using atomic layer deposition (ALD) in order to test nanofiltration membranes of customized pore size. On laboratory scale, nanofiltration tests are performed with water prepared with different concentration of salts and NOM. On a pilot scale, nanofiltration tests will include also IEX brine from drinking water treatment plants.

Scientific relevance

The work will contribute to understand the different approaches used to remove Natural Organic Matter, and can be a basis for the choice of the most suitable Natural Organic Matter treatment technique(s) in a specific situation.

Moreover, the work will provide a performance study of the innovative Ceramic Nano Filtration membrane with Atomic Layer Deposition.

Social relevance

The inventory and the integration of the experimental work of different companies and institution can facilitate the optimization of the efforts for research on Natural Organic Matter.

Further, studies on brine treatment using Ceramic Nano Filtration will contribute to waste reduction and resource recovery in the drinking water sector.

Filtration will contribute to waste reduction and resource recovery in the drinking water sector.

Literature

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Interreg project DOC2C`s. Partners: PWNT, South West Water, De Watergroup, University of Lille

Pamela Ceron Chafla

Steering Product Formation in High-Pressure Digestion (Hi-PAD) Systems

Research objectives

This research project aims to explore the feasibility that inside the context of a biobased economy, wastewater can become an innovative source of organic "feedstocks" for the carboxylate platform. High-pressure technology, commonly applied in fields as industrial biotechnology, could act as an operational parameter to steer product formation in anaerobic systems. The underlying mechanisms (physicochemical, biological) will be studied in this project.

Project outline

Introduction

Anaerobic Digestion is a widely used and advantageous technology for wastewater treatment, since besides organic material degradation, biogas is produced (van Lier et al. 2008). Using conventional technology, the methane content reaches 50-75% (IEA Bioenergy, 2009). Previous proof-of-principle research has demonstrated the feasibility of using Autogenerative High Pressure Anaerobic Digestion (AHPD) to produce biogas with improved quality (90-95% CH_4 content) and at a pressure suitable for high-grade use (Lindeboom, 2014a). Furthermore, AHPD has also proved to produce other metabolites (carboxylates), that by themselves or through further conversion, could be interesting for the chemical industry. New insights into waste to bioproduct conversion have established that economically-attractive end-products can be obtained with mixed cultures and complex substrates (Agler et al., 2011). In this context, High Pressure Anaerobic Digestion (Hi-PAD) offers some interesting features. Based on previous work, it is expected that specific pressure effects influence the kinetics and thermodynamics of mixed culture fermentations (e.g. role of the CO_2 partial pressure). This project aims to further address these effects and determine to what extent they can be exploited to improve the fermentation yield and selectivity.

Approach

The research will focus in understanding the mechanisms for selective carboxylates production in Hi-PAD systems, initially considering the effect of elevated pCO_2 in the anaerobic conversion of simple substrates and moving forward to more complex ones. Furthermore, the requirements for process design and optimization will be unveiled.

Results

pH monitoring in Hi-PAD systems

A soft-sensor (model based in PHREEQC) has been developed to estimate the effect of pCO_2 on pH in a physicochemical system working under pressure. In the preliminary version, a basic coupling of the kinetically controlled (fermentation products) and the physicochemical equilibrium reactions is proposed. The results for propionate oxidation at pCO_2=3 bar are presented in Figure 1.

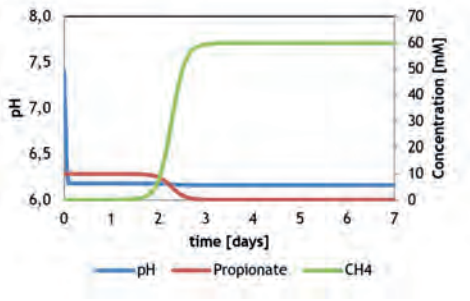

Figure 1: Propionate bioconversion effect on pH and CH_4 production modeled with PHREEQC

Effect of pCO_2 in process kinetics and product spectrum

The effect of elevating pCO_2 in substrate oxidation has been studied for an inoculum coming from an AnMBR treating food wastewater. Kinetic parameters were estimated using the modified Gompertz model (Do et al., 2008):

$$y = A \exp\left\{-\exp\left[\frac{r_{smax} * \exp(1)}{A}(\lambda - t) + 1\right]\right\}$$

The results for butyrate oxidation when the pCO_2 is elevated form 0.2 to 1 and 8 bar is presented in Figure 2. An increased lag phase as well as a decrease in the substrate uptake rate has been determined for increased pCO_2. Regarding the final product spectrum, a transition from methane to an organic acids predominance was observed.

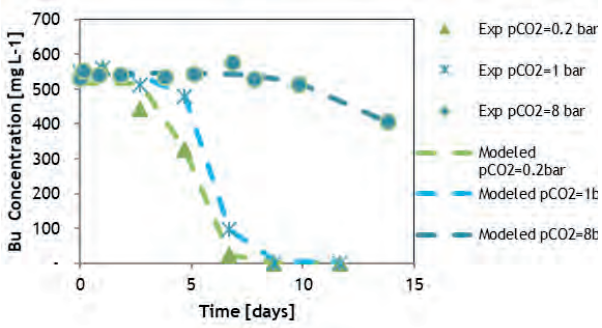

Figure 2: Effect of elevated pCO_2 in butyrate oxidation. Discrete points correspond to experimental data at 0.2, 1 and 8 bar. The fitted model (Modified Gompertz) for each of the treatments is presented in dashed lines.

Scientific relevance

HPD has been proposed as a cost-effective technology for direct biogas upgrading. However, its possible use inside the "carboxylate platform" remains as an unexploited field of study. The forthcoming results of this research will provide insights into establishing HPD as an innovative and cost-effective resource recovery technology.

Social relevance

Increased waste production is a direct consequence of population growth, so alternatives to sustainably reduce/treat them are required. Wastewater treatment has traditionally been seen as an expenditure and an environmental compliance requirement. The transition to a resource recovery/biobased economy is helping to change this perspective. This research project aims that inside this context wastewater can become an innovative source of organic "feedstocks" for the carboxylate platform.

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Key words: High Pressure, Anaerobic Digestion, Carboxylates Production, Resource Recovery, Undefined Mixed cultures

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Lihua Chen

Origination, Stabilization and De-stabilization of Microbial Ecology in Drinking Water Distribution Systems (DWDSs): Quantity, Community, Target Bacteria (opportunistic pathogens and antibiotic resistant bacteria/genes)

Research objectives

1. Investigating the origin and development of microbial communities, opportunistic pathogens and antibiotic resistance genes (ARGs) in unchlorinated and chlorinated DWDSs.
2. Investigating the de-stabilization of microbial ecology during transition effects subjected to irregular changes during events such as switching supply water quality and/or disinfection strategies.

Project outline

Introduction

The supply of safe drinking water is important to public health. The main challenge to drinking water utilities is to deliver produced drinking water to customers that is microbiologically safe and biologically stable. The treated water enters drinking water distribution systems (DWDSs) together with particles, cells, and nutrients, which subsequently contribute to biofilm formation and loose deposits accumulation during water distribution (Liu, Bakker et al. 2014). The origin and development of biofilm and loose deposits in DWDSs is, meanwhile, the accumulation process of inorganic and organic contaminants over a period of decades. In return, the release of such material accumulated in distribution system to bulk water can result in the deterioration of tap water quality, which has been commonly observed as higher turbidity and particle loads , and/or higher cell numbers, and/or greater presence of specific bacteria in tap water compared to treated water (Liu, Ling et al. 2016). Therefore, it is critical to understand the real profiles of microbial ecology in DWDSs, bring the theoretical measurement forward to practical management. Driven by the development of water purification technologies and the tighten of drinking water regulations, efforts have been made to improve the treated water quality, including: the use of alternative water sources, upgrading water purification technology at water treatment plant, and shifting of disinfection strategies. These operations constitute the causes of irregular changes in supply water quality, which might induce transition effects that disturb the stabilized microbial ecology in DWDSs. The destabilization of DWDSs microbial ecology may lead to serious water quality risks (Liu, Zhang et al. 2017), such as the water discoloration observed in large area of Beijing, China, when the supply water quality was improved in 2008 (Li, Li et al. 2010); and the recent Flint drinking water crisis in Michigan, U.S., where elevated blood lead was detected in children after water source change (Hanna-Attisha, LaChance et al. 2016). Besides, reversible shifts in microbial communities were observed after the disinfectant strategies switching from chlorination to chloramination (Wang, Proctor et al. 2014). In some emergency cases, high concentration of chlorine will be used temporarily for guaranteeing drinking water biosafety (Hou, Song et al. 2013), which might cause the destabilization of the original niche of microbial ecology in DWDSs, being worthy of attention.

Approach

1. A novel online particle sampling system (OPSS) was used to investigate the temporal variations of the suspended solids in DWDSs, which can indirectly indicate the occurrence of transition effects after irregular changes caused by source water switching.
2. Pilot set-ups including chlorinated and unchlorinated distribution loops are being built at Oasen Drinkwater to study the origin, development and destabilization of microbial community, pathogens and ARGs in DWDSs.

Results

The variations of supply water quality represented by suspended solids were monitored in real time and sensitively detected by applying OPSS (Figure 1), which indirectly indicated the extent of biofilm detachment and/or loose deposits resuspension in DWDSs. Notably, it was found that potential transition effects might occur due to the source water switching during a short term. After the long-term operations, the water quality was dramatically improved, indicating the effectiveness of the application of source water switching.

Scientific and Social relevance

Safe drinking water is a basic for human beings. This study will help us systematically understand the real profiles of microbial ecology in DWDSs, providing solid theoretical foundations to practical management, which could ultimately facilitate the guarantee of drinking water biosafety.

Figure 1: The illustration of OPSS

Literature

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Drinking water distribution systems, Microbial community, ARGs, Pathogen

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Oasen drinking water company

Mingliang Chen

Ceramic membranes modified by Chemical Vapor Deposition or Atomic Layer Deposition for oil/water emulsion separation

Research objectives

This research aims to change ceramic surface properties by means of Chemical Vapor Deposition (CVD) or Atomic Layer Deposition (ALD) method to mitigate membrane fouling in oil/water emulsion separation.

Project outline

Introduction

Due to the rapid industrial growth, such as those in oil and gas, petrochemical, food, textile, leather and metal finishing industries, vast amounts of oily wastewater are produced every day. These oil/water mixtures should be appropriately treated to meet the stringent discharging regulations. Furthermore, the explosive growth of world population and economy has resulted in greater demands for clean fresh water, freshwater scarcity is thus becoming a huge challenge for global residents, especially in certain underdeveloped countries. To address this issue, recycling oily wastewater could be considered.

Membrane technology has been developed greatly over the last 30 years due to the continuous research and development in both academia and industry (Hua et al. 2007). Additionally, membrane separations also has been introduced as an effective way to separate oily wastewater as they have higher oil removal efficiency, lower energy cost and more compact design compared with traditional techniques (Padaki et al. 2015). Recently, ceramic membranes are gaining more and more interests in oil/water separation process due to their higher permeate flux and lower membrane fouling. Compared with their polymer counterparts, ceramic membranes have higher mechanical, chemical and thermal stability, which makes them more suitable in harsh conditions (Hyun and Kim 1997). All membranes, however, suffer from serious fouling problems during filtration process, in which a layer of oil or surfactant is formed on the membrane surface or membrane pores are plugged with oil. The membrane fouling will cause a severe decrease of permeability, resulting in a lower flux or higher operating pressures. As a consequence, operating cost increase due to chemical cleaning and membrane replacement (Ebrahimi et al. 2017). Reducing membrane fouling can lead to a decrease in operating cost and an increase of ceramic membrane applications in oily wastewater treatment market.

Approach

In this study, the ceramic membranes with different pore sizes will first be modified by CVD or ALD to change membrane surface properties such as surface charge, hydrophilicity and roughness. After modification, the membrane will be characterized by porometry, SEM, water contact angle etc.. Then, both the modified membrane and pristine membrane are used for synthetic oil/water emulsion separation to evaluate their antifouling performance.

Scientific relevance

Ceramic membranes modification via CVD or ALD are well studied for water treatment and gas separation, but few research focus on oil/water emulsion separation. This study will help us understand how ceramic membrane surface charge and hydrophilicity affect membrane fouling for filtration of oil/water emulsion.

Social relevance

The antifouling ceramic membranes can improve membrane permeate flux and reduce membrane cleaning frequencies and chemicals. Thus lower energy consumption and fewer chemicals will help to reduce membrane operation cost.

Literature

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Key words:
ceramic membrane, membrane modification, Chemical vapor deposition, Atomic layer deposition, oil/water emulsion

Zhe Deng

Energy recovery from nitrogen-laden industrial wastewater using anaerobic technology

Research objectives

To develop a new alternative for nitrogen removal from industrial wastewater, we aim to recover the nitrogen as a fuel for solid oxide fuel cell (SOFC) from nitrogen-laden industrial wastewater using anaerobic technology. Instead of energy input to remove nitrogen, electricity is produced from the recovery of ammonia and methane.

Project outline

Introduction

Nitrogen (N) in wastewater is commonly considered a pollutant that potentially causes eutrophication, algal bloom, and further leads to oxygen depletion and fish toxicity in the aquatic environments. Many industries, such as N-fertilizer producers, pesticide and soybean-processing factories, as well as reject water disposal, confront the issue of discharge of N-rich wastewaters, particularly with respect to the increasingly stringent regulations on nutrient emissions.

Recently, nitrogen in the form of ammonia (NH3) has been regarded as the potential and technically feasible fuel for electricity production in SOFCs, owing to the relatively low price, the fact that it is carbon-free, and easy and safe to store and transport compared with other fuels [1,2]. NH_3-fed SOFCs are becoming a trending research topic. However, NH_3-fed SOFCs have not been considered in the area of nitrogen (N) removal from wastewaters. Nitrogen in wastewater is being regarded as a pollutant and requires energy for removal, nevertheless, with a NH_3-fed SOFC, it can be removed while producing electricity.

Conventionally, streams with both a high N concentration and high organic content, such as distillery, slaughterhouse, and fish processing wastewaters, are treated by anaerobic digestion, with the aim of producing biogas. A posttreatment is always required due to the high N concentration in the effluent [3]. The innovative idea proposed within this project is to recover both CH_4 in the biogas and NH_4+ in the effluent as energy sources, by combining anaerobic digestion with SOFC.

Approach

- fundamental understanding of the anaerobic process treating nitrogen-laden wastewaters
- detailed studies on the organic matter conversion kinetics and NH3 inhibition kinetics
- define key factors and proper indicators for the process of obtaining ammonia fuel from the anaerobic process

Scientific relevance

Current nitrogen removal methods applied in wastewater treatment plant consume significant amounts of energy, and massive studies have been done focusing on reducing the energy input [4–7]. Nonetheless, nitrogen in the reduced form, that is NH3, is a promising fuel for SOFC. Although researchers started to recognise this fact, the NH_3-fed SOFCs have not been applied in real case, nor has it been considered in the area of nitrogen removal from wastewaters.

Social relevance

By developing the new alternative, nitrogen in nitrogen-laden industrial wastewaters will be removed while no external energy is required. Instead of a pollutant, nitrogen in wastewater can be a potential fuel next to biogas.

Literature

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Key words:
Nitrogen rich inustrial wastewater, anareobic digestion

Cooperation with other institutes:
BIOTHANE

Alex Duinmeijer

Research on the mechanisms to prevent FOG layer formation in wastewater pump sumps

Research objectives

Obtaining knowledge about mechanisms of formation and degradation of debris layers in wastewater pumping stations. Knowledge will be used to adapt the current design guidelines for wastewater pump sumps.

Project outline

Introduction

Wastewater pumping stations can experience problems due to the presence of floating debris in the pump sump. This floating debris mainly consists of solidified fat, grease and oil (hereafter called FOG) and the individual particles can accumulate to a closed floating layer. The presence of FOG can result in pump failures that can result in a 16% increase of yearly volume of combined sewer overflows as shown by Korving et al. (2006) for a specific case. Moreover, the removal of the FOG is an expensive, very unhygienic and labour intensive work and should be minimized.

The current guidelines for sump design (e.g. ANSI/HI (2012)) only deal with the transport of pollution in a superficial manner for a limited number of sump geometries (i.e. trench type and circular sumps). According to the author there is a need for a more generic formulation of design guidelines which provides a balanced compromise between avoiding poor flow conditions and air-entrainment on one hand and avoiding the formation of FOG layers on the other hand. Therefore, the author has started an experimental research on mechanisms to prevent the formation of FOG layers.

Approach

The use of free-surface vortices is defined as a potential mechanism for the transport of FOG particles towards the pump suction inlet. The ability and efficiency of this mechanism is initially qualitatively studied in a real scale test facility (Duinmeijer & Clemens, 2016). Based on this research, an extensive laboratory study is conducted in a ø600 mm vortex tank, see Figure 1.

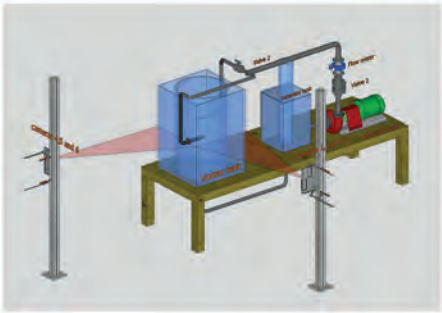

Figure 1. Schematic overview experimental vortex tank for research on the ability of the free-surface vortex as transport mechanism for FOG particles.

A theoretical vortex transport model is developed that predicts the transport ability of a vortex as function of a set of parameters. Next, the practical applicability and efficiency of a free-surface vortex is tested in real wastewater pumping stations that experiences problems with accumulation of FOG layers.

Results

Stereo PIV measurements showed that the vortex downflow is concentrated in a small radial region around the axis of symmetry with a maximum of approx. 10 to 20% of the total inflow. This is important data in understanding the behavior of a particle in the vortex flow. A novel 3D-PTV method is used to record the particle track in the vortex. The recordings of 600 experiments showed clear relations between particle transport and particle and vortex characteristics.

Scientific relevance

The experimental data from experimental and field research in wastewater pump sumps is considered essential for science-based optimized design of wastewater pumping stations. The experimental research provides insights in the flow phenomena's in wastewater sumps with respect to the accumulation of individual FOG particles into solid FOG layers and the prevention of FOG layer formation.

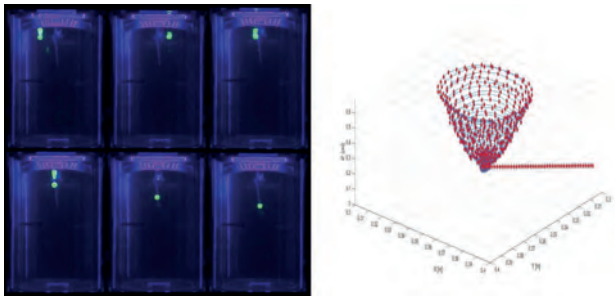

Figure 2. Left: transport of a ø38 mm sphere by the free-surface vortex. The particle travels with a helical movement towards the vortex air core and travels then along the vortex air core in downward direction. Right: computed 3D track of the sphere using the 3D-PTV method.

Social relevance

Preventing the formation of FOG layers decreases pump failures and therefore increasing the sewer system serviceability. As a result, the yearly volume of CSO spills of raw wastewater into receiving surface water bodies decreases which provides a better environmental health. Also, less pollution of pump sumps significantly decreases the annual costs for sump cleaning and pump failure repair costs.

Literature

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Key words:
Pump sump, FOG layers, vortex, experiments

Cooperation with other institutes:
Municipality of Rotterdam & Deltares

Carina Eisfeld

Plant pathogen removal by managed aquifer recharge and quantitative microbial risk assessment

Research objectives

AGRIMAR – Managed Aquifer Recharge for Agriculture

AGRIMAR is a water reclamation project in agriculture. In this project changes in water quality regarding plant pathogens after managed aquifer recharge (MAR) treatment are investigated. The transport processes of plant pathogenic bacteria will be identified to predict their fate during soil passage in the MAR system and to assess microbial risks related to recycling of water used in irrigation.

AGRIMAR provides a self-supplying freshwater resource for farmers. Tile drainage water (TDW) is reclaimed for the storage in a managed aquifer recharge (MAR) system from where it can be used for irrigation in times of drought.

Project outline

Introduction

AGRIMAR investigates MAR technology that collects fresh tile drainage water (TDW) for storage in brackish aquifers in times of precipitation surplus, and retrieves it in summer for crop irrigation (Fig. 1). It serves as a self supplying freshwater resource for farmers. The system is based on aquifer storage, transfer and recovery where water is injected into a well for storage and recovered from a different well. The soil passage between both wells provides a natural water treatment step.

The TDW may be contaminated with surface water and contain plant pathogens which could be present in the recycled water. To prevent the spread of crop diseases by contaminated irrigation water the survival of selected plant pathogens in the MAR system will be studied. We focus on three plant pathogenic bacteria, namely Ralstonia solanacearum (RS; wilt), Dickeya solina (DS; blackleg), and Pectobacterium carotovorum (PC; soft rot, blackleg) which are of high ecological and economical importance.

The AGRIMAR research is conducted by two PhD studies. My PhD research is focussed on microbiological water quality treatment during agricultural MAR. I work in close collaboration with Emiel Kruisdijk (the second PhD in the AGRIMAR research). Emiel's research is focused on the geochemical field characterization (including push-pull tests), regional MAR assessment and reactive transport modelling.

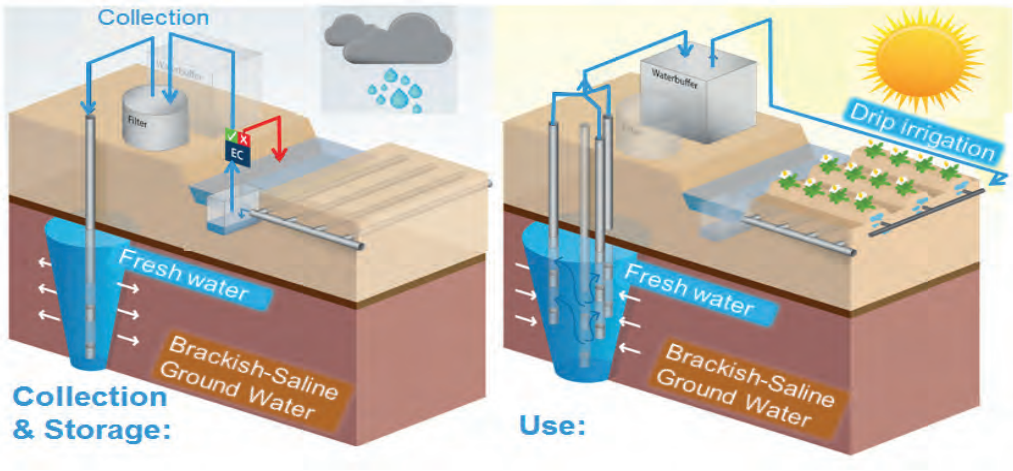

Figure 1 MAR technology: Tile drainage water (TDW) is collected and stored (left) in the underlying sandy aquifer confined by clay (the hydrogeological situation in the region). In times of water needs (summer), the stored water is used for irrigation (right).

Approach

First, the pathogen fate will be studied in the lab with batch and column experiments, where the conditions of the aquifer will be simulated. The results of the bacterial survival will be used to model the die-off of the bacteria in saturated sediments using HYDRUS-1D and to predict their fate in the aquifer. Second, the removal of bacteria will be studied under field conditions at the new MAR pilot site in Breezand in the Netherlands. These results will be compared with the model predictions. To determine the risk MAR-treated water could pose for agriculture quantitative microbial risk assessment (QMRA) will be used. This includes dose-response experiments of the bacteria with susceptible plants to identify the acceptable risk level of plant pathogens in irrigation water.

Scientific relevance

Transport processes in the soil are well studied for human pathogens but few is known about the transport and survival of plant pathogens. For the first time, transport process parameter estimation for plant pathogens in saturated sediments will be assessed. The results of the lab and field experiments combined with QMRA will show if MAR is a feasible technology to provide safe (contaminant free) irrigation water.

Social relevance

Freshwater is a scarce resource, especially in saline deltas like the Netherlands where brackish groundwater prevails. Agriculture is the biggest water consumer accounting for 70-80 % of the total water use worldwide.

AGRIMAR proposes a local MAR system to secure fresh water with good water quality for agriculture. Therefore, the project faces a worldwide problem and we try to determine the conditions (QMRA) needed to apply the system for various environmental conditions. By providing pathogen free irrigation the spread of plant diseases will be reduced and loss of food crops is prevented.

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Start date project: Oct 2014
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Key words:
Pump sump, FOG layers, vortex, experiments

Cooperation with other institutes:
Municipality of Rotterdam & Deltares

Astrid Fischer

Managing chemicals of emerging concern in the water cycle

Research objectives

The aim of this PhD is to develop a coherent understanding of the issue of chemicals of emerging concern (CECs) in the water cycle, by addressing the problem in a in a multidisciplinary way.

Project outline

Introduction

Water authorities responsible for the quality of the surface water and drinking water companies using the surface water for their production are challenged with the question if, where and how to abate the CECs in the urban water cycle. The most effective strategy under given conditions is often unclear to these stakeholders as it requires insight into several aspects of the contaminants such as sources, properties, and mitigation options. Furthermore the various parties in the urban water cycle such as water boards, drinking water companies, industry, agriculture, and the public are not always aware of each other's requirements and priorities. Processes to set priorities and come to agreements are lacking, hampering the articulation and implementation of possible solutions. At the moment the information is there, but it is scattered within various scientific fields. These fields include but are not limited to; (micro)biology, organic chemistry, (eco)toxicology, civil and chemical engineering, law and environmental policy. Much of this information has not yet been brought together and set in context of other relevant fields. An overview is missing that can enable new insights.

Approach

To solve the problem of dispersed information and a lack of overview, the Interreg project TAPES (Transnational Action Programme on Emerging Substances) was established. The aim of TAPES was to create a joint knowledge platform on CECs in the urban water cycle. As part of this knowledge platform a Decision Support System (DSS) was developed in strong cooperation with stakeholders within the whole water cycle. The DSS was developed to serve as a point of departure for getting the relevant stakeholders together and finding common ground. Stakeholders were interviewed to identify their requirements and expectations for the DSS. The overall conclusion from the interviews was that the stakeholders had sufficient information on CECs, but that the relevance of the information often was unknown. The main issues mentioned were:

1. Emerging substances in water
   a. Sources
   b. Are there adverse effects on human health, the ecosystem or susceptible functions of the water system
2. Possible mitigation measures
   a. Choice of measure, eg. removal efficiencies and costs
   b. Location of the measure (if relevant)

Results

To address the issues outlined above it was therefore decided to focus on environmental fate, decentral mitigation options, central mitigation options, legal frameworks and (eco)toxicology, as these were seen as the most relevant when trying to answer the question whether and where to abate these substances in the water cycle. The DSS will give the user information on the source, pathway, chemical characteristics and (eco) toxicity of individual emerging substances, together with information on the efficiency of water treatment technologies for drinking and wastewater. Also decentral technical and non-technical mitigation methods were included, as requested by a part of the stakeholders (Figure 1).

Besides filling the DSS the information gathered will be used to create a coherent understanding of CECs in the water cycle by exploring what (new) insights can be gained from addressing the issue of chemicals of emerging concern in the water cycle in a multidisciplinary way, by looking at environmental fate, decentral mitigation options, central mitigation options, legal frameworks and (eco)toxicology all together.

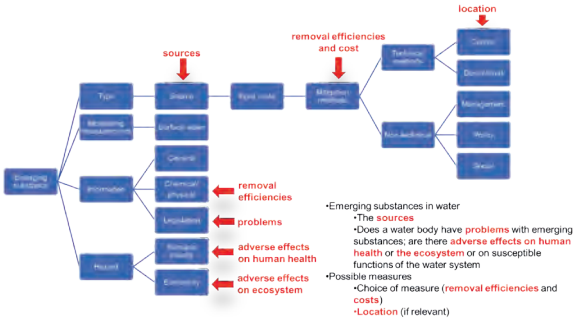

Figure 1. Diagram of information included in the DSS.

Scientific and social relevance

The DSS and the produced papers aims to be the link between the scientific knowledge available and the people that need to use this not always easily accessible knowledge in their daily work to make better and more informed decisions. As such it is not only scientifically relevant, but it is actively making science relevant outside the scientific community, which is its social relevance.

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Key words:
Emerging substances, water treatment techniques, water cycle

Cooperation with other institutes:
KWR, Waternet, Waterschap De Dommel, TZW, VITO, De Watergroep, FHNW

Mingyan Fu

Regeneration of granular zeolites saturated with organic micropollutants

Research objectives

The objective of AdOx project is to realize an innovative adsorption – oxidation process for the removal of organic micropollutants (OMPs) from municipal wastewater. Zeolites are used as an adsorbent and the saturated zeolites are regenerated with ozone. The goal of the project is a new OMPs' removal technology, characterized by high removal efficiencies, low costs, and low environmental impacts.

The AdOx research consists of two parts: adsorption and regeneration. My PhD research is focused on the second part, oxidation regeneration of saturated granular zeolites. The objective of my research is to find out the optimized operational conditions of the oxidation regeneration processes and scale up this promising technology in practical utilization. The first part, adsorption of OMPs on granular zeolites, is conducted by Marij Zwart (the other PhD candidate in the AdOx project).

Project outline

Introduction

Organic micropollutants (OMPs) end up in aquatic compartments, such as surface water, ground water and even drinking water, at concentrations in low level between few ng/L and several µg/L. They have a negative impact on water quality and environment. OMPs can be natural or anthropogenic substances such as pesticides, industrial compounds, pharmaceuticals, person care products, steroid hormones, drugs of abuse and others. The effluents of municipal wastewater treatment plants (WWTPs) are an important way for the discharge of especially pharmaceuticals into surface water. However, most of the conventional WWTPs are not designed to eliminate OMPs at low concentrations, making the treatment processes not an effective barrier.

Adsorption is a widely used separation process and can be used for the removal of a broad range of organic and inorganic pollutants from water. In the last decades, zeolites have been evaluated as one of the alternative adsorbents for OMPs' removal from wastewater. Zeolites are porous crystalline aluminosilicates with various frameworks formed by SiO4 and AlO4 tetrahedrons connected by oxygen atoms. These crystalline structures have a uniform pore size, making zeolites different from other microporous adsorbents. Pore sizes are in the range of a few Å, allowing small molecules to enter the solid frame and excluding large molecules, thus making zeolites selective adsorbents.

However, as a separation process, adsorption cannot degrade pollutants to harmless substances. Furthermore, the adsorbent has a limited adsorption capacity and needs to be regenerated or renewed when saturated after a certain operational period. The most applied regeneration method for activated carbon is thermal calcination under low oxygen conditions. For this the granular activated carbon is transported to a factory. An important advantage of zeolites is the possible on-site regeneration by a strong oxidant like ozon.

Approach

The research is divided into four parts.

1. Investigate the oxidation rate of OMPs adsorbed on granular zeolites Ozonation regeneration column tests will be conducted both in water phase and gas phase.

2. Investigate the regeneration performance of granular zeolites in long-term operation
   Find out the adsorption capacity recovery after each regeneration cycle.

3. Compare with other oxidation methods for regeneration of granular zeolites The other oxidation methods include ozone with hydrogen peroxide and Fenton-like reactions. Find out the difference between the oxidation methods.

4. Determine which type of reactor is suited for an on-site regeneration processes The performance of fixed-bed reactor and fluidized-bed reactor will be investigated.

Scientific relevance

The degradation of OMPs has been found to be enhanced by the combined use of ozone and zeolites. However, there are rarely full-scale industrial applications due to not enough understanding of the process. Moreover, the role of zeolites as a catalyst is also not clear. The AdOx project will provide information about regeneration kinetics and efficiency with zeolites in packed bed or fluidized bed conditions.

Social relevance

The increasing use of chemicals along with growing populations and increasing urbanization pose new challenges to wastewater treatment that are not met by conventional WWTPs. The 'Memorandum of Understanding Delta-approach Water Quality and Fresh Water' signed on 16th November 2016 mentioned the removal of OMPs from secondary effluent as one of the realistic options. The AdOx process can effectively and selectively remove the OMPs from wastewater and may have a low environmental impact and low costs.

Literature

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Figure 1. Ozonation regeneration set-up

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Organic micropollutants (OMPs), oxidation regeneration, granular zeolites, municipal wastewater

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Waternet, Waterschap De Dommel, Hoogheemraadschap Rijnland, Hoogheemraadschap Delfland, Witteveen + Bos, Xylem Water Solutions

Victor Servando Garcia Rea

Treatment of phenolic wastewater in AnMBR under extreme conditions: BioXtreme-following up

Research objectives

This research aims to analyze the biological degradation process of phenol, p-cresol, and resorcinol in saline anaerobic membrane bioreactors (AnMBR) under mesophilic and thermophilic conditions.

This PhD project is part of the BioXtreme project, which its goal is to understand the treatment of chemical wastewaters under extreme conditions by AnMBR technology to show the potential of this technology to cope with industrial/chemical wastewaters.

Project outline

Introduction

Rapid industrialization resulted in the generation of a large quantity of industrial wastewater (Shao et al. 2006; Ozgun et al. 2013). These include food processing, pulp and paper, textile, chemical, pharmaceutical, petroleum tannery, and manufacturing industries (Lin et al. 2013) among others. These wastewaters present a challenge for the conventional biological treatment methods because of their extreme characteristics such as high organic strength, high toxicity, high temperature, and high salinity (van Lier et al. 2001).

It is in this niche in which the Bio-Xtreme project enters, having the goal of developing mesophilic and thermophilic anaerobic membrane (AnMBR) treatment technology for wastewater with high concentrations of salt and aromatics. The project targets the urgent need for sustainable and cost-effective treatment of these types of wastewaters making them suitable for reuse (van Lier 2013) (Figure 1).

An AnMBR can be defined as a biological treatment process operated without oxygen and using a membrane to provide solid-liquid separation (Lin et al. 2013). In an AnMBR, biomass can be effectively retained inside the reactor providing optimal conditions for organic matter degradation without any carry-over of suspended solids (SS). By incorporating membranes to anaerobic wastewater treatment, superior effluent quality regarding chemical oxygen demand (COD), suspended solids and pathogen count can be achieved in comparison with conventional anaerobic processes, and a stable treatment performance can be obtained to meet stringent discharge standards (Ozgun et al. 2013)

Approach

Four AnMBRs will be used for the experimental approach. Synthetic wastewater containing phenol and phenolic compounds are used as a model for the toxic degradation research, different variables such as cosubstrate dosage, high temperature, high sodium concentration, or a mixture of phenolic compounds are being tested.

Results

Cosubstrate effect on the phenol conversion rate has been determined, as well as the effect of thermophilic (55 °C) operation. Effect of high sodium concentration is being researched currently, and in the coming months, the degradation of a phenolic mixture under saline conditions will be studied.

Scientific relevance

This study will help to understand the degradation process of chemical wastewaters in AnMBRs. Currently, AnMBRs are not fully applied for the treatment of industrial or recalcitrant wastewaters, so more research is needed to be done to assess the AnMBR like an appropriate technology for the treatment of this kind of effluents.

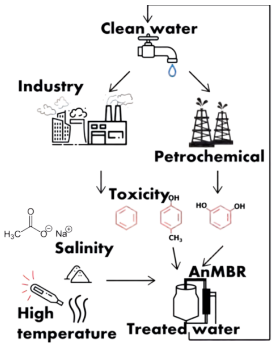

Figure 1. Use of AnMBRs towards closed water loops in industrial processes.

Social relevance

Every day tons of toxic wastewaters are generated and discharged (a great percentage without treating) all over the world, which is a major concern because of their environmental impact. If an adequate performance of AnMBR is achieved, a breakthrough for the chemical wastewater treatment will be delivered helping to reduce the water footprint and presenting a very viable option for closing water cycles.

Literature

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BioXtreme
AnMBR for chemical wastewater treatment

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Key words:
Anaerobic membrane bioreactor, BioXtreme, phenol, phenolics, thermophilic, high salinity

Marieke de Goede

Broadening and renewal of the Dutch drinking water benchmark

Research objectives

This study is initiated to develop a framework to broaden and renew the Dutch drinking water benchmark. The benchmark can be broadened by adding new subjects to it. The idea is that adding new subjects will push organizations to learn and improve on these subjects leading to improvement of the drinking water supply sector. The research develops a framework that decides on adding new themes and deleting "exhausted" themes.

Project outline

Introduction

Benchmarking is a management instrument for performance comparison. In the drinking water sector it serves two goals. On the one hand improvement of the performances of the water supply companies and on the other hand it is a form of accountability for the sector (ILT 2012). The drinking water benchmark is first executed over the year 1997. Since then, the productivity of the drinking water supply sector has significantly improved (Dumaij and van Heezik 2012).

Approach

First an evaluation of the current drinking water benchmark is executed to get an overview of the effects of the Dutch drinking water benchmark. This evaluation is performed by literature research and interviews with the Dutch drinking water companies. Based on this evaluation a framework will be designed to make the benchmark fit for the future.

Results

When the drinking water benchmark is made fit for the future, with the use of the framework, the negative effects of the current benchmark are expected to be solved:

- The current drinking water benchmark has two goals: improvement and justification. If a benchmark serves two goals, organizations can become too focused on showing that there level of performance is sufficient that the improvement objective is under pressure (de Bruijn 2002).
- Benchmarking can slow down innovation: innovation means exploring of the unknown. Innovation increases the risk that the results are lower than expected. Benchmarking rewards reproduction of the known.
- The learning effect from the Dutch drinking water benchmark seems to be decreased. While productivity grew between 2000 and 2008, currently the growth stopped, as can be seen in Figure 1.
- Variations in performances between drinking water supply organizations have decreased. Because of small variation, there is less differentiation between good and bad performance. This makes the impact and learning effect of the benchmark smaller (van Helden and Brouwer 2005).
- Participating in the benchmark became mandatory in 2012. When performance measurements become mandatory the chances of undesired effects (i.e. strategic behavior) increase. The measures become targets and as Goodhart's law explains: 'When a measure becomes a target, it ceases to be a good measure'.
- The Dutch drinking water benchmark only has attention for the short term, and does not focus on long term plans of organizations.

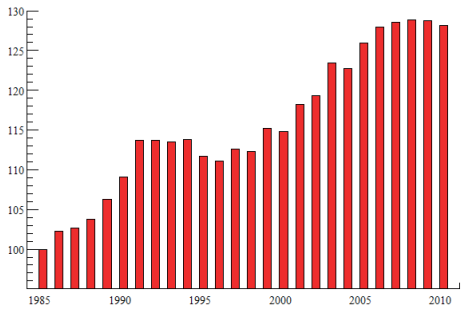

Figure 1. Productivity index numbers of drinking water

Further research plan

The goal to make the benchmark fit for the future requires that themes that are benchmarked should be able to change, because the future changes and some themes lose impact and get exhausted. Besides future developments and consumer preferences, also "sudden events" will be incorporated as in input variable. The research is framed along six specific research questions:

- How can a benchmark be made fit for the future?
- How can consumer preferences be integrated in a benchmark?
- how can "sudden events" be translated into a benchmark?
- What should a framework – that integrates future changes and "sudden event", that decide on adding new themes and deleting "exhausted" themes and that incorporate consumer preferences – look like?
- What are the effects of application of the framework?
- How does the designed framework fits in the current governance structure of the Dutch water sector?

Social relevance

Improvement of the Dutch drinking water benchmark should lead to improvement of the drinking water supply sector. Making the benchmark fit for the future will lead to a situation where drinking water organizations are learning from each other again. This is expected to improve their performance on the subjects which fit with the changed environment the drinking water companies operate in. Good performance on these subjects is expected to improve the overall performance of these organizations.

Literature

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Key words:
Drinking water benchmark, risk management, assets management, innovation, sustainability, water cycle, future orientation

Cooperation with other institutes:
VEWIN, Oasen, PWN, Waternet

Adrian Gonzalez Ortega

Maximisation of energy recovery from sewage sludge with an innovative digestion process

Research objectives

1) to unravel the composition of the non-degraded fraction of waste activated sludge (WAS) after pre-treatment and anaerobic digestion; 2) to devise a method to increase WAS digestibility and to improve the quality of digestate.

Project outline

Introduction

WAS is produced at 60-90 g dry solids per day per person-equivalent (Appels et al., 2008) and consists of proteins, humic substances, carbohydrates and microorganisms. It also contains pathogens inorganic matter and heavy metals, therefore, it is a threat for both human and environmental health and needs to be disposed off safely. The most common method to stabilize WAS prior to dewatering and final disposal is via anaerobic digestion (AD), which results into volume reduction and methane production. However, AD requires a long solids residence time (SRT) of 20-30 days, while a low yield of COD to CH4 conversion is reached (Nielsen et al., 2011).

In order to increase the methane production during the anaerobic digestion of WAS, several sludge pre-treatment techniques (e.g. thermal, chemical, ultrasonic) have been studied and applied. Pre-treatments usually increase the WAS biodegradability, however it is not clear which parts are especially affected during pre-treatment and during AD and which substances remain unaffected. In addition, other properties such as dewatering and hygienization are seldom assessed.

Approach

1. Literature review to grasp the mechanisms and limitations of pre-treatment techniques and to select the best pre-treatment in terms of energy balance. The ideal pre-treatment technique implies not only a high methane production but also improvements in dewaterability and reduction of pathogens in digestate.
2. Use laboratory grown WAS in different pre-treatment experiments to keep track of the variation of its components after pre-treatment and AD.
3. Characterisation of the non-degraded fraction and to devise strategies for its degradation.
4. Scaling-up considering the variable composition of real WAS.

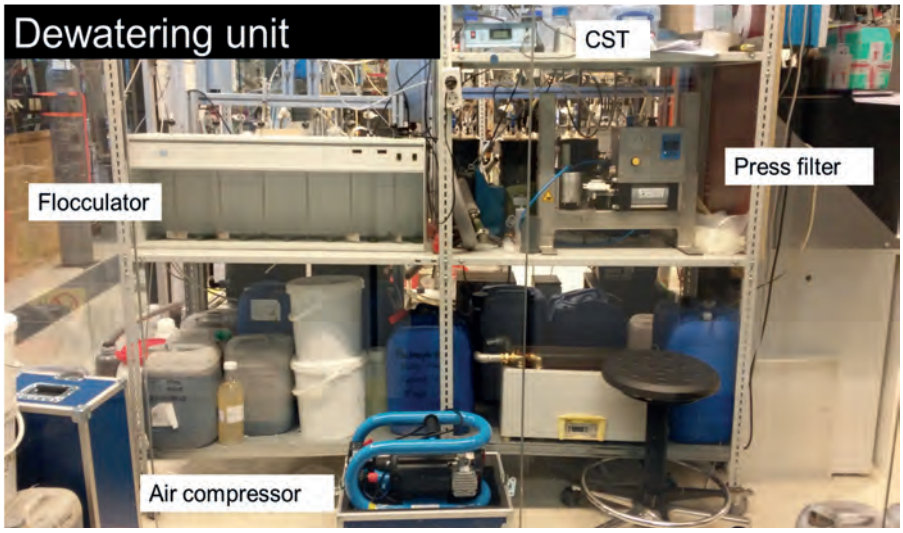

Figure 1. Diverse devices for the measurement of dewaterability of digestate

Results

- Literature review about pre-treatments (in progress) listing the effects of several pre-treatments in the main components of WAS (proteins, carbohydrates, humic substances, cells and combinations among them) and trying to explain the often-encountered contradictory results in literature (Gonzalez et al., 2018).
- An experiment was performed to exchange monovalent and divalent cations to lose the flocs of WAS. The sludge degraded faster but did not produce more methane.
- Thermochemical pre-treatment was able to significantly increase the production of methane; results for dewaterability and reduction of pathogens is in progress. This treatment method will be further studied and optimised within this project.

Scientific relevance

Focus on the analysis of the non-degraded part after application of both pretreatment and AD and assessment of relevant properties of sludge: methane production, dewaterability and reduction of pathogens.

Social relevance

Costs for WAS disposal determines to a large extent the economy of a sewage treatment plant (STP). In the Netherlands, where incineration is the sole option, the total costs are between €150-200 million per year. Any improvement in AD efficiency by means of pre-treatment will lead to a further reduction of sludge for disposal (Devlin et al., 2011) and in lower cost for the taxpayers.

Literature

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Key words:
Waste Activated Sludge, pre-treatment, anaerobic digestion, methane production

Cooperation with other institutes:
Royal Haskoning DHV B.V.

Bayardo Gonzalez Rodriguez

Arsenic Removal for Drinking Water Treatment in Nicaraguan Rural Communities

Research objectives

The aim of this research is to enhance fundamental understanding of As(III) and As(V) removal by NF membranes. These finding will be used to develop an effective and affordable NF treatment system driven by Human and Solar power for the removal of arsenic in groundwater for rural communities and small towns in Nicaragua.

Project outline

Introduction

Water ingestion with high concentrations of Arsenic (As), leads to greater cancer risk than any other common water contaminant. (Smith AH et al, 2007). In Nicaragua, a volcanic country in Central America, drinking water sources are influenced by geothermal waters - particularly in rural areas. As a result, rural communities are exposed to elevated arsenic concentrations (up to 900 µg As/L). The World Health Organization (WHO) has recommended a provisional guideline for safe drinking water of 10µg As/l. A clean and safe drinking water supply is a basic human right that is being denied to poor and rural communities affected by arsenic poisoning and a limited access to water.

Figure 1 Keratosis caused by ingestion of water with arsenic to a resident of the community of El Zapote (Alina Gomez, 1996)

Approach

In the first PhD year, the aim was to gather all the available information related to arsenic in Nicaragua. This information is scattered in different institutions (e.g., the Nicaraguan Institute of Aqueducts and Sewers, Ministry of Health, etc.). The second step consists in locating arsenic affected communities and determine As concentration, As speciation, As source, as well as measuring the chemical and physical composition of water. This baseline study allowed for a smart design of experimental procedures for the laboratory experiments to be executed in the Netherlands. In this stage, a pilot research is currently ongoing to investigate the effect of elevated temperatures (50 degrees!) on the performance of low-pressure NF membranes for arsenic rejection. The pilot is built in the western part of Nicaragua, in the municipality of Telica. The shallow alluvial aquifer of this area is influenced by the hot fluids associated with active geothermal waters located in the volcanic chain of “Los Maribios”.located in the volcanic chain of “Los Maribios”.

Figure 2 Testing an NF pilot plant for arsenic removal in a rural community in Nicaragua.

Scientific relevance

Nanofiltration (NF) membranes have proved to be reliable in removing arsenic species from water over a wide range of operational conditions. Furthermore NF is a promising technology for arsenic removal since it requires less energy than traditional reverse osmosis membranes. However the biggest challenges ahead lie in applying the technologies in poor and rural communities. Therefore is a need for systematic investigation of the use of NF membranes for small scale systems.

Social relevance

In Nicaragua the knowledge of arsenic removal systems comes from the research performed by local universities or NGOs working with water and sanitation. Despite the great efforts of the universities and NGOs, there is still very little hands-on experience with arsenic removal. For this reason, it can be said that this first and long-term study is aimed at evaluating, adapting and developing arsenic removal systems so they can be used at a local level. By combining scientific inquiry with a concern for social welfare, this study will be useful as a document of reference in universities, research centers on water resources, NGOs and institutions working on water supply projects or managing this service at a private or public level.

The Director of UNICEF in Nicaragua, Philippe Barragne-Bigot, who a few years ago led several research related to arsenic problems in rural communities in Nicaragua, recently defined arsenic as a forgotten deadly threat. Therefore, this study will be of great help to understand the real reach of the arsenic problem in Nicaragua.

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Start date project: Jun 2014
Expected end date: Jun 2018

Key words:
Arsenic, removal, groundwater, geothermal waters,Nanofiltration

Cooperation with other institutes:
The National Water Authority (ANA), Nicaragua

Jink Gude

Understanding arsenic mobility for smart fixation during drinking water treatment

Research objectives

- Understanding arsenic redox behavior and arsenic adsorption.
- Developing a water quality model for arsenic removal during groundwater treatment.
- Optimizing arsenic removal in groundwater treatment plants by adjusting operational parameters and/or adding natural groundwater components.

Project outline

Introduction

Arsenic removal is extensively researched because intake of arsenic can lead to skin disease, cancer, kidney heart failure and diabetes and paralysis. WHO guidelines on arsenic are 10 µg/l, but drinking water companies in the Netherlands recently set a new target value, arsenic concentrations smaller than 1 µg/L, to eliminate every health risk.

Expensive and invasive methods for complete arsenic removal exist. However, more elegant solutions for this concentration range are yet to be investigated for existing groundwater treatment plants. Current practices for arsenic removal include reverse osmosis, which has excellent arsenic retention, but such an installation is expensive for the removal of few micrograms of arsenic. The same is valid for building a polishing step that can be applied by passing the water through adsorptive media or ion-exchange resins. More realistic options are the use of strong oxidants in combination with coagulants like ferric chloride to adsorb all arsenic. However the use of these chemicals must be accompanied with extensive safety measures.

This research project will develop alternative solutions for smart fixation of arsenic to concentrations below 1 µg/L without expensive installations and 'dangerous' chemicals. Preferably natural components will be added before or during treatment to minimize cost, making large adjustments to the treatment schemes obsolete and do not compromise the stability of the groundwater.

Approach

The focus of the research will be to understand the natural arsenic removal capacity of groundwater treatment plants during (1) abstraction/mixing, (2) aeration, (3) short storage, and (4) sand filtration.

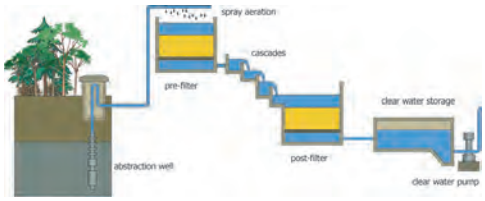

Figure 1. Typical groundwater treatment set-up in the Netherlands

For this purpose, extensive measurements in 3 typical groundwater treatment plants were executed. The measurements included typical groundwater parameters, but also arsenic speciation, analysis of filter sand coatings, backwash water and supernatant water experiments. A graphical abstract of the findings is shown in Figure 2. The results of these measurements are published and unravel the major aspects and mechanisms of arsenic oxidation and adsorption during groundwater treatment.

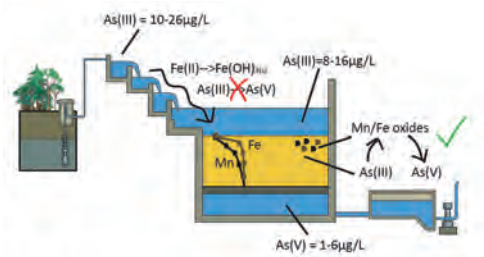

Figure 2. Arsenic mobility during full-scale aeration and rapid sand filtration

Results from extensive jar test with arsenic, iron and manganese are being interpreted. Subsequently batch reactors and column tests will be used to further investigate reaction kinetics under controlled, isolated conditions. Based on the results of the previous steps a model for kinetic arsenic behavior during oxidation, precipitation and adsorption reactions will be developed.

Scientific relevance

Most detailed arsenic related studies are executed by geochemists and are concerning arsenic processes on an infinite time scale in the soil. In these studies the focus lies on equilibrium reactions, rather than kinetics. Existing arsenic removal studies are focussed on removal of moderate to high arsenic concentrations in groundwater containing low iron. Virtually no research has been done on arsenic oxidation and adsorption behavior at very low concentrations in a natural groundwater matrix. The aim of this research project is to develop a model that will predict arsenic oxidation, precipitation and adsorption processes during groundwater treatment.

Social relevance

The best drinking water for a reasonable price is the ambition of every drinking water company. Arsenic is a substance that even at low concentrations is now considered for removal, but not at all cost. By understanding the detailed mechanisms of arsenic removal at low concentrations, we are developing new, elegant technologies to assure safe water.

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Key words:
Arsenic removal, low concentrations

Noor Gulamussen

Potentials of sewage water reclamation for industrial use in Maputo, Mozambique

Research objectives

Perform a literature review focusing on water reclamation for industrial applications in sub-Saharan Africa.Develop a comprehensive assessment of environmental and technical conditions, where the main gaps, opportunities and priorities for water reclamation projects are identified and valued. Identify water requirement for industries in Maputo. Develop appropriate technologies for wastewater treatment and water reclamation in those industries. Test the selected technologies.

Project outline

Introduction

Water is a critical natural resource that is becoming progressively scarce mainly due to increasing demand as a result of high population, economic growth and climate change (Schewe et al., 2014; United Nations, 2015). Serious water shortages and stricter regulations on wastewater discharge increase the interest in water reclamation worldwide (Rietveld, Norton-Brandão et al. 2011). On the other hand, the potential for resource recovery from wastewater and sludge is largely untapped and in developing countries only a small portion of wastewater is used in a planned and safe manner, while the majority remains untreated or partially treated, and is more commonly used in the unregulated than formal irrigation sector (Wichelns, Drechsel et al. 2015). Compared to surface water, reclaimed wastewater can be a more attractive source, because of low fluctuations of water quality and its abundant availability (Van Agtmaal, de Boks et al. 2007). The planning for water reuse is crucial for sustainable water resource management as it can constitute an essential component of local efforts to optimize water use and reduce the water shortage (Wichelns, Drechsel et al. 2015). This project will identify and evaluate technological and socio-economic options for water reclamation for industrial use in sub-Saharan countries – the case of Maputo, Mozambique.

Approach

In this project a mixed methods approach of qualitative and quantitative research is used. First a literature review on water reclamation for industrial use in sub-Saharan Africa was conducted to derive lessons for implementation of industrial water reclamation projects in Sub-Saharan Africa. The City Blue Print approach will be adapted to identify the main gaps, opportunities and priorities for water reclamation projects and value them.

Finally, some industrial applications of the case study will be concept proved with laboratory test and pilot test

Results

Findings from the literature review show that extensive experience exists in technology and management practices that can allow successful implementation of water reclamation projects in sub-Saharan Africa. Under the conditions of deficient sanitation services and low levels of technical expertise, the main challenge is to develop a framework that can facilitate the integration of social and technological methodologies and help to introduce water reclamation in water allocation planning, including the development of specific legislation for industrial water use and disposal.

The preliminary results of City Blue Print assessment indicate that the geometric average of the 25 City Blueprint indicators, i.e. the Blue City Index, for Maputo was 1.8. Sanitation infrastructure and waste water treatment are key priorities as almost 90% of the city's population rely on on-site sanitation and less than 20% of the generated wastewater is treated at a central treatment plant. The city's industry is relatively close to sewage water sources which is an opportunity to reclaim wastewater for purposes that require less stringent water quality such as cooling processes. With this, it can be concluded that the potential savings in water consumption and overall costs, may pose a promising solution to increase Maputo's water sustainability.

Identified application for use of water reclamation in construction industry indicate from pilot tests that the effluent from wastewater treatment plant in Maputo could potentially be a source for concrete production, when sufficiently treated and disinfected, to minimize health risks

Scientific relevance

The project will contribute on new approaches and technologies in planning and design of wastewater treatment systems in the context of sub-Saharan countries by developing:

Novel conceptual models for implementation of water reclamation in industry The concept of "water-fit-for-use" that will result in a matrix tool linking raw water quality, required water quality and possible (scalable) water treatment technologies.

Social relevance

This approach will reduce the pressure on the limited water resources and increase the total available water supply for domestic use. It will also create driving forces for appropriate sanitation services. A direct impact of this project will be the reduction of nutrients and other pollutants entering waterways and the preservation of wetlands and sensitive marine ecosystems, reducing also health risks in touristic areas

Literature

Rietveld, L., et al. (2011). "Possibilities for reuse of treated domestic wastewater in The Netherlands." Water Science and Technology 64(7):1540.

Schewe, J., et al. (2014). "Multimodel assessment of water scarcity under climate change." Proceedings of the National Academy of Sciences 111(9): 3245-3250.

United Nations. (2015). Water for a sustainable world. World water report

Van Agtmaal, J., et al. (2007). "Evaluation of feed water sources and retrofitting of an Integrated Membrane System." IWA, Antwerpen: 1.

Wichelns, D., et al. (2015). Wastewater: Economic Asset in an Urbanizing World. Wastewater, Springer: 3-14

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Key words:
Water reclamation, Industry, Maputo

Cooperation with other institutes:
Edusrdo Mondlane University

Hongxiao Guo

Cascade system concept to enhance hydrolysis rate in anaerobic digestion of waste activated sludge

Research objectives

To investigate the cascade principle on the hydrolysis rate in anaerobic sludge digestion and subsequent reactor performance in comparison with conventional continuous stirred tank reactors (CSTR) in waste activated sludge treatment.

Project outline

Introduction

Waste activated sludge (WAS) is an inevitable by-product generated in biological wastewater treatment plant. Anaerobic digestion (AD) is an established technology for the treatment of WAS from the standpoint of organics reduction and energy recovery. Hydrolysis of (large) particulate organics to simpler derivatives is generally recognized as the rate-limiting step in the WAS digestion. Hydrolysis occurs mainly via microbial hydrolytic enzymatic reactions, which is dependent on the substrate concentration following Michaelis-Menten kinetics [1]. In general, increasing the substrate concentration could accelerate the enzymatic reaction. In the generally applied CSTR reactors, which are operated at retentions times between 20-28 days, the non-hydrolysed substrate concentration is very low. Increased substrate concentrations (non-hydrolysed WAS) can be attained by applying plug-flow conditions. Based on this theory, a novel cascade anaerobic digestion system, using CSTRs in series, was proposed for WAS treatment. The objective of the research is to establish a cascade system with an overall solids retention time (SRT) less than the SRT in a comparative CSTR system.

Approach

The cascade AD system comprised three 2.2 L CSTRs (R1-3) and a 15.4 L CSTR (R4). A sludge recirculation system from reactor 3 to 1 was implemented with the recycle/feeding ratio of 10%. In parallel, there was a conventional CSTR with the working volume of 22 L as the reference. Both systems were run at 35 ± 1 °C and overall HRT of 22 days.

TCOD was measured with test kit (Hach, USA). Biogas composition was measured using gas chromatography (7890A, Agilent, USA). Daily biogas volume produced was measured with a gas flowmeter (Ritter, Germany). Hydrolysis rate was calculated by the modified equation based on [2]:

$$\text{Hydrolysis rate (g COD L}^{-1}\cdot\text{day}^{-1}) = \frac{\left(\frac{\text{massSCOD} + \text{massCOD}_{CH_4}}{\text{day}}\right)_{eff.} - \left(\frac{\text{massSCOD} - \text{massVFA}}{\text{day}}\right)_{inf.}}{\text{volume of reactor}}$$

Results

Current reactor studies are conducted for a period of 125 days. Methane production and TCOD became relatively stable since day 69, and the cascade and reference system were both operated at stabilized conditions for 56 days. Compared to the conventional CSTR, the cascade system achieved approximately 1.2 times higher methane production and reduction of TCOD. As for the hydrolysis rate in each reactor (Fig.1), the result shows a clear reduction in hydrolysis rate from R1 to R4, while the hydrolysis rate in the reference was just at the middle of those in R4 and R3. Considering the total volume of both cascade and CSTR system, it was observed that the total hydrolysis efficiency of cascade system was 1.37 times (12.21 g COD/day) improved compared to that of the reference (8.92 g COD/day). The results revealed that the cascade system could indeed enhance the hydrolysis rate and improve the sludge reduction in comparison to the conventional CSTR.

Scientific relevance

Following Michaelis-Menten kinetics, an increased substrate concentration should lead to an enhanced hydrolytic enzymatic reaction. Therefore, a reactor configuration using smaller reactors in series (cascade set-up) instead of a single reactor with a large volume would allow for higher sludge loading rates, or smaller overall required reactor volume. In addition to researching the impact on the hydrolysis rate, foreseen results will also reveal whether the extent of hydrolysis can be improved. The cascade set-up also physically separates methanogenesis from hydrolysis/acidogenesis, which may lead to a higher stability when overloading conditions are experienced.

Social relevance

The application of AD for WAS is generally limited by its low hydrolysis rate, resulting in the requirement of high SRTs in conventional CSTRs. Accelerating the hydrolysis step by applying a cascade based process design is a promising approach to obtain an enhanced sludge reduction efficiency at shorter SRTs. If successful, this will result in a significant drop in treatment costs, impacting the economy of WAS treatment.

Literature

[1] Cornish-Bowden, A. 2013. The origins of enzyme kinetics. Febs Letters, 587(17), 2725-2730.

[2] Wu, L.J., Qin, Y., Hojo, T., Li, Y.Y. 2015. Upgrading of anaerobic digestion of waste activated sludge by temperature-phased process with recycle. Energy, 87, 381-389.

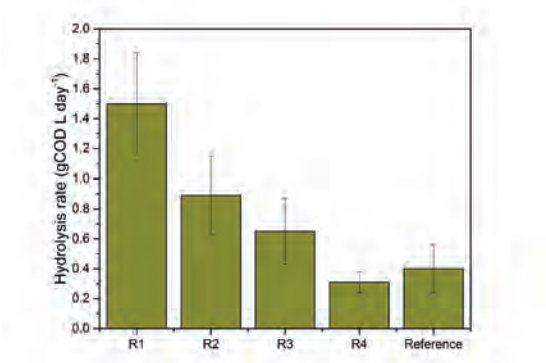
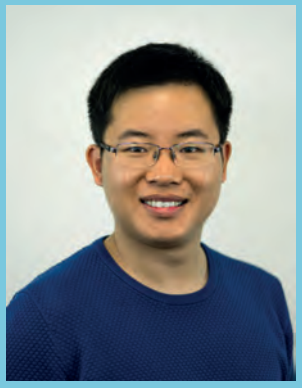


Figure 1. Distribution of hydrolysis rate



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Key words:
Anaerobic digestion, bioenergy, resource recovery

Cooperation with other institutes:
Royal Haskoning DHV

Juan Pablo Gutierrez

Suspended sediments in a highly turbid river: implications for infiltration capacity in simulated bank filtration

Research objectives

The main purpose of this study is to evaluate the recovery of the infiltration capacity in a simulated RBF system because of physical clogging and subsequent self-cleansing processes. To achieve this, physical modeling was applied to assess the infiltration rates as a function of flow velocity-shear stress, riverbed grain size, and suspended sediment size and concentration. Cake and deep bed clogging was assessed during this study.

Project outline

Introduction

Riverbank filtration (RBF) is a surface water filtration method for drinking water through the banks and bed of a river source, using extraction wells located near the water body in order to ensure direct aquifer recharge. Riverbed clogging may occur on the surface (external clogging) or within the porous media (internal clogging). The extent of scouring is determined by the magnitude of the shear stress and the properties of the riverbed and cake layer deposited onto the riverbed. Scouring or self-cleansing capacity of RBF systems is commonly assessed in terms of riverbed particle size (considering critical shear stress) and the shear stress exerted by the river flow. Reported shear stress values typical for river streambeds range between 1 to 100 N/m2, considering a value of 20 N/m2 as reasonable (Hubbs, 2006). However, the incipient motion of sediments depends on critical shear stress, which is a function of riverbed-armor layer characteristics.

Approach

Physical modeling was applied to emulate the infiltration rate based on clogging and self-cleansing phenomena for a potential RBF system. A movable bed physical scale model based on a relationship between dimensionless bed shear (Shields parameter) was used to evaluate the recovery of the infiltration rate. In order to abridge the research, the following variables were selected: (1) bed particle size, (2) suspended sediment concentration, (3) suspended sediment size and (4) bed shear stress, as a function of the Shields parameter.

Results

A straight tilting flume with two canals was used for emulating the river flow (Figure 1). Infiltration columns placed at the bottom were used to determine the effect of variable shear stress conditions on self-cleansing and infiltration processes. The infiltration rate never recovers to its initial capacity regardless of the bed shear stress assessed. For the homogeneous suspended sediments, the infiltration rate did not show any increase even if the cake layers were partly removed because of the irreversible deep bed clogging happening under such conditions, which determines the overall infiltration capacity independently from the existing bed shear stresses. For the mixed suspended sediments, cake layer cracks during the clogging experiments were observed. Therefore, uneven erosion patterns occurred during scouring experiments caused by the presence of the existing cake cracks increasing the longitudinal cracks extent on cake layer formation. Even if a high mobilization of the mixture cake layer during the scouring experiments occurred, the immediate infiltration rate recovery is associated with preferential flows caused by the ameliorated cake cracking on the surface.

Scientific relevance

The scouring or self-cleansing capacity of RBF systems is commonly assessed in terms of riverbed particle size (considering critical shear stress) and the shear stress exerted by the river flow. This research assesses the influence of the suspended particles carried by the river as a key factor determining the production yield as a function of infiltration recovery.

Social relevance

This research allows to determine the feasibility of using RBF considering the characteristics of the particulate matter. However, it must be considered that the characteristics are seasonally dependent and variable through the time.

Literature

Hubbs, S.A., 2006. Changes in riverbed hydraulic conductivity and specific capacity at Louisville, in: Hubbs, S.A. (Ed.), Proceedings of the NATO Advanced Research Workshop on Riverbank Filtration Hydrology: Impacts on System Capacity and Water Quality. Bratislava, Slovakia, pp. 199–220. doi:10.1007/978-1-4020-3938-6_9

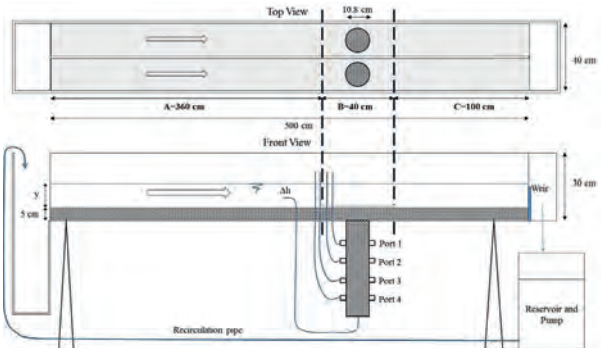

Figure 1. Scheme of the experimental setup

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Key words:
Infiltration recovery, scouring, self-cleansing and shear stress

Cooperation with other institutes:
Cinara Institute / Universidad del Valle

Nan Jiang

The application of high-silica zeolite pellets for the adsorption of organic micro-pollutants in columns

Research objectives

The objectives of the project are to synthesize and apply high-silica zeolite pellets as a potential adsorbent for OMP adsorption in practical water treatment. The aim is to ensure high water quality standards at lower operational costs and at a lower environmental footprint compared to activated carbon.

Project outline

Introduction

High-silica zeolites are promising adsorbents for the adsorption of organic micro-pollutants (OMPs). In literature, most of the research focusses on zeolites powders and batch scale adsorption experiments. For application of high-silica zeolites in water treatment, more effort is needed to investigate the zeolite pellets and their application in column experiments. This will help with the scale-up of the batch experiments and design for practical application. The application of zeolites pellets will be a further step to fulfil the adsorption-regeneration process in real water treatment. In this study, high-silica zeolite pellets were synthesized by zeolite powders and clays. The mechanical strength, rate of adsorption and breakthrough time of high-silica zeolite pellets were studied to evaluate their possible applicability.

Approach

To investigate mechanical strength of zeolite pellets, extruded zeolite/clay paste was sintered at the temperatures of 550, 650, 750, 850 and 950°C. Triclosan was selected as targeted OMP in batch scale and column scale experiments. In the column experiment with the feed triclosan concentration of 10 mg L-1, the empty bed contact time (EBCT) was 15 min which is equal to the commonly applied contact time in full scale water treatment installations. The concentration of triclosan aqueous solution was analyzed by HPLC. In the column experiment with short contact time of 1 min, the feed triclosan concentration was ~2 µg L-1. The concentration of triclosan aqueous solution was analyzed by Elisa Kits.

Results

From results of jar tests, zeolite pellets which were sintered at higher temperature showed higher mechanical strength. The mechanical strength increased only slightly between 750 to 950 °C.

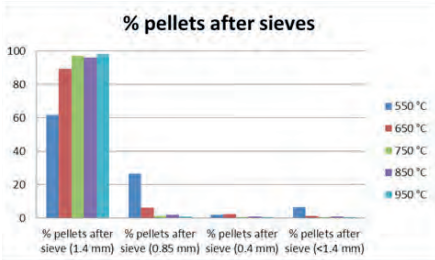

Figure 1. The effect of sintered temperature on the mechanical strength of zeolite pellets characterised by jar tests and the mass of pellets passing sieves (jar test at 300 rpm for 9 h)

When the dosing of zeolite pellets was 25 mg L-1 in 10 mg L-1 triclosan aqueous solution, the adsorption equilibrium time of the pellets took around 50 days.

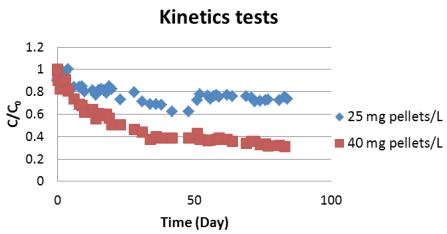

Figure 2. The kinetics of zeolite pellets (sintered temperature 750 °C) at the pellet dosage of 25 and 40 mg L-1.

The column experiments continued for 180 days which was longer than the expected breakthrough time (120 days). The complete breakthrough was not observed at the end of the experiment that the concentration of triclosan effluent was around 2.0 mg L-1. Since no biological growth was detected in the column, the unexpected performance of the column could only be attributed to adsorption of triclosan by zeolite pellets.

In short contact time column experiment, zeolite pellets showed reasonable adsorption efficiency for triclosan with a feed concentration of ~2 µg L-1. During a period of 30 days, the concentration of triclosan effluent remained ~0.5 µg L-1 with the removal rate of ~75%.

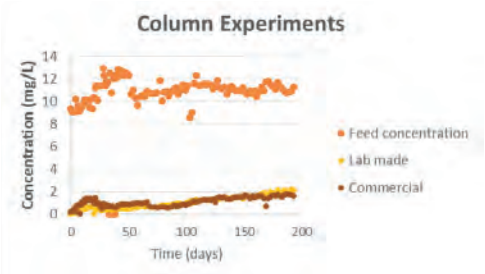

Figure 3. Breakthrough curves of column experiments using lab made and commercial pellets. Commercial zeolite pellets: Product name Z-700, Zeochem, pore size ~7 Å.

In short contact time column experiment, zeolite pellets showed reasonable adsorption efficiency for triclosan with a feed concentration of ~2 µg L^{-1}. During a period of 30 days, the concentration of triclosan effluent remained ~0.5 µg L^{-1} with the removal rate of ~75%.

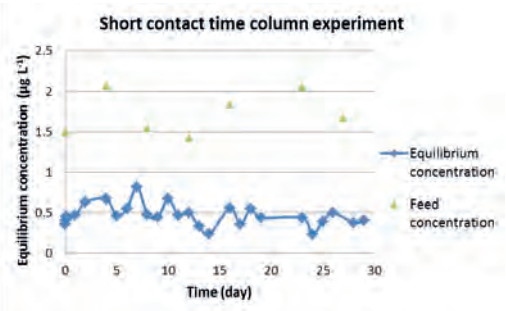

Figure 4. Breakthrough curves of column experiments using lab made zeolite pellets.

Social relevance

High-silica zeolites powders have been proven as an efficient adsorbent for the removal a broad range of micropollutants. Concerning the practical use of high-silica zeolites, it is worthwhile to exploring the application of high-silica zeolite pellets. By testing the performance of zeolite pellets in column scale experiment, zeolite pellets could be expected for further application in full scale treatment plants.

Literature

Jiang, N., Shang, R., Heijman, S. G., & Rietveld, L. C. (2018). High-silica zeolites for adsorption of organic micro-pollutants in water treatment: A review. Water research.

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zeolites pellets, micropollutants, NOM

Cooperation with other institutes:
Evides, PWN, Oasen, HWL

Maarten Keuten

DIPool: Dutch Innovative Pool
Advanced UV-based technology for pool water treatment

Research objectives

Reduction of chemical disinfectants in public swimming pools. This can be done by combining alternative disinfection techniques with adapted water treatment in a new pool water treatment concept including aspects of hygienic control of pool visitors. The goal is to have chemical disinfectant free swimming pool water for public swimming pools.

Project outline

Introduction

The main disadvantage of chemically disinfected swimming pools is the formation of unwanted disinfection by-products (DBPs). Reducing DBPs by abandoning chemical disinfectants introduces new challenges for pool water treatment. The DIPool project investigates swimming pool water treatment without chemical disinfectants to face these challenges. In cooperation with University of Twente, the effect of the "Watching Eyes" phenomenon on pre-swim shower behaviour of swimmers was investigated in 2017. The principle behind this phenomenon is that when someone has the feeling that he/she is being watched, they automatically behave pro-socially. This phenomenon also works with a picture of a pair of eyes.

Picture of "Watching Eyes" and shower pictogramm used during the study Results of observations

Approach

A desk study was done to select pictures of watching eyes and a shower pictogram. A field study was done in a holiday-park swimming pool, because this made it possible to investigate the effect of different interventions on the pre-swim shower behaviour of swimmers, with different population of subjects during each intervention but equal research conditions (e.g. lay-out, routing). To measure the effect of these "Watching Eyes", three different methods were used: visual observation, by means of a questionnaire and measuring the pool water quality.

Results

By observation, the effect of "Watching Eyes" showed to be effective in improving pre-swim shower behaviour by 28%, but the effect of a single showering pictogram was even more effective (40% improvement). Measured by observation, pre-swim shower attendance was 35-49%, while measured by questionnaire, it was 73-80%. The difference between observations and questionnaires can only be explained by dishonestly filled out questionnaires. Strangely, the effect on water quality was found to be even larger; "Watching Eyes" reduced the pollutant release by 56%, while a shower pictogram reduced pollutant release by 69%. The release of pollutants per swimmer was found to be reciprocal to the concurrent number of swimmers in the pool. Based on the results it is expected that swimmers are more likely to pee in the pool when there are less swimmers concurrently present. It was therefore concluded that the presence of watching eyes improves pool water quality, but the absence of watching eyes deteriorates pool water quality.

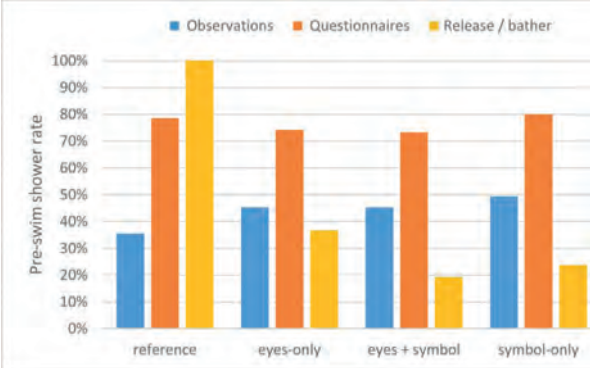
Scientific relevance

Current pool water treatment relies on chemical disinfection. The development of a pool water treatment with alternative disinfection techniques is a new field of expertise. The influence of the dynamic bathing load

on the water quality must be kept in control. Creating stable microbial pool water without the use of chemical disinfectants can lead to new viewpoints for comparable water treatment processes.

Social relevance

Since the early ages bathing and swimming play an important role in communities. The use of water basins changed over the ages from religious via hygienic to more recreational and educational purposes. During this development bathing and swimming has always been a social activity. Complaints about “swimming pool odour” and eye irritation are common reasons why nowadays some people never visit public swimming pools. UV-Disinfected swimming pools will provide healthy swimming without nuisance from disinfection by-products.



Questionnaires and water sampling during the study

Publications in 2017

Maarten Keuten, Marjolein Peters, Hans van Dijk, Mark van Loosdrecht, Luuk Rietveld
Microbial quality of swimming pool water with treatment without disinfection, with ultrafiltration, with UV-based treatment and with chlorination
Abstract and oral presentation for 7th International Pool and Spa Conference 2-5 May 2017 on Kos (Greece)

Marjolein Peters, Maarten Keuten, Merle de Kreuk, Hans Vrouwenvelder, Luuk Rietveld, GertJan Medema
Quantitative microbial risk assessment for an indoor swimming pool with chlorination compared to a UV-based treatment
Abstract and oral presentation for 7th International Pool and Spa Conference 2-5 May 2017 on Kos (Greece)

Joyce Ribbers, Maarten Keuten, Thomas van Rompay
I spy, I spy with my little eye
Abstract and oral presentation for 7th International Pool and Spa Conference 2-5 May 2017 on Kos (Greece)

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Start date project: Jan 2009
End date project: Nov 2018

Key words:
Swimming pools, alternative disinfection, disinfection by-products, anthropogenic pollutants, pool water treatment, CFD, biofilm formation potential

Cooperation with other institutes:
Hellebrekers Technieken, Van Remmen UV techniek, Akzonobel Industrial Chemicals, Coram International, Sportfondsen Nederland

Rian Kloosterman

Improving the effectiveness of assetmanagement of the drinking water process

Research objectives

Vitens, drinking water company in the Netherlands, wants to know how they can integrate future uncertainties in their decisions of today. This is important because the long life time of the assets of the drinking water infrastructure (DWI) conflicts with quick anticipating on changes in the environment. Resilience is used as concept to develop design principles.

Project outline

The main research question is how resilience enhancing design principles (REDP) can be used to develop treatment options for investments in DWI systems to reduce the chance of nominal performance loss due to disruptions at the long term?

It is necessary to answer some sub questions.

1. How to describe the complexity and how to characterise the DWI system?"
2. How to use REDP to develop treatment options for the interface of DWI systems from an engineering perspective?
3. How to use REDP to develop treatment options for the interface of DWI systems from an ecological perspective?
4. How to align the REDP from engineering and ecological perspectives to develop treatment options for DWI systems?

Results

Two draft publications are submitted.

1) An Integrated System Approach to Characterize a Drinking Water Infrastructure System
2) Sustainable planning of societal infrastructures; a resilient approach to prevent conflicting claims of infrastructures in a case study in the Netherlands

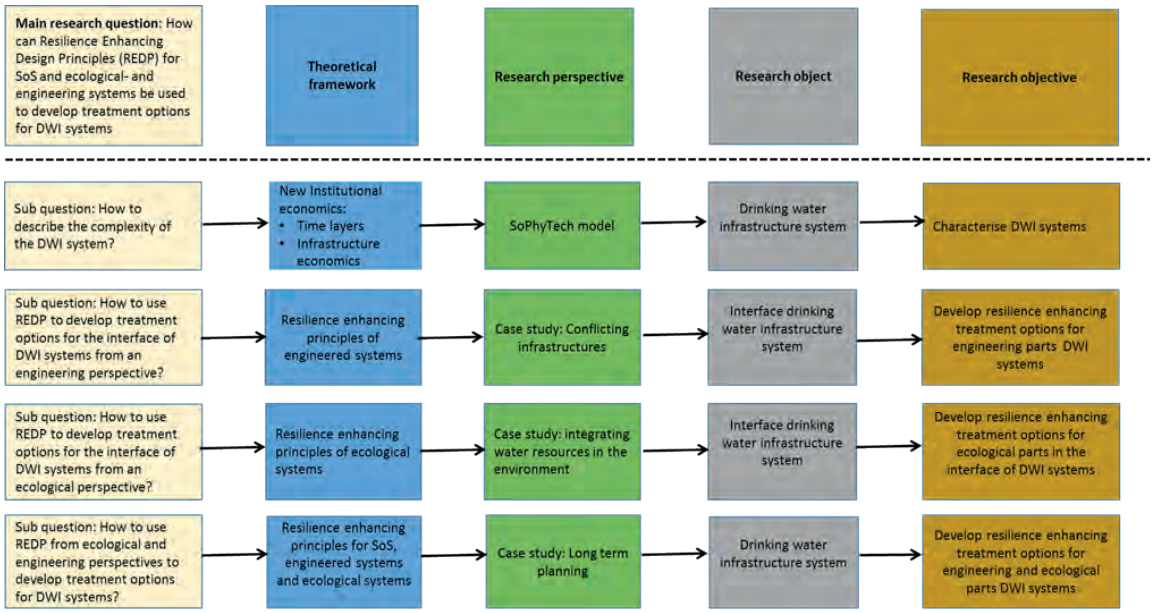
Scientific and social relevance

Handling uncertainties in societal infrastructures is an important issue due to aging assets and changing societal demands.

The scientifically contribution is the application of the resilience concept on this issue

Literature

PM



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Start date project: May 2012
Expected end date: Oct 2021

Key words:
Strategic assetmanagement, governanace, long term uncertainty

Cooperation with other institutes:
TBM

Guido Kooijman

Application of flocculants in todays sewage treatment plant

Research objectives

Effects of application of flocculants as chemically enhanced primary treatment on a sewage treatment plant with a special focus on pharmaceutical removal, anaerobic digestion and sludge dewatering.

Project outline

Introduction

Application of chemically enhanced pre-treatment (CEPT) is not widely used in the Netherlands. This is mainly because the critical COD/N ratio for denitrification will be negatively influenced by extensive pre-treatment. However, with the perspective of a low COD/N tolerant sewage treatment plant (STP) such as Nereda with nitritation and Anammox (Winkler, Kleerebezem, & van Loosdrecht, 2012), CEPT is a concept that will regain attention in the future. Although CEPT is used already since the '30, in the Optimix project CEPT is evaluated as a solution for today's problems. Micro pollutant treatment, sludge dewaterability, improved biogas anaerobic digestion as well as small footprint sewage treatment plants (STPs) are considered in this project.

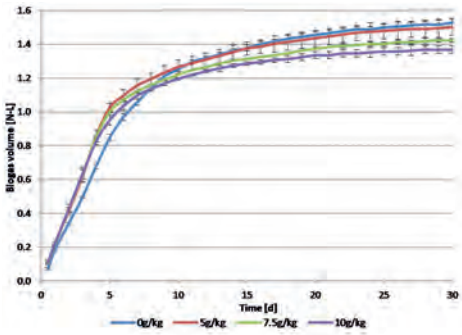
Approach

The consumption of pharmaceuticals has increased over the last decades and is expected to further increase in the future (Griens, 2010). The treatment of these compounds in STPs is not complete and therefore pharmaceuticals are accumulating in the environment. In literature, pharmaceuticals are reported to sorb to large extent to colloids. And since CEPT with flocculants enhances the removal of colloids, a large share of pharmaceuticals were expected to be concentrated in the primary sludge, facilitating the treatment of these persistent compounds. Application of CEPT will also have an impact on the subsequent STP treatment units. The anaerobic digestion (AD) may be affected and since flocculants are known to be poorly biodegradable in AD, the final sludge dewatering might be favored by CEPT as well. CEPT were used to flocculate raw sewage to create the samples for our laboratory experiments. Furthermore, experiments with primary, secondary and digested sludges were performed to study the effects of CEPT dosage.

Results

Although pharmaceuticals are reported to sorp to colloids in sewage to large extent, they could not be removed from wastewater by removing the colloids with flocculation. We investigated the reason for this and it appeared that pharmaceuticals do not sorp to small particulates (>0.1 µm).

The sludge resulting from CEPT with flocculants appeared to be better degradable in anaerobic digestion (AD) with higher degradation rates and higher biomethane potential (BMP) of the sludge. This was investigated and it was concluded that this was partially due to the flocculation of more easily degradable material and partially due to the reduced viscosity. Adding flocculants directly to the digester showed a higher digestion rate but a lower Biomethane potential (BMP) due to irreversible binding of the substrate. This is shown the figure below.



Also sludge dewatering is affected with the application of CEPT with flocculants. Even after digestion the effects of flocculants applied in the primary settler is well maintained resulting in a particulates and a lower soluble protein content.

Scientific relevance

This work gives more insight in the effects of flocculants on an anaerobic digester and opens the new perspective on pharmaceutical sorption in sewage.

Social relevance

The treatment plant of the future will allow for a lower COD/N ratio and this will open the opportunity to remove as much as possible COD from the wastewater as possible. Doing this with flocculants can have several advantages such as small plant food print, higher biogas or VFA production, lower aeration requirements and increased dewatering of waste sludge.

Literature

Griens, A. M. G. F. (2010). Data en feiten 2010 - het jaar 2009 in cijfers. Stichting Farmaceutische Kengetallen.

Winkler, M.-K. H., Kleerebezem, R., & van Loosdrecht, M. C. M. (2012). Integration of anammox into the aerobic granular sludge process for main stream wastewater treatment at ambient temperatures. Water Research, 46(1), 136–44. doi:10.1016/j.watres.2011.10.034.

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Key words:
Anaerobic digestion, micro pollutants, flocculants, sludge dewatering

Cooperation with other institutes:
Hoogheemraadschap van Rijnland
Nalco B.V.
Het Waterlaboratorium

Franca Kramer

Ceramic nanofiltration as the key step for sustainable wastewater treatment with reclamation of water, energy and nutrients

Research objectives

Where people live and work, wastewater is produced. This water needs to be cleaned before it can be discharged. Moreover, the quantity of clean and safe water is decreasing worldwide, as well as our current nutrient sources like phosphate mines that are depleting. The goal of this research project is to study a new concept of reclamation of water, nutrients and energy from municipal wastewater. The concept consists of a fine sieves to remove large particles followed by a newly developed ceramic nanofiltration (NF) membrane. The wastewater is expected to be concentrated with at least a factor 5, which results in a more than 80% water recovery. This water is polished with reverse osmosis to make it suitable for industrial use, while the concentrate from the ceramic membrane and the debris is fed to a digester to produce biogas, while nutrients from this flow are recovered by precipitation, see Figure 1.

This PhD research focusses on ceramic NF, the core of this concept. The research objectives are (i) testing the feasibility of this concept, (ii) investigating the quality and the robustness of the ceramic NF membranes on the long-term, (iii) researching how to control the fouling onto the membrane surface, and (iv) gaining insight in the phosphate rejection mechanisms of ceramic NF.

Approach

First, the feasibility of this sewer mining concept was determined by testing the filtration duration of pre-sieved municipal wastewater without cleaning. Moreover, the potential of using ceramic NF as pre-treatment for RO was studied. Second, the quality of new produced membranes and the robustness of these membranes on the long-term was assessed for the application of treating (pre-sieved) wastewater. Filtration of high organic loads requires treatment of hypochlorite to remove the fouling from these membranes. The long-term effect of this chemical treatment was determined. Third, different fouling methods will be tested to find the most efficient and sustainable method to prevent and/or remove (ir)reversible fouling. Finally, phosphate retention mechanisms will be studied to be able to find the best strategy to recover phosphate from the municipal wastewater.

Results

Pre-sieved municipal wastewater can be treated by ceramic NF for over 5 days without cleaning the membranes (Figure 2). More details about the feasibility of this sewer mining concept can be found in Kramer et al. 2015.

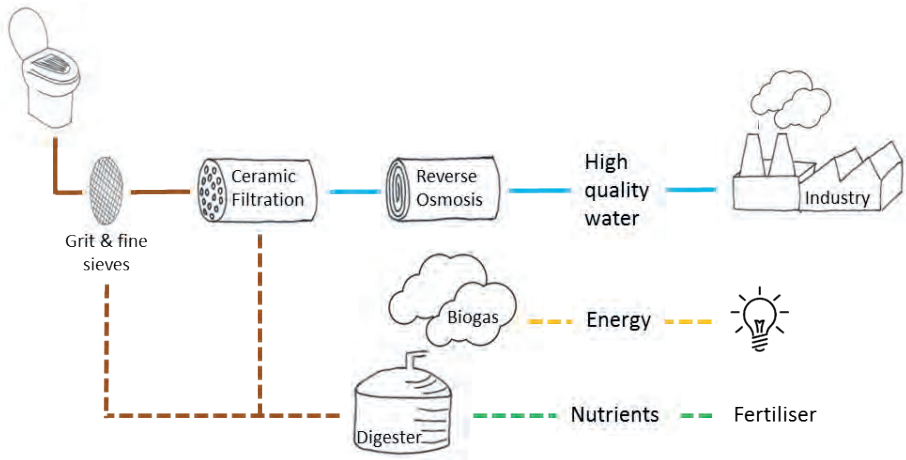

Figure 1. Sewer mining concept for treatment of municipal wastewater for the recovery of high quality water, energy and nutrients.

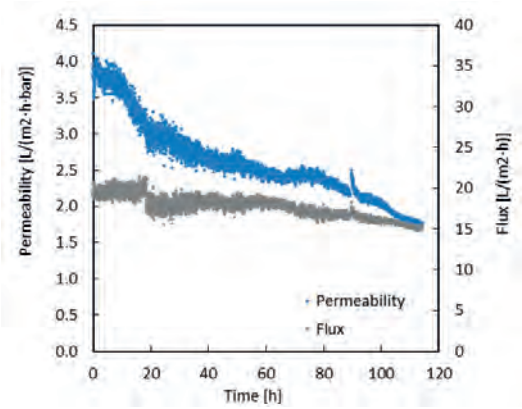

Figure 2: Permeability and flux in time of ceramic NF using pre-sieved municipal wastewater. Duration of 5 days without cleaning the membranes (Kramer et al. 2015).

Scientific relevance

Scientific knowledge on ceramic NF membranes is very limited especially in terms of wastewater treatment. This PhD research will lead to the understanding of the ceramic NF and the driving forces of the filtration process. With this knowledge, the ceramic NF process can be designed to operate in the most economical efficient way, considering the amount water produced and energy and chemical consumption.

Social relevance

Currently municipal wastewater is treated as a waste, after treatment the water is discharged into the river. In this ceramic NF concept municipal wastewater is used as a resource for the reclamation of high quality water, energy and nutrients. As our current reserves for fresh water, energy, and nutrients (e.g. phosphate) are becoming scarce, this concept will contribute to a more sustainable society.

This research is part of the RINEW (Rotterdam Innovative Nutrients Energy Water) project, which is searching for alternative concepts for the reclamation of municipal wastewater from city areas and transfer it to valuable products. RINEW is a collaboration between Evides Industriewater, TU Delft, the City of Rotterdam, Hoogheemraadschap van Delfland, Waterschap Hollandse Delta, and Clean Tech Delta.

Literature

Kramer, F.C., Shang, R., Heijman, S.G.J., Scherrenberg, S.M., van Lier, J.B., Rietveld, L.C., 2015. Direct water reclamation from sewage using ceramic tight ultra- and nanofiltration. Sep. Purif. Technol. 1–21.

Shang, R., 2014. Ceramic Ultra- and Nanofiltration for Municipal Wastewater Reuse. PhD Thesis.

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Start date project: Jun 2014
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Key words:
Ceramic Nanofiltration, wastewater, demi water production, sewer mining

Cooperation with other institutes:
Evides Industriewater

Onno Kramer

Hydraulic modelling of liquid-solid fluidisation in drinking water treatment processes

Research objectives

Developing a better understanding of the hydraulic principles affecting liquid-solid fluidisation in drinking water treatment processes; making improved modelling easier and more accessible; making full-scale implementation more achievable, sustainable and profitable.

Knowledge gap

The main objective is to elucidate the liquid-solid fluidisation system in a fundamentally better way. Starting points concern improving our understanding of the fluidisation principles of natural particles in full-scale pellet-softening reactors and understanding the dependency of the chemical phase to the fluid bed state.

Necessary models

A main aim is to produce a more accurate prediction model of the inner particle-water movements and phenomena of the bed.

Implementation challenges

To improve the performance of full-scale reactors, constraints and sensors have to be developed.

This will help water engineers design more efficient reactors and tackle current challenges.

Project outline

Introduction

In the Netherlands, an annual 400 million m³ water is softened in drinking water treatment plants applying fluidised bed pellet-reactors. Here, sand is generally used as seeding material and marble pellets are produced as a by-product. To improve sustainability, calcite pellets are dried, crushed and sieved and re-used as seeding material. To predict the fluidisation behaviour of particles in fluidised bed reactors, theoretical knowledge is generally used that pertains to spheres that are perfectly round. For natural and imperfectly shaped particles, numerous semi-empirical models have been published, but there is no general agreement on which equation is the most accurate. In many cases, shape factors are introduced for particle diameter to improve numerical results. The particle diameter, an important variable in prediction models is often obtained through traditional sieve analyses. This method is not suitable to quantify particle dimensions of irregular shaped particles.

Research objectives

The performance of the chemical process in pellet-softening reactors is proven dependent on the state of the fluidised particle bed. In the transition from a fixed to a fluidised bed state, after increasing water throughput, the drag force on particles increases. This research will show the dependency of the drag of the actual particles size and change in orientation. It will demonstrate that the shape of the particle will not decline, but that the re-orientation will cause the drag force to decrease considerably. This revisited approach will result in a better understanding and prediction of the fluid bed state.

In the Moody chart, the friction factor is plotted against the Reynolds number, with an emphasis on the turbulent flow. In liquid-solid systems, the flow regime is generally assumed to be laminar. In an improved approach, the friction factor is represented without using the default log-log method.

More advanced morphological particle properties will be obtained using image analyses techniques which makes prediction models become more accurate.

Improved prediction models are calibrated using pilot plant experiments and validated in full-scale reactors.

Approach

We aim to improve our knowledge on the hydraulics of the liquid-solid fluidisation phenomena to optimise the softening process in fluid bed reactors. Research will take place at the Weesperkarspel facility in Amsterdam, in the science lab of the applied university in Utrecht as well in the Process and Energy department laboratory at the 3ME faculty.

Results

Scientific relevance

substantial fundamental knowledge regarding hydraulics of liquid-solid fluidisation phenomena. The use of the drag force substitutes the prolonged usage of the indistinct particle shape factors. Many frequently used approaches

and models can now be compared using the modified Moody's drag-Reynolds diagram without the log-log scales; the laminar and turbulent regimes can be explained better.

Models

Accurate empirical using symbolic regression techniques and also theoretical prediction models for liquid-solid fluidisation reactors increase the opportunity to better maintain and optimise chemical process circumstances while improving water quality. The models will be implemented in the softening process.

Opportunities

New knowledge and improved models are starting points for the optimisation and development of similar water treatment processes, e.g. active carbon and sand filtration processes, and are even useful for other industrial processes and interdisciplinary fields.

Economical relevance

If optimal fluidised bed conditions are successfully implemented in the full-scale facility of Waternet, at least 10% of caustic soda can be saved, i.e. 200 k€/y.

Education

More than a dozen students cooperating in this project will gain theoretical knowledge and practical scientific skills which they, as young professionals, can use on the professional market.

Literature

Powder Technology

Water Research, a Journal of the International Water Association

Water Science and Technology: Water Supply

International Journal of Multiphase Flow

Particuology

Chemical Engineering Science

Journal of Water Supply: Research and Technology – AQUA

Drinking Water Engineering and Science (DWES)

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Start date project: Nov 2016
Expected end date: Nov 2020

Key words:
Drinking water; hydraulic modelling; liquid-solid fluidisation; drinking water treatment processes

Cooperation with other institutes:
Waternet, HU University of Applied Sciences Utrecht, Institute for Life Science and Chemistry

Emiel Kruisdijk

Agriculture & Managed Aquifer Recharge (AGRIMAR): Drainage Water Recycling for Irrigation and Surface Water Quality Protection

Research objectives

Agricultural Managed Aquifer Recharge is a promising method for securing water availability and economic gain in the agricultural sector. However, the risk of groundwater pollution with agrochemicals during storage in aquifers is currently unknown. The research objectives of this study are:

1. What conditions/processes control subsurface water treatment of pesticides and nutrients?
2. What is the optimal MAR design and operation for water treatment of pesticides and nutrients?

Project outline

Introduction

Flourishing agricultural areas are essential for food security and economic growth of the cities they sustain. AGRIMAR presents an innovative and interdisciplinary approach to achieve sustainable agriculture under climate change in saline deltas of the Netherlands and elsewhere. AGRIMAR aims to provide solutions for two major agricultural water problems:

1. Surface water carries plant pathogens causing diseases such as brown rot to (seed) potatoes and flower bulbs; its use for irrigation is prohibited or unwanted
2. Brackish groundwater and climate change further deteriorate fresh water availability.

AGRIMAR investigates managed aquifer recharge (MAR) technology that collects fresh tile drainage water for storage in aquifers, and retrieves it in summer for crop irrigation (Figure 1).

This nature based solution secures water availability, recycles water and nutrients, improves surface water quality, and yields economic gain. However, major research gaps are the (predictive) understanding of the conditions and processes improving both chemical and microbiological water quality in MAR. Water and agricultural legislations require this research to minimize risks of groundwater pollution and pathogen outbreaks.

The AGRIMAR research is conducted by two PhD studies. My PhD research is focussed on water quality treatment during agricultural MAR. I work in close collaboration with Carina Eisfeld (the second PhD in the AGRIMAR research). Carina's research is focussed on pathogen risk assessment of agricultural MAR systems.

Approach

My research is divided in three subtopics:

1. Aquifer reactivity

The fate of agrochemicals in the subsurface depend on the reactivity of the aquifer. Processes expected in the subsurface are degradation and sorption. This occurs during aquifer-groundwater interactions in the aquifer. The aquifer reactivity will be studied in-situ using push pull tests combined with reactive transport modelling.

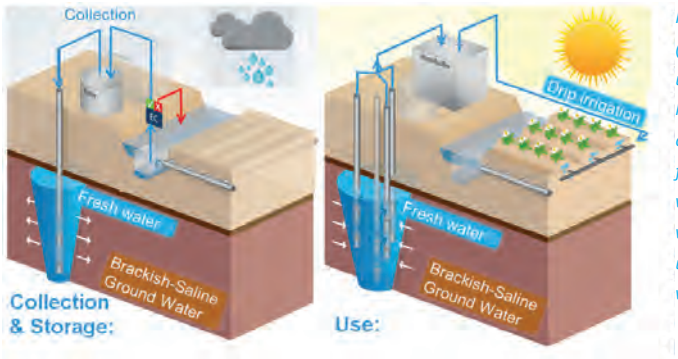

Figure 1. MAR technology: Tile drainage water (TDW) is collected and stored (left) in the underlying sandy aquifer confined by clay (the hydrogeological situation in the region). In times of water needs (summer), the stored water is used for irrigation (right). in this MAR example, one water well with two screens is used for injection, whereas three wells each with two screens are used for abstraction. Microbiological and chemical water quality is improved during aquifer passage.

2. MAR performance

An agriculture MAR system will be monitored for 2 years. The monitoring is focused on tracking the fate of agrochemicals in the MAR system. In collaboration with Carina Eisfeld (PhD AGRIMAR – Plant pathogens) a MAR water quality and pathogen fate coupled density-dependent groundwater flow and biogeochemical reaction model will be built. The model will be used to optimize MAR system construction, application and treatment.

3. MAR prognosis

Regional scale-variations of physical and geochemical aquifer properties will result in differences in MAR performance. In this subject the MAR performance is assessed on regional-scale. By assessing the differences in aquifer properties, feasibility maps can be developed. These maps will indicate areas which are especially favourable or less well suited for agricultural MAR systems.

Scientific relevance

Whereas insight in physical water quantity aspects of MAR has recently made progress, (predictive) understanding of the biogeochemical and (micro)biological water quality aspects is limited, especially for this novel MAR application using abundant available TDW. The following research gaps are identified and addressed:

1. What conditions/processes control subsurface water treatment of pesticides and nutrients?
2. What is the optimal MAR design and operation applying the developed reactive transport model?
3. What is the projected variation of MAR performance at regional scale?

Social relevance

Fresh water is a scarce resource and especially in saline deltas like the Netherlands water availability for irrigation is limited. AGRIMAR proposes a local MAR system to secure fresh water with good water quality for agriculture. Therefore, the project faces a worldwide problem and we try to determine the conditions needed to apply the system for various environmental conditions. By providing pathogen free irrigation the spread of plant diseases will be reduced and loss of food crops is prevented.

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Key words:
Sustainable Agriculture, Water Security, Food Security; Pesticides; Water Quality; Managed Aquifer Recharge

Cooperation with other institutes:
Acacia Water

Bin Lin

Alleviation of organic fouling of ceramic membranes by oxidation

Research objectives

- To develop a new route to combine the advanced oxidation process (AOPs) with membrane filtration to alleviate the fouling of ceramic membranes;
- To prepare the proper highly-efficient catalysts for better inducing AOPs on membrane surface to facilitate the decomposition or detachment of fouling layer from membranes;
- To investigate the mechanism of fouling alleviation by using oxidation on membrane surface in terms of mass transfer of H2O2 within catalyst layer, fouling layer and membrane surface.

Project outline

Introduction

Ceramic membranes are among the most promising technologies for water purification, owing to their superior resistance to mechanical, chemical, and thermal stresses (Karnik et al. 2005). Membrane fouling by organic pollutants still remains the key obstacle for the application (Kim and Dempsey 2013). Generally, the membranes must be cleaned frequently to remove the organic foulants on the surface or inner pores. Hydraulic cleaning (e.g., backwash, or forward flush) has been widely reported for fouling mitigation, but proved not effective for physically irreversible fouling (Shang et al. 2015). Too frequent chemical cleaning (e.g., acidic or caustic cleaning) basically produces damages to membrane integrity and also a large chemical consumption (Simon et al. 2013). As such, oxidation has attracted ever-increasing attention for fouling control of ceramic membranes. Most studies about catalytic oxidation mainly focus on oxidative process in the slurry mode. However, the process or mechanism of catalytic oxidation of catalysts immobilized on membrane surface are still lack of knowledge. There are still large challenge to effectively apply catalysts on ceramic membrane surface for fouling mitigation, such as the poor mass transfer efficiency of oxidant within the defined membrane surface. Hence, in this study, the process and mechanism of catalytic oxidation on membrane surface will be deeply investigated to shed new light the fouling alleviation for ceramic membrane.

Approach

Different catalysts for Fenton reaction will be prepared and immobilized on membrane surface. The catalyst coated membrane will be applied to fouling test to have fouling layer on membrane surface. The membrane cleaning efficiency of different catalyst-based ceramic membrane are compared when applied into Fenton (-like) reaction.

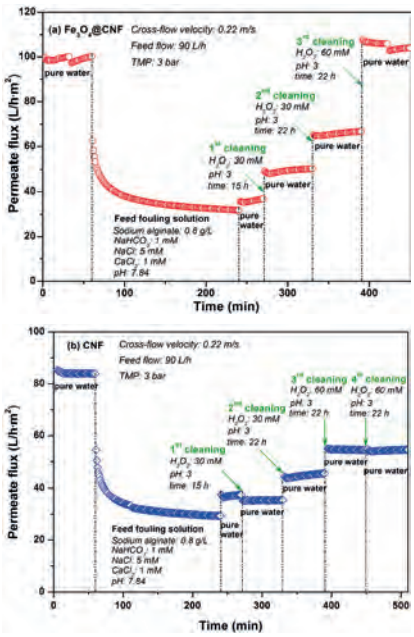

Fig.1. The permeate flux evolution of Fe3O4 coated ceramic nanofiltration membrane (a) and pristine ceramic membrane (b) during the fouling and Fenton cleaning processes.

Results

As shown in Fig.1a, for the Fe3O4 coated ceramic nanofiltration membrane (Fe3O4@CNF), the permeate flux during cleaning could be increased a lot with the increasement of H2O2 concentration (from 30 mM to 60 mM) or the soaking time, and reached a complete recovery. By contrast, as seen in Fig. 1b, the pristine membrane (CNF) without any immobilization of Fe3O4 catalysts exhibited very limited flux recovery during the same cleaning process, even when further continuing the

cleaning operation for much longer time. During the cleaning process, the iron dissolution and H2O2 decomposition can be detected (data not shown), indicating the occurrence of Fenton (-like) reaction in this process. These results implied that the Fenton (-like) reaction induced by iron oxide nanoparticles appears effective for membrane cleaning, which could be a potential approach for fouling alleviation of ceramic membranes.

Scientific relevance

Scientific knowledge over the AOPs confined on ceramic membrane surface is quiet limited. It is still lack of knowledge how Fenton (-like) reaction can be applied on the decomposition or detachment of fouling layer when the catalysts are immobilized on membrane surface. The rational design of this active filtration system represents a great stride in on-demand initiated AOPs and in moving the AOPs within confined spaces to break the conventional reaction efficiency limit.

Social relevance

The implementation of membrane processes has become a well-established technology in water treatment, and the demand for membranes increases yearly by 8%. Fouling control has been viewed as the crucial issue for better applying ceramic membrane in industries. More efficient approach (e.g., AOPs) for membrane fouling alleviation is urgently needed to reduce the chemical consumption and damage to membrane. Therefore, AOPs confined on membrane surface provides the potential opportunity for better application of ceramic membrane into water treatment.

Literature

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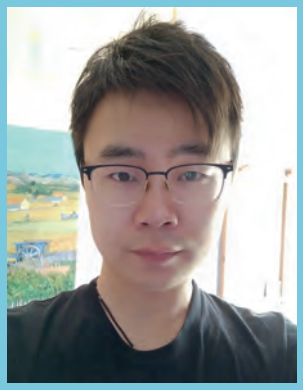
Kim, H.-C. and Dempsey, B.A. (2013) Membrane fouling due to alginate, SMP, EfOM, humic acid, and NOM. Journal of Membrane Science 428, 190-197.

Shang, R., Vuong, F., Hu, J., Li, S., Kemperman, A.J.B., Nijmeijer, K., Cornelissen, E.R., Heijman, S.G.J. and Rietveld, L.C. (2015) Hydraulically irreversible fouling on ceramic MF/UF membranes: Comparison of fouling indices, foulant composition and irreversible pore narrowing. Separation and Purification Technology 147, 303-310.

Simon, A., Price, W.E. and Nghiem, L.D. (2013) Changes in surface properties and separation efficiency of a nanofiltration membrane after repeated fouling and chemical cleaning cycles. Separation and Purification Technology 113, 42-50.



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Start date project: Oct 2017
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Key words:
Ceramic membrane, fouling, oxidation, cleaning

Cooperation with other institutes:
CSC

Niels van Linden

From pollutant to power

Research objectives

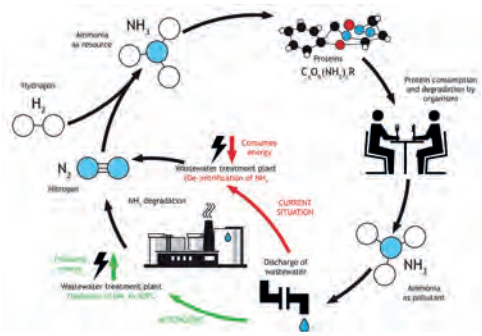
The objective of the From Pollutant to Power research is to develop an energy positive system, including a solid oxide fuel cell, removing ammonia from low carbon/high nitrogen residual water.

Project outline

Introduction

Ammonia (NH3) is world's second most produced chemical and is a vital resource for crop growth and protein production. One of the reasons NH3 becomes present in residual (waste) water is protein degradation by organisms. NH3 is seen as a pollutant in residual water, because excessive discharge of nitrogen (N) in residual water leads to eutrophication of receiving surface waters and subsequent deterioration of the aquatic environment.

In order to avoid environmental pollution, N must be removed from residual waters, before the water is discharged. Current methods applied in wastewater treatment plants (WWTP) consume significant amounts of energy: the energy consumption of N removal by nitrification-denitrification requires 57 MJ/kg-N, whereas the more recently developed energy-efficient Anammox process, which is applied at full scale to treat sludge reject-water, still requires 19 MJ/kg-N (Magri et al., 2013).



The From Pollutant to Power research focusses on the recovery of NH_3 from residual streams and subsequent energy recovery by using NH_3 as fuel ¬in a solid oxide fuel cell (SOFC).

Approach

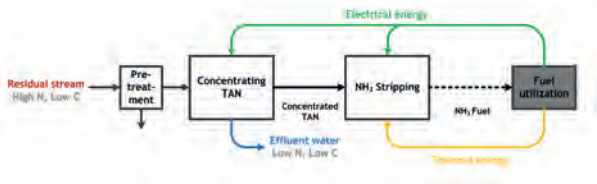
In an SOFC working at higher temperatures than 500 ºC, NH_3 is cracked into nitrogen gas (N_2) and hydrogen gas (H_2). The H_2 is oxidized using oxygen ions (O^{2}-), which is present in air. The off-gas of an SOFC contains harmless N_2 and water: no greenhouse gas emission. The electrochemical process results in the production of both electrical and thermal energy: the oxidation of NH_3 in an SOFC theoretically yields 14 MJ/kg-N in total. An SOFC is a highly efficient energy conversion technology, having an electrical efficiency of approximately 50% and a total energy efficiency of 85 – 95% (Ni et al., 2009). An SOFC has specific fuel requirements, which do not match the composition of the residual water streams: the fuel should be gaseous and contain very low levels of oxidants, H_2S and siloxanes (Papadias et al., 2012). Therefore, a suitable NH_3 fuel must be produced from the residual streams.
To this end, a concentration step and a gas extraction step are required. By concentrating the amount of TAN (Total Ammoniacal Nitrogen, the sum of NH_3 and NH_4^+), higher NH3 concentrations in the fuel can be achieved in the gas extraction step, while the thermal energy consumption can be reduced in addition. The selection of the most suitable technologies for these steps is key to this research. After the selection, experiments will be conducted in order to optimize the energy efficiency of the respective technologies. Simultaneously, a mass and energy balance tool will be developed to evaluate various scenarios.

The produced electrical and thermal energy can internally be used, in order to produce a suitable fuel from the residual water streams. When the energy consumption of the fuel production process is lower than the energy production of the SOFC, an energy positive system to remove NH3 from residual streams can be realized.

Results

Experiments with an SOFC on NH3 fuel showed that 8.5 MJ/kg-N of electrical energy could be produced when using a 10% w/w of NH3 fuel, while 4.5 MJ/kg-N of electrical energy could be produced with a 5% w/w NH3 fuel. Electrodialysis has been identified as suitable technology for concentrating TAN. The electrical energy consumption

for the 90% TAN removal from sludge reject water proved to be 6.8 MJ/kg-N. Furthermore, vacuum membrane stripping proved to be able to produce a gaseous permeate, containing NH3 in concentrations 8-10 times higher than the liquid feed with a thermal energy consumption of 25 MJ/kg-N.



Scientific relevance

Multiple topics in this research will be of scientific relevance, such as the mass transport mechanisms and energy consumption for concentrating TAN and stripping NH3. Also, the performance of an SOFC on NH3 fuel produced from residual streams (water-NH3 mixtures) has not been studied yet.

Social relevance

The processing of NH3 in the described system addresses both the generation of clean energy and the treatment of residual water. As NH3 is here no longer seen as pollutant, but as an energy source, this could lead to a paradigm shift: from pollutant to power.

Acknowledging NH3 as a clean alternative energy source from residual waters complements the promotion of NH3 usage for residual generated sustainable energy storage (wind, sun, hydropower, etc.) (ISPT, 2017).

Literature

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Key words:
Electrodialysis, vacuum membrane stripping, SOFC, ammonia, energy

Cooperation with other institutes:
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Konstantinos Makris

Residual lifetime of plastic sewer pipes

Research objectives

The objective of this project is to provide sufficient knowledge on the current state of plastic sewer pipes and joints in The Netherlands and predict their residual lifetime. The parameters that accelerate the degradation of plastic sewer systems will be investigated and assessed, while appropriate methods for lifetime prediction will be established.

Project outline

Introduction

A large part of the sewer system in The Netherlands is occupied by plastic materials (PVC, PE, PP, GFRP, etc.), which have been used extensively since 1960's. While the factors which determine the lifespan of plastic pipes and joints have been explored regarding water and gas distribution systems (e.g. Arsénio 2013, Visser 2010), the same does not apply for sewer systems in which the environment is totally different and more hostile.

Today, sewer asset management and deterioration models usually depend on visual inspections and have the tendency to connect the age of a pipe to its structural condition. However, pipe age and CCTV inspection data, used as main input in models and in decision making, have proved not to offer a realistic picture of the actual sewer conditions (Stanic 2012). Thus, more deep approaches have to be implemented in order to have a more comprehensive view.

Approach

The literature review on the subject indicates that sewer plastic pipes are expected to achieve a service lifetime of more than 100 years. However, the exploration of the available inspection data files (by the municipalities of Almere and Breda) has provided indications of several possible defects that occur in plastic sewers, even from the first years of operation. This discrepancy will be explored by testing pipes which are defective according to inspections. The performance of the elastomeric joints will be also investigated and assessed, in order to explore if wastewater has an impact on the rubbers used.

Therefore, in collaboration with the municipality of Breda, operating plastic pipes will be exhumed from the ground and will be tested concerning their structural integrity. Hence, these experiments will focus on the assessment of the current state of the sewer systems. Based on the results of the experiments, the research will be directed towards a deep material science approach, or a pipe-soil interaction approach, or a combination of both if needed.

Scientific relevance

This project aims at understanding and communicating the failure mechanisms that prevail in polymer sewer pipes and how these mechanisms affect the functionality of the system. By conducting experiments and developing models, methods which take into account both the structural and operational conditions in sewers will be established. Part of the results from this research is expected to be valuable for plastic pipes used also in other applications.

Social relevance

In an effort to save capitals, municipalities have become more cautious whether a pipe has to be replaced or not (Rioned 2016), shifting to a less proactive approach. Reactive replacement, however, could lead to unpredicted costs and working loads, while the release of untreated sewage to the environment, until the damage is noted and fixed, could cause severe consequences. Hence, making a trustful estimation about the period that a pipe is expected to fail is a key issue for sewer asset management, leading to better decision making and more affordable investments.

Literature

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Key words:
Sewer asset management, Plastic pipes, Elastomeric joints, Pipe degradation, Lifetime assessment

Didrik Meijer

Criticality of urban water networks

Research objectives

This research aims to develop a methodology for identifying critical elements in urban water networks and systems based on the structure of the networks.

Project outline

Introduction

Urban water networks consist of many elements. The performance of the network depends on the functioning of the individual elements. The relative contribution of an element for the network's performance depends on the characteristics of the element and its position in the network. Once the degree of criticality of the elements in a network is known, inspection, maintenance and rehabilitation can be tailored in accordance with the degree of criticality instead on maintaining all elements to the same quality level as is presently done in practice.

Approach

The research focuses on identifying critical elements in urban water networks based on the geometry and location of the elements in the network instead of using iterative hydraulic calculations. The graph theory can be used to analyze networks with limit calculation effort and is therefore used as starting point.

Scientific relevance

The currently available methods to identify critical elements require time-consuming iterative calculations and the processing of the amounts of output data. Further, the results are dependent on the chosen test-load which implies that the results are likely not to reflect the actual situation. Because of the limited calculation effort, the graph theory allows the analysis of large networks that are now, for practical reasons, beyond the scope of methods applied so-far.

Social relevance

A maintenance approach of networks based on the criticality of the network elements allows system mangers to optimize the maintenance of their systems and make better-informed decisions, on one hand this leads to a more effective and efficient use of means, on the other hand a higher level of serviceability for the system as a whole can be obtained.

Literature

Meijer, D.; van Bijnen, M.; Langeveld, J.; Korving, H.; Post, J. Identifying Critical Elements in Sewer Networks Using Graph-Theory. Water 2018, doi:10.3390/w10020136

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Key words:
Criticality, Networks, Asset management, Graph theory

Cooperation with other institutes:
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Antonio Manuel Moreno Rodenas

Uncertainty propagation in water quality integrated catchment modeling

Research objectives

Evaluate how uncertainties are propagated through the different sub-models in integrated catchment models for water quality assessment. And identify the main contributors to modeling uncertainty.

Project outline

Introduction

This research has as main target to increment the current knowledge on catchment scale water quality modeling.

The objectives involve:

- Study how operational applications of integrated catchment modeling affect the model structure definition
- Evaluate the effects of spatiotemporal variability in rainfall inputs on receiving water impacts at large scale urbanized systems.
- Assess how uncertainties propagate through the different components of a simplified integrated catchment model
- Use knowledge extracted on error propagation to direct models structure improvements and monitoring efforts.

Approach

In the Eindhoven catchment, calibrated detailed water quality models are available for the sewer, WWTP and receiving water, together with a simplified integrated model (eg. in Langeveld et al., 2013). In addition, validated monitoring data are available in all sub compartments.

This provides an excellent opportunity to assess the propagation of uncertainties in integrated models, as monitoring data are available on the input (rainfall) and the output (ammonia and dissolved oxygen concentration in the receiving waters), as well as intermediate locations (CSOs, WWTP influent/effluent). This enables the influence of model structure uncertainty transmission to be examined by comparing the uncertainty in the full and simplified models.

Scientific relevance

Watershed management under model-based decision making requires of a deeper knowledge of the uncertainty produced in current water quality models, this project will try to provide a more complete identification of the production and transmission of it in each sub model part. This can lead to a better understanding of the overall process and to be able to highlight the further research needs on data acquisition.

Social relevance

An incorrect investment plan can either overestimate or underestimate the real needs of the physical system, wasting social resources or not fulfilling the quality requirements. With a finer assessment of the uncertainty in model results, decision makers can select corrective measures and management practices under an objective and informed perspective.

Literature

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Key words:
Uncertainty Analysis, Integrated Catchment Modelling, Geostatistics

Cooperation with other institutes:
EAWAG Swiss Federal Institute of Aquatic Science and Technology, Luxemburg Institute of Science and Technology, University of Sheffield, University of Bristol, Ch2m (Jacobs), Wageningen Universiteit, Justus-Leibig-Universitaet Giessen, University of Coimbra

Julian Muñoz Sierra

BioXtreme – Anaerobic wastewater treatment under extreme conditions

Research objectives

The aim of the study is to understand the bioconversion of model organic compounds (e.g., phenol) existing in industrial wastewaters streams under extreme conditions such as high and fluctuating salinity and high temperatures. The research is focused on the most suitable technology for this purpose (i.e. anaerobic membrane bioreactors, AnMBrs) to encourage reclamation of process waters for reuse. Attention is paid to the bioaugmentation of specific microbial communities and their dynamics.

Project outline

Introduction

Industrial wastewaters generated in oil and chemical industries are often characterized by extreme conditions such as the presence of refractory and hazardous chemical compounds, high salinity, high temperatures. Particularly for these extreme types of wastewaters, the conventional biological technologies have many limitations, but membrane assisted bio-treatment offers many advantages such as in-reactor bio-augmentation of the required bacterial species and maximized sludge retention times (SRT), ensuring high metabolic conversion properties per unit of reactor volume. In case auto-immobilization or sludge granulation is difficult, application of membrane technology for pre-treating industrial process waters has several striking advantages: i) system compactness, allowing installation at or even inside the industry; ii) production of suspended solids free effluents, simplifying effluent upgrading techniques; iii) full retention of specific bacterial communities that are required for conversion of complex, recalcitrant and hazardous compounds.

There is an urgent need for sustainable and cost-effective treatment technology that can make this water suitable for (re-)use. BioXtreme is aiming to deliver such a technology. If industrial effluents are properly treated, pollution can be prevented, and water produced can serve as an alternative source for existing freshwater resources or industrial processes.

Approach

A selection of waste streams of interest was made, i.e. at those industries where increased water efficiency is considered but hampered by the nature of the organic pollutants present. The treatability of the process water stream is researched under controlled lab conditions and synthetic wastewater making use of down-scaled reactor systems. Relevant aspects of interests are addressed such as biomass retention/bio-augmentation, conversion/toxicity of organic compounds, microbial population dynamics, and sludge filterability. Studies are conducted with phenol. Phenol is a key intermediate in the anaerobic conversion of a wide variety of aromatics, and, therefore, is of particular interest. Anaerobic treatment of phenol-containing wastewater has been mostly carried out using granular reactors, and its application has been limited to mesophilic and ambient temperature making the anaerobic degradation of phenolic compounds under thermophilic and saline conditions a challenge for AnMBRs.

Experimental set-up

The experiments are performed using three laboratory scale anaerobic MBR reactors with an effective volume of 6.5 L, and using ultra-filtration (UF) membrane modules. The systems are equipped with feed, recycle and effluent pumps, pH and temperature sensors and gas meters. The temperature of the jacketed reactors is controlled at 35.0 and 55.0 ± 0.8 °C by thermostatic water baths. Currently, tubular PVDF membranes with 5.5 mm inner diameter and 0.64 m length are employed. A UASB reactor is also used to carry out a comparison study. The experimental set-up is connected to a computer running LabView software to control all pumps and collect pH, temperature, pressures, and biogas flow data on-line.

Scientific relevance

Extreme conditions in the process water and wastewater of the industrial sector encourage the development of non-conventional biological treatment solutions. The research will increase the understanding of how phenol is converted by the microorganisms, what is the influence of different conditions on the biomass properties, microbial community and functionality, and how the process is addressed within the technology selected (AnMBR). Findings are compared with current technologies (e.g. sludge bed technologies), elucidating the added advantages of the developed extreme AnMBR bioreactor, including new process configurations and water reuse possibilities.

Impact

Enabling the An-MBR application to a wide range of industrial processes with the potential of water reuse.

Challenge

Finding the optimum operational condition for maximised bioconversion under extreme conditions, without being limited by reduced membrane fluxes.

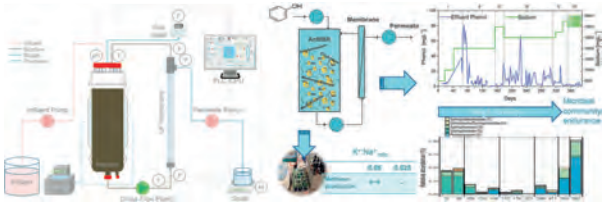

Figure1. Experimental Set-Up/Graphical abstract (Muñoz Sierra, J.D. et al. 2018a)

Social relevance

In the Netherlands, about 80% of the freshwater use is industrial use. The research is focused on fundamental and applied research into the wastewater treatment for application in the industry to compile know-how for optimizing the industrial water cycle and reducing its water footprint. Research with the final aim in water recycling has the potential to improve the effectiveness of the existing technologies and invest in the future well-being of the world's population.

Literature

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AnMBR, high and fluctuating salinity, thermophilic, chemical wastewater

Cooperation with other institutes:
Evides Industriewater, Paques B.V

Eva Nieuwenhuis

Decision-making for integrated urban drainage systems: dealing with uncertainties stemming from a system in transition

Research objectives

This research aims to 1) understand the role uncertainties play in the decision-making process for more integrated systems; 2) provide insights into the dilemmas and trade-offs involved for urban drainage decision makers at strategic, management and operational levels; and 3) provide measures to cope with these uncertainties and dilemmas.

Project outline

Introduction

Ongoing urbanization, changing environmental conditions, water quality regulations and increasing economic concerns put pressure on the management of our urban drainage system. Across Europe, systems are deteriorating and many sewers have to be replaced the upcoming decades. Hence, scholars and policymakers have been raising the question if we should reconsider our traditional water management practices. While it is yet unknown how such new urban water systems should exactly look like, it has been widely acknowledged, both among scientists, policymakers and practitioners, that the challenges of twenty-first century urban water management require solutions where problems are approached in a more integrated way.

Such integrated systems display typical characteristics of complex socio-technical systems. It implies that urban drainage systems will be tighter coupled with other systems, introducing more, and more diverse, interrelationships than in traditional systems. Urban drainage systems are embedded in the larger urban environment where they interact with, e.g., roads, green roofs and surface water. Moreover, integration introduces the involvement of more actors, all having different interests, responsibilities and perceptions.

What does this complexity mean for the urban drainage decision makers? Complexity inherently introduces uncertainty; uncertainty about the system performance, about the decisions of involved actors and about the institutions. This uncertainty leads to management dilemmas for urban drainage decision makers at different organisational levels. Urban drainage decision makers have to deal with these dilemmas: they have to make decisions under uncertainty and have to make sure that service levels will be met, both now and in the future. A better understanding of the role uncertainties play in the decision-making process for more integrated urban drainage systems is needed.

Approach

Yet, it is unknown what the particular uncertainties are and what decision-making dilemmas they are resulting into. This involves further empirical analysis. First, the uncertainties and dilemmas that decision makers face are defined, after which their role in the decision-making process can be further investigated. Interviews and observations are therefore an important part of this research. A mixed methods approach is applied, combining Q methodology and case study research. After data collection, the empirical data is analysed and compared with existing literature, aiming to develop new insights and to formulate measures for urban drainage decision makers that help them dealing with the complexity of the urban environment.

Scientific relevance

Technical sewer asset management and modelling studies often focus on building robust and flexible systems, thereby mainly considering how to deal with physical system uncertainties related to e.g. urbanization and climate change. Such studies, however, do not necessarily take into account the social complexity of the technical solutions: the changing conditions and demands like climate change and urbanization necessitate more integrated systems. This implies that urban drainage systems become tighter coupled with other urban systems (systems-of-systems), putting additional constraints on the multi-actor decision-making process.

This research takes the unique perspective of the urban drainage decision-makers: how should urban drainage decision makers deal with uncertainties that come with a transition to more integrated urban drainage systems? The physical urban drainage infrastructure constrains the multi-actor decision-making: the technical infrastructure is already there and has to be dealt with. The tight coupling with other urban systems (systems-of-systems)

put additional constraints on the multi-actor decision-making process. Hence, this thesis combines the social multi-actor perspective with the technical systems-of-systems perspective.

Social relevance

This study uses an empirical approach: it focuses on the uncertainties that urban drainage decision makers currently face when acknowledging the complexity of integrated urban water systems. Since this study provides measures for urban drainage decision makers to deal with these uncertainties, it carries significant societal value.

Literature

Publications based on previous projects:

Nieuwenhuis, E., Langeveld, J., & Clemens, F. (2018). The relationship between fat, oil and grease (FOG) deposits in building drainage systems and FOG disposal patterns. Water Science and Technology, 77(10), 2388-2396.

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Key words:
Multi-actor decision making; Social-technical systems; integrated urban drainage solutions; integrated urban water systems

Cooperation with other institutes:
TU Delft, Technology Policy and Management, Multi-Actor Systems

Celma Niquice

Water reclamation for irrigation in Maputo, Mozambique

Research objectives

Identify the potentials and constraints of using (partially) treated wastewater for irrigation and gather insights that allow translating those findings into the context of sub-Saharan Africa and, in particular of Maputo; Perform a mass balance to the water and nutrients (N,P) in the Maputo city; Quantify risks associated with use of partially treated wastewater for irrigation in Maputo; Investigate the fate of nutrient and balances in peri-urban area of Maputo irrigated with wastewater.

Project outline

Introduction

Mozambique is facing water shortage and from the total available water flow only 46% is produced in the country. Projections indicate that urban water demand will increase by about 40%, with industrial use being expected to augment by about 65% (TWWW and GWP, 2013). Additionally, the storage capacity is low and limits the expansion of agriculture, industries and the overall economic development of the country. Furthermore, access to sanitation services both in cities and rural areas, is deficient. Less than half of population has improved sanitation systems, and only limited amounts of wastewater is treated. Inn some areas, untreated or partially treated wastewater is unsafely reused in irrigation. Also in, Maputo, many of these issues can be identified with the situation being further exacerbated by population growth. A possible solution to address these issues is water reclamation. Some studies have pointed positive effects of water reuse in agriculture, such as that adequate water reclamation contributes to addition of water source as well the addition of nutrients for the crops increasing yields (Duran et al 2003) and contributes to urban development (Agodzo et al 2003). This study aims to evaluate the potentials for water reuse for agricultural purposes in Maputo.

Approach

The research methodology involve both quantitative and qualitative analysis based on available primary and secondary data obtained through direct observations, direct interviews to individuals and field measurements. In addition, a literature review was conducted to analyze current practices for irrigation with reclaimed water in Sub-Saharan countries, to evaluate reclaimed water potential for irrigation in Maputo. QMRA will be used to estimate the human health risks associated to current practices, using non-treated wastewater in irrigation.

Results

Findings from the review show that great opportunity for sub-Saharan Africa to implement water reclamation in planned manner. In addition, it also serves as an alternative for developing countries in offering better sanitation services through revenue generation

- Restrictive guidelines are unrealistic with current farmer practices.
- Guidelines considers the water quality at the point of use, which is a limitation because developing countries have inefficient or inexistent wastewater treatment facilities and contamination is prone to occur throughout the supply chain.
- Irrigation water does not have to necessarily meet the quality as defined in the guidelines' standards to ensure human health protection. The use of a multi barrier approach (figure 1) is proposed and might be much more cost-effective in ensuring environmental and human health. This alternative comprises wastewater treatment and critical point barriers, such as crop restrictions and post-harvest handling throughout the supply chain, which are combined to reduce health risks.

Scientific relevance

This project is expected to contribute to:

- Development of water reclamation solutions for irrigation that can be applied to the local situation.
- Knowledge about local water quality available from different sources.

Social relevance

From this research is expected that contribute to:

- Reducing the risks associated with untreated water for irrigation purposes.
- Building a realistic approach for water reclamation in agriculture for Maputo.

- Increasing the relevance of water reuse as means of adding water to the water cycle guaranteeing the availability of water in Mozambique for irrigation.
- Influencing institutions and companies to change their decisions making and contributing to sustainable development of Mozambique.

Literature

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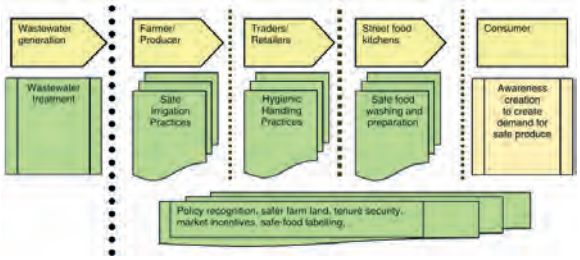

Figure1:MultipleBarrier Approach (Keraita et al., 2010)

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Key words:
Water reuse irrigation, waste water treatment, Agriculture water reclamation

Cooperation with other institutes:
UEM, UNESCO IHE

Gabriela Karina Paulus

Development and application of Multiplex qPCR for Antibiotic Resistance Genes in the Water Cycle

Research objectives

Develop, Evaluate and Apply Multiplex qPCR assays to detect ARG and dissemination in environmental water systems with higher accuracy than NGS and a higher throughput than regular qPCR, to obtain an accurate picture of ARG in the urban water cycle.

Methods

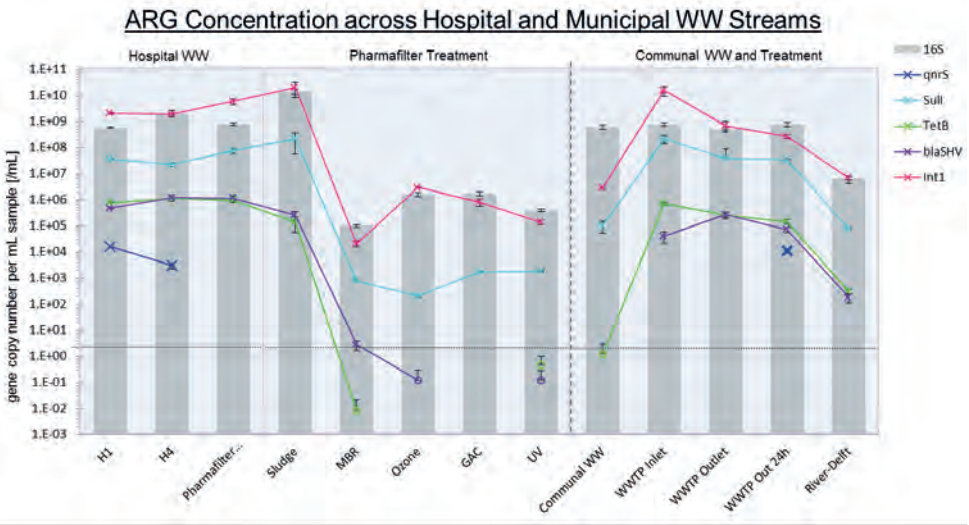
Six genes were included in the study: 16S rRNA, blaSHV, IntI, qnrS, SulI and TetB. The selection was based on the available literature and the clinical relevance. Multiplex Q-PCR assays were composed by combining M1: internal control, SulI and qnrS and M2: 16S rRNA, blaSHV, TetB and IntI. Compatible probes were designed and the Multiplex qPCR assays were evaluated using composite controls with varying, predetermined concentrations of ARG as well as with spiked environmental samples. After development the Multiplex qPCR, assays were applied to different surface water samples collected along the river Rhine catchment (NL, DE and CH) , starting from relative undefiled conditions upstream in Switzerland to more anthropogenically polluted area's in Germany and the Netherlands. Furthermore wastewater samples from a Dutch hospital were investigated for the presence of ARG, the standard communal treatment was compared to on-site waste water treatment with a Pharmafilter.

The ARG concentrations measured were corrected by the factor of loss of genetic material of the internal control added before the DNA extraction process. All qPCR experiments were done in triplicate.

Conclusion

Multiplex qPCR

Accurate quantification of genes in composite and spiked environmental test samples could be achieved and exact quantification of ARG is therefore possible with the developed Multiplex qPCR assays. ARGs could accurately be identified and quantified through the developed multiplexes, even at in test samples with concentrations of ARGs varying as far as 100-fold. The high throughput and accuracy of the multiplex qPCR efficient quantification system is of additional value as the concentration of the significant spectrum of ARG in environmental samples is often unknown and large concentration disparities between different ARG are to be expected.



ARG Distribution along the Rhine

SulI and IntI were the most abundant ARG found. IntI concentrations varied across the Rhine with 3.3E+02 (Diepoldsau, CH) up to 3.6E+06 (Utrecht, NL). SulI concentrations were more stable with variotions from 1.2E+03 to 1.0E+04. TetB and blaSHV could detected in the area between the Swiss-German border. A correlation between the concentration of IntI and the concentration of other ARGs could be observed. Overall, the expected increase of ARGs across the Rhine could not be observed.

ARG Concentration in Hospital and Municipal WW and the Advantages of local WW Treatment

High concentrations of ARGs could be detected in hospital WW. Further, a broader range of ARG could be detected in hospital WW when compared to municipal WW, with the Quinolone resistance genes (qnrS) being present only in hospital effluent.

The local treatment of hospital WW (with Pharmafilter installations) reduced the ARG concentrations by 3 to 5 log units, reducing the ARG concentrations to below ARG concentrations in communal WW effluent, both in total numbers and normalized to 16S rRNA.

A local treatment of high-risk WW effluents might therefore be beneficial in terms of ARG reduction.

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Key words:
antibiotic resistance, bioinformatics, mobile genetic elements, toxicology

Cooperation with other institutes:
KWR Watercycle Research Institute

Javier Pavez Jara

Formation and impact of recalcitrant and/or toxic compounds generated in Thermal Hydrolysis Process (THP) of waste activated sludge

Research objectives

To understand the mechanisms behind the formation of recalcitrant and/or toxic compounds generated during THP of WAS, used as a pretreatment before anaerobic digestion. Furthermore, to understand possible implications of these compounds in subsequent treatment steps after sludge digestion, such as rejection water and wastewater treatment.

Project outline

Introduction

Anaerobic Digestion (AD) is widely used to reduce, stabilise and recover energy from primary and secondary sludge generated in the treatment of municipal sewage [1]. Sludge management is a fundamental topic of concern in modern WWTP, where it can represent about 50% of the total sewage treatment costs [2]. Therefore, improving sludge conversion to methane and reduction if excess sludge production is desirable in WWTPs.

Many researchers agree that generally the rate limiting step in AD of sewage sludge is the hydrolysis of particulate matter and complex polymers to soluble substrates[2-4]. In order to enhance this hydrolysis, to improve the methane yield, and to reduce sludge retention times in the anaerobic digesters, varieties of sludge pre-treatments have been developed in lab scale with various levels of success. Examples are mechanical, thermal, chemical or biological pre treatment methods or an integration of these[5]. The aim of the current investigation is focused on Thermal Hydrolysis Process (THP), and how the compounds generated in this process affect the rest of the sewage treatment process.

Several THP pre-treatment technologies are commercialised at industrial scale, such Cambi®, Biothelys®, Exelys®, THP®, Lysotherm®, Turbotec®. All full-scale THP processes treat the sludge at elevated temperatures in a range of 160-180°C and a process time of 20-40min to reach an acceptable extent of cell disruption, avoiding the formation of refractory compounds at higher temperatures. Nevertheless, several authors have reported the formation of refractory compounds during THP, without a clear consensus about the specific components that are being formed and how to avoid the formation of these. Also, an increase in nutrients solubilisation has been reported. The combination of both recalcitrant or even toxic refractory compounds and the increased nutrient concentrations may result in operational problems in the subsequent steps of sewage treatment.

These compounds might affect the biological consortia in AD and its subsequent rejection water treatment. Also, nutrients solubilisation may have unexpected consequences in the next steps of sewage treatment, such as pipe clogging (phosphates precipitation), inhibition of the anaerobic biology by ammonia, or others. Therefore a clear understanding of the effects caused by THP on the complete wastewater treatment is required in order to propose strategies to overcome operational problems associated with this technology.

Approach

The proposed research consists of literature research, laboratory research, on-site research.

Results

In process, no published results yet.

Scientific relevance

This project allows to understand the behaviour of the recalcitrant compounds and nutrients released in THP and the effect of them on the next steps in sewage treatment. A fundamental understanding of the composition and characteristics of these compounds, as well as the process of formation will be generated.

Social relevance

Recalcitrant compounds formed during THP process may have a toxic effect on the receptors water bodies or even human health. Hence, a well understanding of the processes involved in the formation of these compounds is fundamental to prevent their formation and possible adverse side effects.

Literature

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Key words:
Thermal pressure hydrolysis, anaerobic digestion, melanoidins.

Cooperation with other institutes:
TU Delft, Vechtstromen, De Dommel, Vallei en Veluwe, Waterbedrijf Limburg, Paques BV

Antonella Piaggio

AD-DAF: Effects of microaerophilic conditions on sludge rheology and biomass activity in Anaerobic Digestion

Research objectives

The purpose of this research is to study the effect of microaerophilic conditions in Anaerobic Digestion, when applying a dissolved air flotation (DAF) system for biomass retention, in order to separate solid retention time (SRT) and hydraulic retention time (HRT) during anaerobic digestion of diluted waste streams. In this study, air is used for flotation and concentration of biomass in a DAF, which will be coupled to a digester (CSTR). This system will be compared to an Anaerobic Membrane Bioreactor (AnMBR). Focus of this study will be on sludge rheology and microbiological effects of microaerophilic conditions in this AD-DAF as opposed to completely anaerobic conditions in the AnMBR. To conduct the above, a laboratory scale AnMBR and AD-DAF system be designed and used to treat synthetic domestic concentrated wastewater.

Moreover, this study also comprehends an investigation on DAF particle removal, assessing the characteristics of process operations and how gas bubble sizes influence particle separation with different particle characteristics (charge, zeta potential, etc.).

Project outline

Introduction

Anaerobic Digestion (AD) is a strictly anaerobic process where oxygen is toxic for the methanogenic bacteria, and generally operates at an oxidation-reduction potential (ORP) of about -400 mV. AD has four main phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis; either hydrolysis or methanogenesis determines the overall conversion rates (van Lier, et al., 2008). Hydrolysis is often considered the slowest and bottleneck of anaerobic digestion, especially when treating wastewater with a high particulate matter content (Visvanathan and Abeynayaka, 2012). Furthermore, both steps are affected by wastewater characteristics and reactor operation conditions.

Hydrolysis process can be done by facultative and anaerobic microorganisms. According to Jenicek, et al. (2014), establishing microaerobic conditions during anaerobic digestion could lead to improving the products formed. Under these conditions, facultative microorganism may grow and promote hydrolysis, enhancing the overall AD process.

Micro-aeration may be a novel treatment to enhance AD, but it is also being used for separation of liquid and particulate matter in Dissolver Air Flotation systems (DAFs). As anaerobic Membrane Bioreactors (AnMBR), DAF are able to decouple hydraulic and solids retention times, withouth the flux limitations that AnMBRs usually have. On the other hand, DAF removal efficiencies and effluent quality after DAF treatment are lower than in AnMBR. Thus, coupling DAF and AD is a novel treatment train that needs to be further assessed.

Approach

The research will focus on the evaluation of the AD+DAF system, based on the assessment of a laboratory scale DAF, the AD-DAF system and an AnMBR (used for comparison). As can be seen in Figure 1, the research is divided into 2 main work-packages that depend on each other.

On the first work-packages, batch trials related to bubble behavior and particle removal will be performed on a DAF column. The information gained on this work-package will be used for coupling of the DAF system with anaerobic digestion (work-package 2). Additionally, the AD-DAF system will run continuously and batch, to further asses the effects of microaerophilic conditions on AD. The Work-package 2 additionally compromises the comparison between the AD-DAF and an AnMBR, both fed with the same synthetic wastewater.

Scientific relevance

This research will help in the deep understanding of effects of microaeration in anaerobic digestion. Furthermore, it is a promising approach for wastewater treatment, since the proposed system can be used in decentralized treatment and is flexible.

Social relevance

The outcomes of this research may be useful for water stress cities, where water availability plays a key role in economic development and population health, because it is centre on resource recovery and treated (waste)water reuse. The project is part of the LOTUS-HR programme that studies water treatment and safe reuse for the Delhi

drain water, India.

Literature

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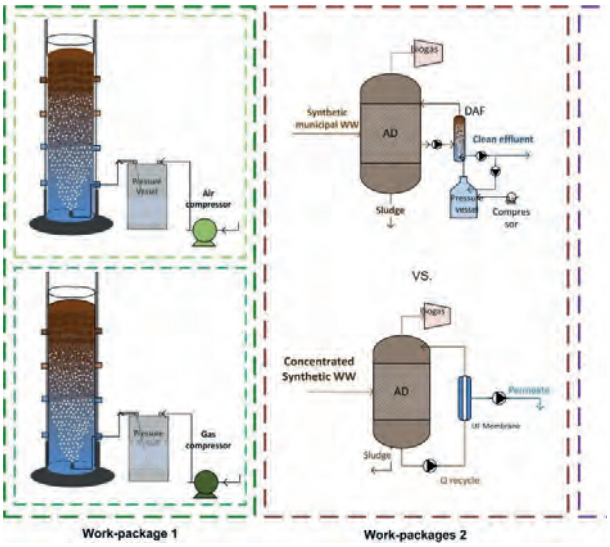

Figure 1: Schematic representation of the research work packages

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Key words:
Wastewater, DAF, anaerobic digestion, resource recovery

Cooperation with other institutes:
IHE Delft, National Environmental Engineering Research Institute (India), The Energy and Resource Institute (India), Nijhuis.

Matthijs Rietveld

Solids in sewer systems

Research objectives

Post et al. (2016) have shown that most failures of sewer systems occur in the anterior part of the sewer system. This anterior part consists of lateral house connections and gully pots. This research will focus on the maintenance of these gully pots. Proactive maintenance is used to prevent flooding, but proactive maintenance can only be provided in a cost efficient way if enough information or knowledge is available.

Currently, the physical phenomena of transportation and accumulation of solids in sewer systems are not fully understood. The objective of this research is to increase the knowledge on solid transport and accumulation of in gully pot to improve maintenance strategies.

Project outline

Introduction

Sewer systems have two inputs, namely wastewater and storm water. Both streams consist almost entirely of water, but the small amount of entrained solids give raise to a wide range of problems.

The two main problems caused by these solids are accumulation and pollution. Accumulation occurs at all places in sewer systems. This leads to restrictions and blockages, which causes, according to Fraser and Ashley (1999), premature spills.

These events do not only cause nuisance, but also environmental damage and health risks, because these solids are highly polluted, according to Fulcher (1994).

One of the sources of these solids are the solids that accumulate on streets. Especially the small particles on streets get mobile during wet weather conditions, as shown by Grottker (1987). These mobilised particles enter the sewer system via gully pots.

Approach

The research will be divided in five research questions:

1. What solids are transported to gully pots?
2. Does street sweeping decrease the amount of solids transported to gully pots?
3. What solids got retained in gully pots?
4. What physical mechanisms influence the retention efficiency of gully pots?
5. How fast do gully pots in different environments sil in real life situations?

The first two research questions will be answered by a field measurement. In this project we have installed filters in gully pots in Rotterdam. We measure both the amount and type of solids that are caught in these filters over time. This project will last two years. In the second monitoring year the street sweeping will be intensified to determine the effect on the solid transport to gully pots.

The third question will be addressed in a lab experiment. In this controlled environment we can measure both the input of solids and the accumulation of solids. This can be converted to a catching efficiency, which depends for example on the solid size.

In the same lab setup the flow pattern will be measured via Particle Image Velocimetry (PIV). This will give insight in the physical mechanisms influencing the solid deposition and with that we can answer the fourth question.

The last question will be answered by a statistical model on gully pot silting based on field measurements lasting one year.

Results

The first field project with filters started in April 2018 and will last until 2020. First results clearly show influences of presences of trees and rainfall events.

The sedimentation test in the lab are about half ways. These preliminary results shows strong influences of sediment size, discharge and effective pot depth on the catching efficiency. However, more tests are needed to evaluate for example the efficiency of other geometries and tiny particles.

PIV measurements have been performed and the results are studied at the moment.

The other field project started November 2017 and will last until November 2018. The statistical model has been mainly developed and some results have been published at the UDM conference.

Scientific relevance

This PhD project will give insight in the accumulation and transportation of solids. These phenomena are important in many different research fields. The tests that will be performed will increase the knowledge of these phenomena in the world of sewer systems.

Social relevance

By increasing the knowledge on accumulation and transportation of sewer solids, the maintenance programme can be improved. This will decrease the costs and improve the serviceability of the sewer system. This reduces environmental damage, health risks and nuisance.

Literature

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Key words:
Sewer asset management, gully pots, solids, accumulation

Cooperation with other institutes:
KU Leuven

Muhammad Risalat Rafiq

Water quality assessment of small-scale managed aquifer recharge systems for drinking water provision in coastal Bangladesh

Project outline

Introduction

Sustainable drinking water supply is a major concern issue for achieving MGDs and it becomes a major challenge due to rapid population growth in urbanizing deltas like Bangladesh. SW part of Bangladesh (Khulna-Satkhira-bagerhat) suffer from both safe and fresh drinking water as a consequences of saline-brackish groundwater at shallow depth, elevated arsenic level and less quantity of surface water during dry season with risk of pathogen.

To combat against this, MAR is introduced as promising technique in coastal areas of Bangladesh. A typical MAR system consists of infiltration wells which are constructed to recharge the shallow aquifer using pond and rain water during times of water abundance in the monsoon period. During the dry season when surface water resources dry up, the stored freshwater is recovered from a central well (Figure 1). Other advantages of MAR systems include filtering of pathogens and availability of water sources being protected during cyclonic storm surges that sometimes flood the area.

A consortium of UNICEF, Department of Public Health (DPHE), Dhaka University (Department of Geology) and Acacia Water (Consultants, the Netherlands) built 20 pilot MAR systems in Khulna-Satkhira-Bagerhat regions in 2012. At present, a total of 99 sites have been constructed after initial successes. The NWO UDW DeltaMAR project investigates scientific knowledge caps in relation to the self-propelling of MAR systems in the region. The project includes 4 PhD projects concerning water quantity and quality, governance, and hydrogeological research questions.

Research objectives

This research (started January 2016) aims to assess hydro-geochemical changes (water quality improvements and deteriorations) in Managed Aquifer Recharge (MAR) during injecting fresh water into brackish aquifers; as well storing and later abstracting of mixing water with particular emphasis on potential mobilization of arsenic, which has been observed at some sites.

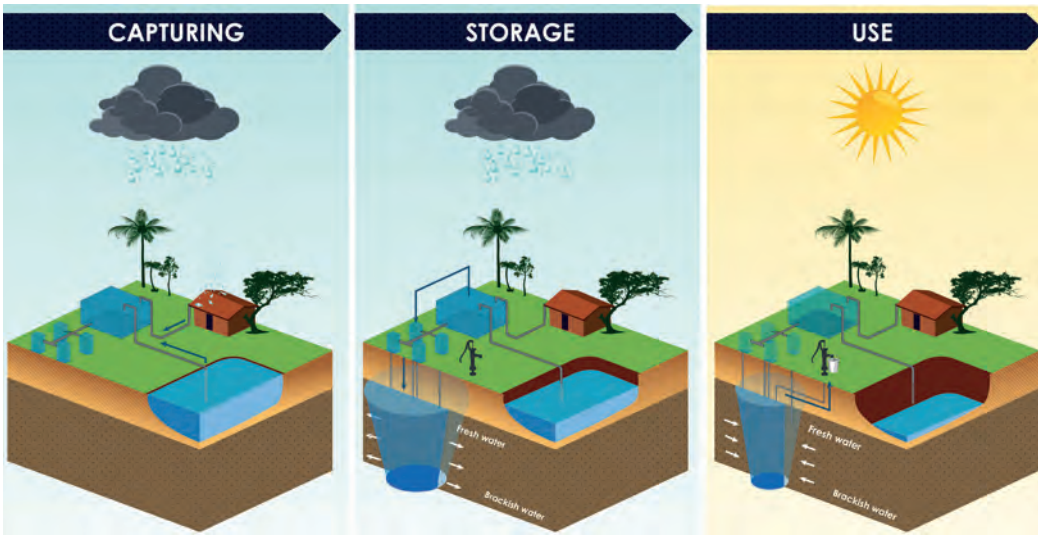

Figure 1: Conceptualized diagram of Managed Aquifer Recharge (MAR) system in Bangladesh

Approach

a) Interpretation of existing data of 99 MAR sites with python-pandas programming to determine sites (four to five) of similar geochemical behavior.
b) Conducting Push Pull Tests (PPTs) and Batch experiments at selected sites to understand site-specific hydro-geochemical hypotheses for trace metal (focus on arsenic) (im)mobilizations.
c) High resolution monitoring at two selected sites to zoom in and for better understanding of the various hydro-geochemical processes in MAR.
d) Hydrogeochemical reactive transport models will be developed and tested with field data using PHREEQC software in order to enable quantitative assessment of water quality changes during MAR at specific locations.

Scientific relevance

Besides saline to brackish groundwater, elevated arsenic concentrations is one of the major issues in the project areas like other parts of country. This research will provide insights in arsenic (im)mobilization reactions during MAR. With the developed geochemical model site specific conditions can be identified that produce the best water quality and low arsenic levels.

Social relevance

The DeltaMAR project aims to set the scientific framework and provide (practical) knowledge to build many more of these MAR systems in coastal Bangladesh and comparable delta settings ensuring water quality and good governance.

Literature

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Key words:
Groundwater quality, Managed Aquifer Recharge

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Department of Geology, University of Dhaka

Daniel Sihombing

Household water safety plan: A comprehensive approach in improving water quality at a household level

Research objectives

This research aims to extend the water safety plan concept to household level in order to provide a better approach to improve the drinking water quality in developing countries and at the same time to increase the probability of household water treatment (HWT) adoption among target group by appropriately influencing behavioral factors that are behind successful adoption of HWT through targeted interventions.

Project outline

Introduction

This research presents a framework called household water safety plan (HWSP). HWSP is a comprehensive and integrated approach which addresses household environmental characteristics, behavior related to water, sanitation, and hygiene (WASH), household water management, and preference on type of HWT to provide appropriate and sustainable solution for clean drinking water quality at household level.

Adoption of HWT, i.e., regularly use it, is one of the key points in this framework. Household water treatment (HWT) is one of the options to improve the water quality at household level. HWT can safeguard public health in areas persistently challenged by efforts to achieve universal access to safe water, especially when the quality of the water distributed by water suppliers is untrustworthy. However, households often do not treat water regularly which leads to small impact on health.

Approach

Modeling the adoption of HWT is the first step in this concept. The model is made based on the assumption that the adoption is influenced by the behavioral determinants or psychosocial factors, and the psychosocial factors are influenced by the people's characteristics or socio-environmental characteristics. The probabilistic model will visualize and model this causal relationship to explain this water-related behavior, i.e., adoption of HWT. The household interview in rural areas in Nepal and Indonesia is the input for the model.

Results

A Bayesian belief network (BBN) model that integrates socio-economic characteristics and psycho-social factors to explain the adoption of HWT based on 512 household interviews in mid-western Nepal was developed (Figure 1). We found that the adoption of technology is influenced by the psycho-social factors norms, followed by the knowledge level for operating the technology. Education, wealth level, and being exposed to the promotion of HWT were the most influential socio-economic characteristics. Furthermore, the scenario analysis revealed that interventions that only target single socio-economic characteristics do not effectively boost the probability of HWT adoption.

Scientific relevance

The research will address the gaps in our understanding of HWTS intervention in developing countries, in particular how to find the optimum strategy to improve the water quality at household level in under-privileged areas. Moreover, this research will also reveal the relationship between household characteristics and behavioral determinants in order to predict the adoption of HWT.

Social relevance

This research will support sustainable development goal of access to clean drinking water for all, especially in low developing countries, and also to help decision makers or relevant stakeholders in designing an implementation program that can positively impact the health of its citizens. Interventions, for at least 1 year, based on the analysis will be done in the study location to validate the model and also the framework.

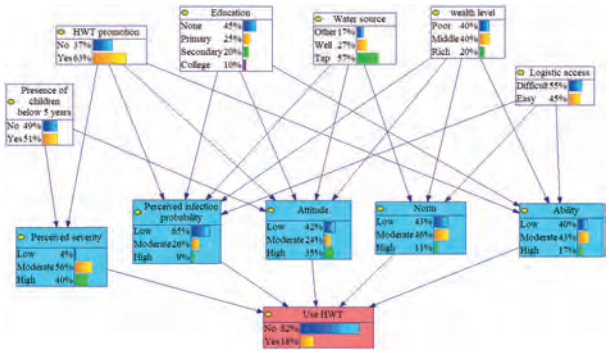

Figure 4. The compiled BBN model of household water treatment adoption in rural Nepal. White nodes represent socio-economic characteristics, blue nodes represent psycho-social factors, and the red node is the outcome of interest. The bars in each node show the probability that a node is in a certain state.

Literature

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Key words:
Household water treatment, household water safety plan, probabilistic model of human behavior, choice model

Cooperation with other institutes:
EAWAG; World Vision in Indonesia, LKP Anugerah Anak Sumba

Mona Soliman

Enhanced low-cost ceramic membrane filters for drinking water treatment

Research objectives

The objective of this project is to enhance the LCMFs for >log3-5 removal of viruses, in order to reach the "protective" to "highly protective" WHO performance target. This goal can only be reached by making innovative changes to the current membranes.

Project outline

Introduction

The proposed project consists of three sub-projects:

a) Enhanced top layer LCMFs are currently composed of one homogeneous porous layer, whereas for virus removal it is desirable to develop (1) a-symmetric membrane structure, and (2) biofilm promotion on the influent side of the membrane to enhance biological degradation of viruses.

b) Incorporation of metal nanoparticles (with ChemE) Metallic nanoparticles have been found to kill viruses, but have not yet been applied in LCMFs. On-site production and smart mixing of nZVI, nAg and nCu ratios would enhance the current recipe for the removal of both viruses and bacteria.

c) Valorising local materials for human-centered design (with IDE) Improved, integrative LCMF design taking into account end-users' needs, awareness, habits, aesthetic appreciations, existing knowledge, cultural values; and dependency on outside sources for material supply, manufacturing and maintenance.

Particular attention will be given to unraveling virus inactivation pathways, including role of reactive oxygen species (ROS), sub-lethal injury, water quality matrix and post implementation inhibitors.

Results

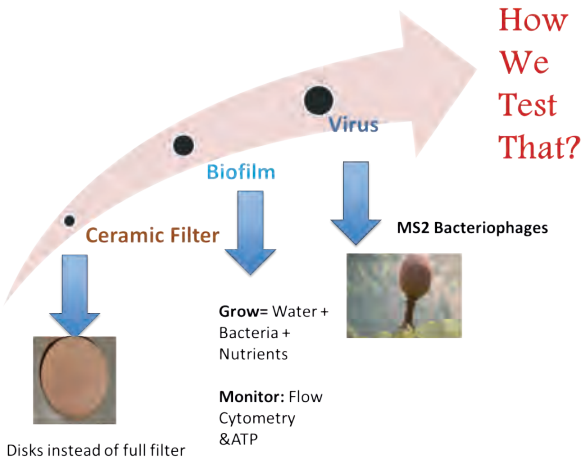
Initial results point out towards low log removal (1-2 logs) under stable conditions which is less that the target removal. However change in conditions lead to 5 log removal of MS2 –used as virus indicator. The latter is still under investigation.

Scientific relevance

The current approach in investigating virus removal and retention in biofilm grown in household treatment has never been investigated before. Despite the natural growth of biofilms in household treatment, it remains unknown if it is a positive addition or negative. Moreover, biofilms grow in drinking water pipes, in soil filtration systems, such as slow sand filters. Thus understanding the interaction between biofilms and Virus is valuable knowledge –not just within the studied context but rather on other studies that investigates the relation between them on general manner.

Social relevance

Ceramic water filters (CWFs) are a point-of-use technology aimed to provide safe water for those in low resource settings. CWFs have been shown to effectively remove bacteria and parasites but fall short of meeting World Health Organization targets for virus reduction. Given the global burden of disease of viruses such as rotavirus and norovirus, improvements in virus reduction could potentially lead to greater health impacts.



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Start date project: Jan 2016
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Key words:
Virus, Household treatment, Biofilm

Cooperation with other institutes:
UNI, Nigaragua, UNAN, Nigaragua, Nuevas Esperanzas, Nigaragua, Potters for Peace, Nigaragua, Filter Pure and RDI, Cambodia, University of North Carolina, USA, Practica Foundation, Marcel Tielemans, Het Waterlaboratorium

Bram Stegeman

Sewer Leak Detection, Quantification and Location

Research objectives

This research aims to develop a methodology for detection, quantification and location of sewer leakage based on a combination of existing and new techniques.

Project outline

Introduction

Leakage is one of the dominant causes of structural failure of pressure mains and an important cause of structural failure of gravity sewers. In addition, exfiltration of sewage (wastewater flowing from the sewer system into the ground) might have detrimental environmental effects and threaten groundwater quality used for drinking water production. Infiltration of ground water (groundwater flowing into the sewer system) results in an increased hydraulic loading of wastewater treatment works and a decreased treatment efficiency. Consequently, sewer operators need methods and techniques to be able to detect, quantify and locate leaks.

Approach

In this research two existing in-sewer techniques, focused electrode leak location (FELL) and QUEST-C (Rieckermann et al. 2007) will be further developed and improved and two new techniques derived from geosciences, electrical resistivity tomography and self-potential monitoring will be tested on the same locations. The experiments will be performed in a laboratory setup and on full scale, operational sewers and pressure mains. The potential of the new (geo-electrical) methods will be analyzed for their capabilities to detect and locate and possibly quantify leaks.

Scientific and social relevance

The current available methods do not provide the necessary information about leakage of sewers, pressure mains and subsequent infiltration or exfiltration. In order to obtain the necessary information, there is a need for a clear strategy based on a combination of existing and new techniques. The introduction of new techniques will complement the available technologies for detecting, quantifying and locating infiltration or exfiltration (I/E). The greater choice of techniques will enable sewer system and transport system operators to select an appropriate and cost effective strategy for dealing with leakage that can be readily applied, enhancing the development of novel operation and maintenance concepts.

Literature

Rieckermann, Jörg, Vojtěch Bareš, Oliver Kracht, Daniel Braun, and Willi Gujer. 2007. “Estimating Sewer Leakage from Continuous Tracer Experiments.” Water Research 41(9):1960–72.

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Start date project: Feb 2017
Expected end date: Feb 2021

Key words:
Leak detection, sewer, infiltration, exfiltration, electrical monitoring

Cooperation with other institutes:
Research is part of Cooperation Programme TISCA (Technology Innovation for Sewer Condition Assessment)

Adithya Thota Radhakrishnan

D-SHiT: Domestic Slurry Hydraulics in Transport systems

Research objectives

Focused on studying the transport aspects of domestic slurries, the study aims at characterizing the slurries with respect to its rheological behavior and building a 1-dimensional non-Newtonian multiphase flow model. This enables us to design efficient slurry transport systems for future sanitation concepts.

Project outline

Introduction

New sanitation concepts (Fig. 1) stem from the need for better nutrient recovery from domestic slurries and water management. Traditional sanitation concepts use large amount of water, thereby making the slurries dilute. Whereas, new sanitation concepts focus on reducing the consumption of water and possess pressurized pipelines to transport them. This reduction in the consumption of water are generally attributed to the success of these new sanitation concepts, and investigations show that these slurries can be treated more efficiently.

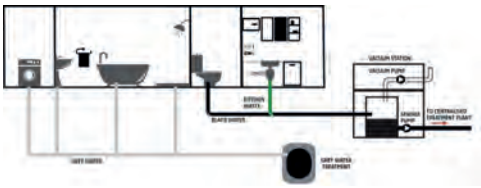

Figure 1. Schematic of a new sanitation concept

Future domestic slurries are likely to contain a significant fraction of grinded kitchen waste; with low water consumption, it makes the slurry concentrated with solids and therefore they exhibit non-Newtonian behavior. A number of transportability issues for new sanitation concepts arise, related to the dilution and multiphase interaction.

The D-SHiT (Domestic Slurry Hydraulics in Transport systems) project was initiated to address these issues of concentrated domestic slurry (CDS); for this the project is divided into three parts.

- Rheological characterisation of non-Newtonian multiphase CDS
- Transport experiments at the pipeline test loop
- Developing a transport model for these slurries

Approach

The rheological characterisation of the slurries will be done using a rotating viscometer resulting in a relation for shear stress for shear rate applied on the fluid. The influence of solid concentration and temperature on the rheology will be determined. The experiments will be performed using slurry samples collected from a small-scale pilot project in Sneek (Leuwarden) running these sanitation concepts.

Artificial slurry which mimics the rheological behaviour of CDS will be used to perform the experiments in the pipeline test loop. Initially the turbulent flow of the fluid will be studied and later the flow with gas. Using the data from experiments, a 1-dimensional transport model will be built to design the transport system. Assumptions that reduce the complexity of the model will be validated using CFD.

Results

The viscosity and yield stress of grinded kitchen waste and brown water increase with concentration of total solids present as seen in Fig. 2. This can be attributed to the complex solid-solid and solid-liquid interaction. A decrease in yield stress and viscosity can be observed with the increase in temperature; due to the increase in thermal activity.

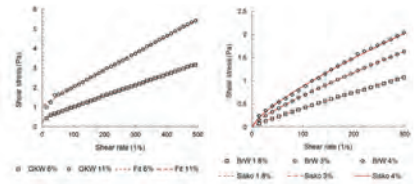

Figure 2. (Left) Rheology of Grinded Kitchen Waste at 11% and 6% solid concentration with Combined Herschel-Bulkley model fit. (Right) Rheology of Brown Water at 1.8%, 3% and 4% solid concentration with Sisko model fit

The assumption that CDS can be modelled as a homogenous single-phase fluid represented by its bulk viscosity and density is verified using CFD (Fig. 3). This is done by mirroring the rheological experiment in CFD where the fluid is modelled as being homogenous and comparing the results (Fig. 4).

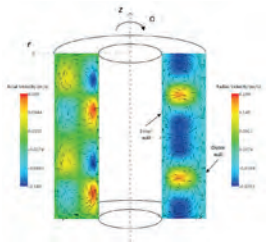

Figure 3. CFD mirror of the rheological experiment

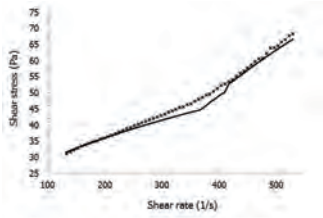

Figure 4. Comparing the experiment results (-) to that from CFD (x)

Social & Scientific relevance

In the industrialized world, flushing the toilet with large quantities of water is a routine. In other parts of the world sanitation is not that simple. Due to lack of infrastructure and water scarcity, around 2.5 billion people have no sufficient sanitation at their disposal. The new sanitation concept overcomes the sanitation problems due to lack of water resources. Moreover, the sanitation concept offers promising results with respect to recovery of nutrients and production of energy (bio-gas). All these benefits can be achieved in large scale if the whole chain of new sanitation systems are economically competitive with the common practise. Although all recent research on the new sanitation concept focus on treatment processes and source separation, to benefit from these concepts all aspects of sanitation systems including the collection and transport need to be considered.

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Key words:
Domestic slurries, rheology, pressure loss, transport design, hydraulics, CFD, non-Newtonian, multiphase

Cooperation with other institutes:
Research is conducted within the framework of a STW project: Waternet, Rioned, STOWA, Deltares, Waterschap Zuiderzeeland, Grontmij, XYLEM

Sara Toja Ortega

Biological Removal of suspended solids by Aerobic Granular Sludge

Research objectives

The aim of the project is to understand the biological mechanisms of removal of suspended solids by aerobic granular sludge (AGS). Specific objectives include:

- To assess the ability of AGS to degrade suspended solids
- To determine the degree of biological degradation of suspended solids in AGS, focusing on the main suspended solids present in municipal sewage.
- To develop accurate methods to characterize suspended solids and their conversions in AGS systems.
- To localize the active regions involved in suspended solids degradation in aerobic granules and flocs.
- To identify microbial agents involved in the hydrolysis of suspended solids in AGS.
- To study the interactions between influent composition and microbiology of AGS.
- To analyse the effect of suspended solids and their hydrolysis products in granulation and granule morphology.
- To evaluate the contribution of suspended solids to biomass growth and nutrient removal.

Project outline

Introduction

Aerobic granular sludge (AGS) is a relatively new water treatment technology that provides an alternative to conventional sewage treatment plants (i.e. activated sludge technology)[1]. It offers the possibility of building compact plants with much lower energy requirements due to the optimal settling properties of aerobic granules, which enable an efficient biomass-effluent separation needless of an additional settling tank and biomass-recirculating pumps. Furthermore, the microbial composition of aerobic granules allows nitrification, denitrification, phosphorus removal and COD removal in a single compartment[2], which further contributes to the reduction of the space needed for wastewater treatment.

In municipal and industrial wastewater, a high percentage of the chemical oxygen demand (COD) to be treated is composed by particulate substrate: in the Netherlands, it accounts for around 50% of the total COD. Suspended solids are degraded well by granular sludge, with average removal efficiencies of 91-99% in full-scale installations. However, lab-scale experiments using synthetic or real wastewaters containing suspended solids resulted in changes in granule structure, creating a rough, irregular surface that negatively affects the settleability of the sludge, and could eventually lead to system instability[3,4].

Despite the strong presence of suspended solids in wastewater, little is known about the mechanism of removal or the fate of these compounds. Localising hydrolysis (i.e. bulk liquid, granule surface, flocs), measuring the amount of degradation of suspended solids and their contribution to nutrient removal, and understanding their impact in granule structure and function is of great interest to exploit the full potential of aerobic granular sludge.

Approach

Hydrolysis and degradation of different types of complex contaminants will be studied, at different redox conditions and at different biomass fractions. Additionally, the microbial populations involved in the degradation of suspended solids will be identified and localized in the granules. The methodology for this will include molecular methods for microbial population analysis, enzymatic activity tests for the study of hydrolytic activity of the sludge and metabolic labeling techniques to track hydrolysis products in granules. The biomass used in the experiments will be both from lab scale and full scale origin.

Scientific relevance

This PhD project will contribute to a better understanding of AGS systems, and the interactions between microbial populations, influent composition and operational parameters.

Social relevance

By understanding the degradation and utilization of suspended solids in granular systems, it will be possible to improve the current AGS technology.

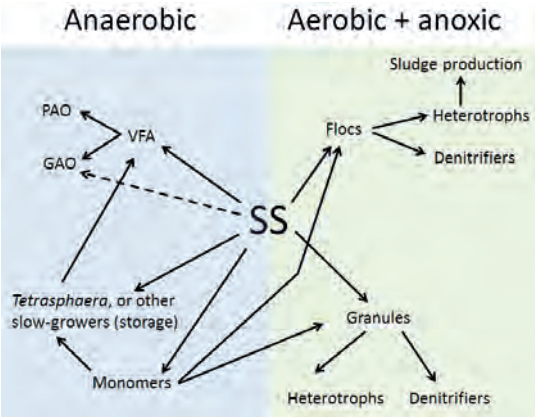

Figure 1. Possible fates of suspended solids in Aerobic Granular Sludge reactors

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Key words:
Aerobic granular sludge, Suspended Solids, Degradation, Imaging

Cooperation with other institutes:
Montana State University, Wageningen UR, Royal Haskoning DHV, Department of Biotechnology (TU Delft)

Henry Wassaija

Biogas-Solid Oxide Fuel Cell (SOFC) Energy System For Rural Energy Supply

Research objectives

The main research objective is the development of a small scale (off grid system) Solid Oxide Fuel cell system for efficient electricity production from biogas. The system should be suitable for employment in rural areas in developing countries.

Project outline

Introduction

The small scale Biogas-SOFC energy system is seen as a next generation off-grid energy technology for both developed and developing countries due to the high thermodynamic efficiency of fuel cells (Biogas-SOFC electrical efficiency of over 50% and 60% for CHP has been reported in literature) [1]. Since high temperature heat is produced as a by-product, such a system can simultaneously promote sanitation among the rural community if faecal matter is used as one of the digester feed stocks.

Nevertheless Biogas-SOFC energy systems still face a major challenge of high initial capital and operational expenditures for gas cleaning. Particularly H2S, but also other trace compounds negatively affect SOFC operation. It is estimated that cleaning of biogas could increase the system capital cost by 6-7% and the annual operational cost by more than 40% [2]. Cost-effective low maintenance gas cleaning is therefore important for economic feasibility of the entire system.

Approach

Therefore, this research focuses on the technical and economic challenges of current commercial and laboratory scale biogas cleaning units. Special focus is directed towards frugal cost mitigation strategies for gas cleaning for example by combined in-situ bioreactor upgrading and application of cost-effective sorbents. Overall this research will be divided in five parts:

1. Techno-Economic Review of Gas Cleaning Units for Small Scale Biogas SOFC Systems For Rural Energy Supply.
2. Study on frugal innovation potential for off-grid energy & sanitation supply in developing countries using Biogas-SOFC systems.
3. A selection of identified potential frugal components of Biogas-SOFC systems will be experimentally tested for their feasibility. For example if local soil and/or biochar can be used to reduce the H2S-concentration in biogas, experiments can be performed to determine its technical and practical feasibility.
4. Modelling of the selected Biogas-SOFC system using software (such as biowin and cycle tempo) for studying the influence of operating parameters on the thermodynamic efficiency of the integrated system.
5. Technical study of the influence of realistic impurities (results from WP3) on the performance of SOFCs during dry/steam/combined reforming (this is an envisaged operating condition for a small scale Biogas- SOFC system).

Figure 1: Schematic overview of Biogas-SOFC system and required steps for integration

Results

Since February 2018, a conceptual design has been made based on literature study which comprises of the several components that will be required to successfully integrate both systems. Currently, multiple rural household digesters in East Africa are being evaluated for their suitability to be integrated with a SOFC in co-operation with SNV and SIMGas B.V.

Scientific relevance

So far limited research has been performed on the dynamic integration of low temperature biological systems (30-40oC) with high temperature (800-1000oC) thermochemical systems. Their physical integration will require us to match biological kinetics with thermochemical kinetics and at the same time put strict requirements on the presence of trace pollutants in biogas. In contrast to biogas upgrading for gas grid injection, for SOFC operation no CO2 removal is needed [3]

Social relevance

Currently, biogas usage in Africa has been focused mainly on heat production for cooking, and aimed at reducing indoor air pollution and overdependence on fuelwood [4]. However, due to the technological revolution, electricity production from biogas could also serve to meet the increasing rural electricity demand in an economical way that is driven by the technological revolution i.e. mobile communication technology. Also, due to the existing sanitation challenges in rural communities in developing countries [5], biogas production from faecal matter can potentially enhance sanitation and hygiene practices in such communities.

Literature

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Start date project: Feb 2018
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Key words:
Biogas treatment, Solid Oxide Fuel Cells, Frugal Innovation

Process and Energy, SIMGas and SNV

Liangfu Wei

Fluoride removal from groundwater by low-cost mineral-based adsorbents

Research objectives

The main objectives of this paper are to a) investigate and compare the F- uptake by the selected adsorbents from groundwater; b) explore the mechanisms of F- removal; and c) evaluate the (dis)advantages of selected adsorbents for F- removal from groundwater.

Project outline

Introduction

Fluorosis due to excessive concentration of fluoride in drinking water has been reported in at least 28 countries. Around 200 million people over the world are under the dreadful fate of fluorosis [1]. The removal of the excess fluoride from groundwater is essential in terms of protection of public health and environment.

Among the different methods reported in literature, adsorption process is considered to be one of the most promising technologies due to its advantages such as low cost, simple operation, and high effectiveness. In the past several decades, over 100 adsorbents have been developed. Various adsorbents have shown strong potential for the removal of fluoride. However, most adsorbents also have drawbacks that cannot or unsuitable be used in drinking water treatment [2, 3]. By means of comparison to over 100 different materials, Bhatnagar et al. (2011) concluded that mineral-based adsorbents are promising for fluoride removal [4]. This might be due to the fact that mineral-based adsorbents normally possess layered or reticulate structure with electropositive multivalent metal ions which present strong affinity for fluoride because the high electronegativity and small ionic size of fluoride [5].

Approach

Experimental studies were carried out with six different, low-cost adsorbents. Before use, all the adsorbents were crushed using a ball mill, then washed using deionized water for several times and dried in an oven at 65°C for 24h. Fluoride solutions with different concentrations were prepared with sodium fluoride (NaF) as the source. All the initial solutions were adjusted to pH 8.5 using NaOH (0.01 M). The batch adsorption experiments were carried out in 100 mL glass bottles with 100 mL fluoride solutions at room temperature (25±0.5°C). After stirring for 7 days, the solutions were filtered by 0.45 μm membrane then were analyzed by Ion chromatograph (IC).

Results

Figure 1 shows the adsorption isotherms of fluoride uptake on slag based geopolymer, struvite and pellets from Bunnik and Sint Jansklooster. The initial F- concentration was 2, 5, 10, 20, 40, 80mg/l, adsorbent dose was 20 g/l.

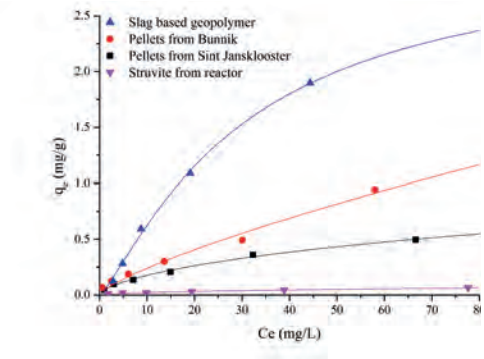

Fig. 1 Adsorption isotherms of fluoride uptake on mineral-based adsorbents.

For all adsorbents, fluoride uptake increased with an increase in the initial fluoride concentration. For the same initial fluoride concentration, the fluoride uptake by slag-based geopolymer was higher than the other sorbents. However, at low concentrations, also softening pellets showed affinity for fluoride. Fluoride removal by struvite was very limited, and there were problems to keep the struvite stable during the experiments. Fly ash- and metakaolin-based geopolymers did not show defluorination effect. These preliminary sorption experiments have shown the potential of softening pellets and slag-based geopolymers for fluoride removal. Future experiments will focus on kinetics, regeneration and leaching.

Scientific relevance

This paper provides the studies on fluoride removal by low-cost mineral-based adsorbents. Six different types of adsorbents were compared for defluorination. Equilibrium studies were carried out and the best adsorbents performer was selected for the optimization.

Social relevance

An optimized defluoridation system with effective adsorbents will be developed, which can be applied to remove fluoride from groundwater to protect the health of people living in the high fluoride regions.

Literature

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Start date project: Oct 2015
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Key words:
Fluoride, Adsorption, Groundwater, PHREEQC

Cooperation with other institutes:
CSC

Peng Wei

Mixing Characterisation for Enhanced Biomass Conversion Using CFD Modelling in Gas-mixed Anaerobic Digesters

Research objectives

(1) In full-scale anaerobic digesters, the influence of specific key factors (rheology, temperature, mixing mode) on mixing processes are identified and quantified by CFD modelling and experimental validation.

(2) Obtaining an optimised reactor design for better operational performance based on improved mixing and hydrodynamics in practice.

Project outline

Introduction

Anaerobic digesters are commonly applied for the stabilisation of excess sewage sludge, converting the biodegradable organic matter into energy-rich biogas. Effective conversion of the organic mass can only be accomplished when proper mixing of the digester content is warranted, maximising mass transfer between substrates and microorganisms. Although, anaerobic digesters are generally implemented as continuous stirred tank reactors (CSTR) (Lindmark et al. 2014), full scale treatment performances are sometimes below expectations: sludge stabilisation and gas production are less than expected. Possibly, the actual full scale mixing regime differs from the theoretical design (Capela et al. 2009). In order to better understand the discrepancy between full scale reactor performance and theoretical potentials, enhanced insight in the actual mixing regime is of great importance. Possibly, full scale performance is limited by short-circuiting or appearance of dead zones inside the reactor (Wu 2013). In the current research, we use computational fluid dynamics (CFD) modelling as a numerical simulation for solving fluid flows, in combination with extensive rheological characterisation of waste activated sludge (WAS) to identify imperfections in flow regimes in anaerobic digesters, aiming at a better digester design.

Approach

(1) CFD modelling implementation, mainly by package ANSYS Workbench and Fluent, using methods of Eulerian-Eulerian and Euler-Lagrange, and non-Newtonian fluid characteristics for the gas-liquid flow.

(2) The full-scale digester with gas mixing in WWTP de Groote Lucht (Hoogheemraadschap van Delfland) is selected for investigation.

(3) Validation, including simulation referred to published experimental results in lab-scale digesters (Karim et al. 2004), and the tracer experiments in the full-scale tank.

(4) The concentric rotational rheometer is utilised for measuring the sludge rheological properties, applying different solid concentrations at various temperatures.

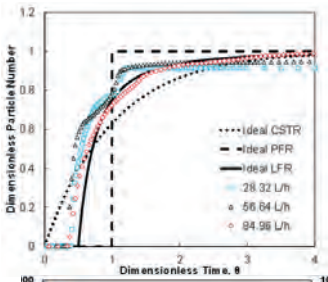
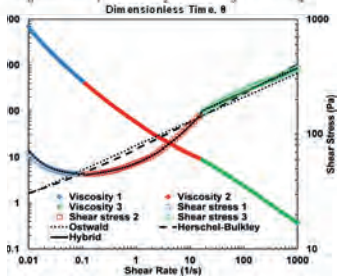


Fig. 1 Predicted results of particles residence time distribution in the lab-scale digester.



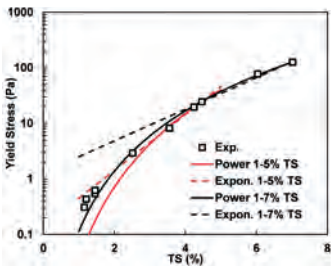


Fig. 2 Rheological properties of the studied WAS (Wei et al. 2018): A) flow curve fitting, TS 6%, and B) correlation between yield stress and the applied TS range.

Results

A lab-scale reactor experiment from literature (Karim et al. 2004) was successfully described by a CFD model choosing proper models for interphase force, bubble size and liquid rheology. The mixing performance was evaluated by particles tracking, showing an approximated laminar-flow reactor (LFR) mixing behaviour that distinctly deviated from the expected CSTR (Fig. 1). This indicates a limited mixing enhancement from the applied gas-sparging strategy. Using the developed model settings, simulation in a full-scale digester was implemented as well. Based on experimental results, the WAS from de Groote Lucht showed considerable TS-dependent, yield-pseudoplastic and thixotropic behaviour (Fig. 2) (Wei et al. 2018).

Scientific relevance

Most mixing studies have been carried out so far on laboratory scale and pilot scale installations. Full-scale studies are limited to tracer experiments, only returning an overall image of solids retention times. The detailed mixing properties in current systems therefore need to be unravelled to reach better performance of current digester systems.

Social relevance

Optimised operation and enhanced biomass conversion in practice will result in more biogas from waste activated sludge. This leads to more energy recovery from wastewater and less release of greenhouse gases during digestate storage and transport. Modification and/or improvement of the design of full-scale digesters will lead to a more sustainable processing of residual organic streams.

Literature

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Key words:
Anaerobic digestion, two-phase flow, computational fluid dynamics (CFD), mixing, temperature, rheology

Cooperation with other institutes:
coupled to STOWA project "Community of Practice -Menging slibgisting"

Job van der Werf

Adaptable and Robust Integrated Real Time Control of Urban Drainage Systems

Research objectives

This study aims to assess a number of fundamental questions that, today, factor into the lack of implementation of Real Time Control (RTC) within Urban Drainage Systems. The main topic of interest is how RTC strategies are capable of handling a change environment, including climate change, change in land use and further restricting legislation. As the project is still in its infancy, the objectives are likely to change.

Project outline

Introduction

All processes within Urban Drainage Systems (UDS) are highly dynamic, both within the short and long term. Due to this, it seems illogical to operate the UDS infrastructure (namely sewer systems and waste water treatment plants) under static conditions. Combined Sewer Overflows (CSOs) are a direct result of overloading of the sewer system, which can be mitigated by expensive expansions of the sewer systems, or decreased through such dynamic operations. Significant advances have been made in the scientific literature on RTC since the late 20th century, yet real implementation of control with a view of the wide system is limited.

One of the key missing links in the industry is a vision towards the distance future. The process of implementing RTC strategies within a catchment is highly time consuming, making it critical to ensure that proposed strategies will be functional within future scenarios.

Approach

The project is interlinked with Waterschap de Dommel, where Petra van Daal-Rombouts proposed the first steps towards a fully integrated RTC strategy during her PhD (which she successfully completed in 2017). Albeit the fact that the project will be mainly model based, due to the high involvement of Waterschap de Dommel the results can be assessed within a real world setting.

The Eindhoven Catchment is specifically of interest due to the high volume and quality of data points available, and the existence of three clearly separated catchments, allowing for the assessment of transferability within a single catchment. The specific methodology is currently being developed.

Scientific relevance

The development of a RTC strategy able to withstand the test of time is absent in the literature. Development of RTC strategies, however, is of ongoing research. This project will allow future developments to effectively take into account future changes, progressing the field towards a more realistic, robust setting of RTC.

Social relevance

Contamination of water resources is a highly relevant societal issue, both for health risk mitigation, aesthetic and legislative reasons. This is combined with an inherent dislike for spending of public money and disruption to traffic (resulting from static solutions to CSOs). Robust RTC strategies can decrease the pollution from CSOs whilst being relatively cost efficient with minimal disruption and nuisance to the public.

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Key words:
Integrated Real Time Control, Urban Drainage Systems, Integrated Modelling, Water Quality, Combined Sewer Overflows

Cooperation with other institutes:
Waterschap de Dommel

Mostafa Zahmatkesh

Bioremediation of Humic compounds from water using fungi

Research objectives

The objective of this research is to study the possibility of removing humic compounds, namely humic acid (HA), from wastewater by fungal treatment.

Project outline

Introduction

This project is part of a STW project entitled "Increasing the utilization of organic waste and low value feeds with the help of lignin degrading fungi", in cooperation with Wageningen University. The research in TU Delft is focused on using White Rot Fungi (WRF) to remove recalcitrant compounds from wastewater. For the last three years the research was focused on humics as targeted compounds for fungal treatment. Humic substances are natural organic substances, which are ubiquitous in the environment, both aquatic and terrestrial. In nature, humic substances are extremely resistant to biodegradation. WRF constitute a physiological group comprising mostly of basidiomycetous, and to a lesser extent, litter-decomposing fungi. WRF are the most abundant wood degraders in nature, which possess the unique ability of efficiently degrading lignin to CO2 [1]. Thanks to WRF non-specific enzymes, they can also degrade other recalcitrant compounds with molecular structure similar to lignin, like azo dyes, poly aromatic hydrocarbons, and humics [2]. Lignin Peroxidase, Manganese Peroxidase, Laccase and versatile peroxidases are the major extracellular enzymes produced by white rot fungi, which are responsible for degradation of recalcitrant compounds [3].

Approach

Prescreening of several strains of WRF has been done in agar plates to evaluate their ability to grow and bleach humic acid. Selected strains tested in liquid phase, and based on results of the jar tests, a 7 Lit fungal reactor was designed to treat wastewater containing humic acid.

Results

Four strains of WRF were selected after prescreening in humic-agar plates for their ability to grow and bleach the humic acid (Fig 1).

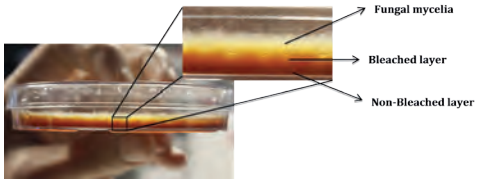

Figure 1. White rot fungi growing on Humic-agar plates, degradation of humics would cause bleaching layers on agar

In the next step, the selected strains were used to remove humic acid from wastewater. Results showed that *Trametes versicolor* could remove around 40% of the humic acid after 3 days and 90% after 15. Laccase activity was correlating with color removal (Fig 2). Results of the liquid chromatography revealed that mechanism of humic removal by WRF is a combination of absorption (by fungal

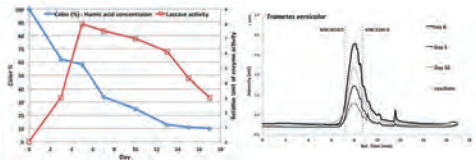

Figure 2. Left: Color removal (humic acid removal) and enzyme activity, Right: Results of Size exclusion chromatography

mycelia) and degradation (by fungal enzymes).

Based on the previous results of jar tests, a sequential batch fungal reactor was applied to treat HA-containing wastewater. Three batches were done and each batch lasted 3 weeks. Results are shown in Table 1.

Figure 3. Left: Fungal reactor (Beginning), middle: Fungal reactor (end of first batch), Filtered samples at the beginning and end of the batch

Batch No.	Decolorization 1st week	Decolorization 2nd week	Decolorization 3rd week
1	41%	87%	92%
2	60%	83%	77%
3	74%	89%	79%

Table 1. Results of the sequential fungal reactor (Decolorization represents the removal of humic acids)

Scientific relevance

Humic compounds can limit the bacterial growth in digesters, cause fouling in membrane units and also reduce the quality of the effluent due to their color. Therefore, removal of humic compounds in wastewater will increase the efficiency of wastewater treatment plants.

Social relevance

Removal of recalcitrant or hardly degradable compounds would increase the efficiency of the wastewater treatment plants, which results in a cleaner and healthier environment, which benefit all living species in it, namely humans.

Literature

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Key words:
Humic acid, Bioremediation, Wastewater treatment, Fungi

Cooperation with other institutes:
Wageningen University

Marij Zwart

AdOx – a next generation adsorption process for removal of Organic MicroPollutants from municipal wastewater

Research objectives

The objective of the AdOx research is to develop an innovative technology, which generates high OMP removal efficiencies, is cost- and energy-efficient, has a small footprint, and avoids the generation of unwanted by-products.

The AdOx project consists of two working packages. I am focussing on work package 1, i.e. concentrating on the adsorption of OMPs on granular zeolites, while work package 2 focusses on the regeneration process.

Project outline

Introduction

Organic micropollutants (OMPs) such as pharmaceuticals, synthetic and naturally occurring hormones, pesticides, wastes of industrial processes and personal care products, can be found nearly everywhere in the water cycle. The vital functions of water bodies for human and aquatic life are susceptible to quality degradation caused by these anthropogenic contaminants. In developed countries with existing sewer systems, wastewater from households and industry is a major source of OMPs. As current wastewater treatment plants (WWTPs) are designed to remove macro-pollutants and nutrients, they are not equipped for the removal of OMPs. Over the last years, posttreatment to remove OMPs from WWTP effluent has gained much attention among authorities responsible for the water quality.

A number of add-on (or effluent-polishing) treatment techniques are available, like advanced oxidation, granular activated carbon filtration, powdered activated carbon dosing, membrane filtration or combinations of the technologies mentioned. However, these technologies each have their drawbacks, such as high energy consumption (membrane filtration), generation of by-products (advanced oxidation), high costs (generation of activated carbon granules) or they require flexibility in the capacity of the existing treatment, which is not always available (powdered activated carbon).

Approach

Due to their molecular sieve properties, both natural and synthetic zeolites are widely used as adsorbents in separation and purification processes. Zeolites with a high Si/Al ratio have been found to be selective adsorbents for the removal of a range of OMPs from wastewater. As zeolites provide a framework of micro-pores which well matches the size of OMP molecules, adsorption of competing background organic material is potentially inhibited.

A wide (fluctuating) range of OMPs is present in WWTP effluent, with significant differences in behaviour and properties. To remove a wide range of OMPs, different types of zeolites should be combined and engineered into one granule. Since zeolites are chemically stable, so can potentially be regenerated by advanced oxidation, without changing the zeolites properties and pore structure.

This study consists of four research phases:

1. The engineering and characterization of granular zeolites
2. The proof of principle of removing a wide range of OMPs from municipal wastewater using granular zeolites
3. The exploration of optimized process configurations
4. Pilot research on feasibility of OMP removal using AdOx

Scientific relevance

It has been proven by previous research at our department that high silica zeolites can adsorb well polar OMPs ((Jiang, Shang et al. 2018).

However, zeolites are powders, and to be used as a functional and cost-efficient adsorbent at a WWTP, granular zeolites have to be produced. These granular zeolites need to retain the adsorption capacity of zeolite powders, while also showing sufficient strength and durability. The production and characterization of granules consisting of a range of zeolites for application as adsorbents in wastewater treatment has not been studied before.

Social relevance

As WWTPs are not designed to remove OMPs, currently most WWTPs are continuously dumping OMPs into the aquatic environment. There is a great need for more knowledge on the impact of (combinations of) OMPs on the aquatic environment and all other functions of water bodies. However, it goes without saying that prevention of this pollution should be pursued and being a cost-efficient and effective technology, the AdOx technology could provide a solution.

Literature

Jiang, N., et al. (2018). "High-silica zeolites for adsorption of organic micro-pollutants in water treatment: A review." Water Research 144: 145-161.

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Key words:
Adsorption, Organic MicroPollutants, Wastewater treatment, Municipal wastewater

Cooperation with other institutes:
KWR, Waternet, Waterschap De Dommel, Hoogheemraadschap Delfland, Hoogheemraadschap Rijnland, Witteveen + Bos | Engineering and Consulting, Xylem Water Solutions Nederland B.V.

Hala Alhamed (PDEng)

Integrated urban water risk-based asset management

Research objectives

The aim of the project is to design a framework for integrated urban water risk-based asset management, and structure the asset management planning problem in line with the system approach. The framework supports water utilities to determine and quantify the key criteria for comparing asset management strategies and will be demonstrated in sewer asset infrastructure in Waternet, Amsterdam.

Project outline

Introduction

Infrastructure urban water asset management decisions are complex and challenging. The complexity lies in the fact that urban water systems are socio-technical systems. Socio- technical system is made up of technology, science, regulation, user practices, markets, cultural meaning, infrastructure, production and networks (Bruijn & Herder, 2009). Complex systems involve multiple stakeholders, multiple perspectives, conflicting interests, various types of uncertainties, and significant intangibles (Rosenhead & Mingers, 2001). The complexity poses challenges on asset management and planning and it requires solutions that address equally complex and interrelated technical and social aspects

Approach

To support decisions in a such complex situation, several methods emerged in practice to offer a representation of the situation to enable participants to clarify their predicaments, converge on a mutual problem and agree on commitments to resolve it (Mingers & Rosenhead, 2004). Problem structuring methods (PSM) is used to structure the asset management problem in Waternet. In analysing the objectives and criteria for decision making in Waternet, multi criteria decision analysis (MCDA) method is followed in this research. Decision making in rehabilitation, repair and /or replacement asset and prioritizing assets is a complex problem. The basic steps of MCDA as defined by (Keeney, 1982) and (Keeney et al, 1996) are;

1- Clarifying values of decision makers

2- Structuring the values in objectives hierarchy of fundamental objectives and means-end objectives

3- Assess the possible impacts of each alternative and developing measures for the fundamental objectives

4- Evaluate, compare alternative and determine primary value trade-offs

Scientific relevance

In recent years, there have been a several academic attempts to find a generic framework for urban water asset managers with the focus on finding engineering solutions to water asset management problems without enough involvement of stakeholders, ignoring the social aspect of the sector (Harvey, 2015).

This research provides a new approach that integrates social and technical aspects of water management in decision making. It introduces a new application of multi criteria decision analysis (MCDA) in urban water asset management and further develops the method into a framework demonstrated in the case of sewer asset management in Waternet.

Social relevance

Urban water infrastructure are strategic components of large social and economic relevance. Thus, it is essential that they are managed rationally and effectively. This project will support the decision for achieving adequate levels of service while maintaining the many characteristics that interest the key stakeholders in a liveable city and transparent decision-making mechanism.

Literature

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Start date project: Feb 2018
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Key words:
Asset management, risk management, urban water, integrated approach

Cooperation with other institutes:
Waternet

Sajad Fathi (PDEng)

Modelling of Subsurface Iron Removal (SIR) - Case study on Corle Pumping Station (The Netherlands)

Research objectives

The main research objective of the project is to investigate the capability to apply a hydro-geochemical model parallel to field-test and experimental design in Corle Pumping Station (CPS) with practical aim of formulation guideline for optimizing SIR-wells.

Project outline

Introduction

In order to achieve high tap water-quality, water must be treated and purified (WHO, 2008). In the treatment and purification of groundwater, a smooth removal of iron and manganese is often essential (Van Halem et al., 2010). High concentration of Fe in the water not only can be harmful subject to human health (Buamah, 2009; WHO, 2008), but also the water may taste metallic, appear brownish (Ahmad, 2012) and more jeopardous can be subsided and whereby block the pipelines (Vries et al., 2017). As a result, it imposes and derives huge sums into water companies to maintain and refresh their water drinking distribution systems (Katumba, 2015; Vitens, 2016).

Subsurface iron removal (SIR) is an old well-established technique to remove iron and manganese from groundwater (Van Halem et al., 2010). The principle of the SIR is that aerated water is repeatedly, periodically and cyclically injected into an anaerobic aquifer through a tube-well, and thereupon relatively displacing the original Fe2+ -containing groundwater (Van Halem et al., 2011). The enriched O2¬-rich (aerobic) injected water around the tube-well oxidizes the Fe2+ by creating O2¬-front zone (Van Halem, 2012). By injecting aerobic (O2-rich) water into an anaerobic aquifer both homogeneous and heterogeneous oxidation process of Fe2+ occur in the aquifer. Homogeneous oxidation process of Fe2+ mainly occurs in the solution at the interface of injected water and native/anaerobic water (Van Halem et al., 2012). It is supposed that heterogeneous oxidation of Fe2+ takes place on the contact-surface of Fe hydroxides dominantly during SIR due to large contact-surface of Fe hydroxides upon the soil grains in the sub-surface.

Although subsurface iron removal is a well-established system since 1970s, no hydro-geochemical model has been confronted with field-test – the datasets from laboratory experiment has been used till now (Appelo & De Vet, 2003; Appelo, & de Jonge et al., 1999). In addition, a current gap exists in provision of guideline-scheme for optimization of SIR-wells world-widely. While the focus of previous publications went into practical and technical point of view of SIR-wells meaning provision of installation guideline (Dixon et al., 2006; Suzanne Mettler, 2002; Doris Van Halem et al., 2010); or investigation and recognition of scientific causes regarding underground processes like cation exchanges during SIR (Van Halem et al., 2012), controlling the formation of reaction zone (Bartak et al., 2017), microbial reduction of Fe (III) and sorption/precipitation of Fe (II) (Liu et al., 2001; D. Vries et al., 2017) and hydro-geochemical modelling using laboratory experiment datasets (Appelo & De Vet, 2003; Appelo et al., 1999; Dirk Vries et al., 2012). Nevertheless, neither none of publications nor BTO reports provide an optimization guideline scheme for SIR-wells in which higher production of Fe-free water can be achieved.

Insight into the mechanism controlling SIR is still restricted (Appelo & De Vet, 2003; Rahman, 2017; Van Halem et al., 2011), and therefore the performance of SIR is hard to estimate and predict a deductive scientific theory for a given location. As a result, it is crucial to determine the hydro-geochemical process specifying (im)mobilization of iron (and other minerals) during SIR operation and develop a tool which can evaluate the potential SIR performance according to its local hydro-geochemical reactions. By the end of this project, we will be able to determine underground contributing factor effecting the Fe-removal breakthrough and thus give an opportunity to company-side to optimize all their SIR-wells meaning saving more money while abstracting more Fe-free water.

Approach

- Literature review on current progress of SIR technology word-widely and hydro-geochemical modelling subject to SIR.
- Develop a hydro-geochemical model for Corle Pumping Station (CPS) in order to discover underground mechanistic processes and chemical interactions/reactions which might influence upon

whole SIR system and thus is of crucial of the research.

- Determination of the risk of aquifer clogging and groundwater pollution by means of hydro-geochemical modelling for the Corle Pumping Station (CPS).
- Discovering of contributing factors affecting directly or indirectly the optimization of SIR-wells for instance: (from functional and technical viewpoint by means of experimental design).
  - Investigation of the optimal endpoints for both Fe and Mn
  - Investigation of the effect of background reactivity.
  - Investigation of operation losses of injected O2.
  - Investigation of the operational contributing factor for achieving smart injection-abstraction cycles.
- Modelling 2D SIR-experiment to investigate heterogeneousity effect of the associated aquifer and vertically variable iron concentration by means of hydro-geochemical model.
- Formulating a guideline for optimization of all SIR-wells results from outcome of the project for the Vitens.

Scientific relevance

- The scientific adding value of this project goes into applying hydro-geochemical model parallel to field test. Meanwhile, the working adding value of this project goes toward formulation optimization guideline with aim of improving the functionality of existing SIR-wells by using both hydro-geochemical analysis and field-tests evaluation.

Social relevance

The development of hydro-geochemical model for the removal of iron in underground rather than above-ground systems can provide a clear vision regarding underground contributing factors in a process of SIR, which in further will be used to answer the concerns of drinking water companies in association with aquifer clogging risk and sediment pollution risk issues. In addition, It can furthermore lead to a reduction in treatment cost and thus produce cheaper tap water rather than other systems which is of interest of all drinking water companies.

Literature

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Key words:
hydrogeochemistry, SIR, iron_removal, geochemistry modeling, aerobic groundwater treatment

Cooperation with other institutes:
Vitens

Manuel Garcia Garcia (PDEng)

Reclamation of nutrients from digestate after green biogas production: Development of a solid/liquid separation process

Research objectives

1)Develop a solid/liquid separation process of digestate of mono-digested cow manure and/or co-digested with farm/agricultural residues. 2) Study of coagulants and flocculants to improve the separation process of suspended solids.

Project outline

Introduction

Phosphorus (P), Potassium (K) and Nitrogen (N) are essential macro nutrients in intensive agriculture. With a population over 7 billion people in the world there are concerns over the long-term availability of these resources (Bolzonella, Fatone, Gottardo, & Frison, 2018). Secondary sources of these nutrients such as digestate after anaerobic digestion from animal manure contain NPK that can be recovered and use as fertilizer. The recovery of these nutrients will promote the circular economy in the farm areas of the EU by adding value to a by-product like digestate with sale costs of 15€ per ton.

This PDEng project in collaboration with Saxion University of Applied Sciences and TU Delft will help to lower the costs of digestate sales while recovering NPK nutrients.

Approach

Literature review will be conducted to decide the election of the mechanical par of the process, the election will be based on performance, CAPEX and OPEX.

Realization of experiments to test the efficiency of the selected coagulants (FeCL3 & Ca(OH2)) and flocculants (PE and bio-PE) to decide the combination and quantity of coagulants and flocculants that will improve the yield of the mechanical part of the process.

Lab set-up will be constructed at Saxion facilities to test the conditions and the performance of the entire process, followed by the scale-up from the lab set-up to a pilot plant size.

Setup of complete process flow diagram (PFD), a complete (P & ID) piping and instrumentation diagram and the drafting of a basic mechanical design. Development of a techno-economical report of the process.

Results

The expected result of this PDEng project is the design of a process that will optimize the solid/liquid separation of digestate of mono-digested cow manure and/or co-digested with farm/agricultural residues to achieve a solid fraction of at least 28% in dry matter and a liquid fraction with a content of less than 5% of total solids that facilitates efficient P recovery afterwards.

The main derivable of this project will be the technology itself, its economic and technical feasibility and a technical report that will include a process flow diagram (PFD), a (P & ID) piping and instrumentation diagram and a basic mechanical design with all the components required.

Scientific relevance

The study will help to develop a solid/liquid separation process of digestate. The performance of this step will impact the following process (composting, ammonia striping, crystallization-precipitation) performance for the recovery of (NPK) nutrients.

Social relevance

High costs of digestate sales affect framers all over the EU territories (Eckermann et al., 2015). This PDEng project as a part of the " Mineralen Terughalen" and "Kassa met Kalk" projects will help lower the costs of digestate sales that are currently soaring above 15 € per ton to 5 € per ton by producing valuable differentiated nutrient (NPK) fertilizers.

Literature

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Expected end date: Feb 2020

Key words:
Bio-based economy, Mineral recoevery (NPK), solid/liquid separation, circular economy, digestate managament

Cooperation with other institutes:
Saxion University of Applied Sciences, HoSt

André Marques Arsénio (Postdoc)

Sustainable freshwater supply in urbanizing Maputo, Mozambique

Introduction

Maputo, like other Deltas cities in the Global South, suffers from freshwater shortage and insufficient sanitation services. Despite the good work done in the country in the WaSH sector since the independency from the colonial power in 1975, there is still a long road ahead: Mozambique has demonstrated a "slow rate of progress" regarding access to safe drinking water and basic sanitation and [1] predicted that the MDG goals for both indicators will only be reached after 2025 instead of 2015.

Research objectives and approach

The main project aims at developing tools and models that allow including water reclamation in future city-wide water and sanitation projects. In this way it will be possible to alleviate the pressure on the existing freshwater sources, reduce risks associated with current unsafe wastewater handling practices while generating revenue that will ultimately allow financing more inclusive sanitations services.

Results

Throughout 2017 I worked on characterizing the flows of Nitrogen and water in the city (Fig. 1). This work has showed that current improvement plans to the city's sanitation infrastructure will have little impact in minimizing the ongoing groundwater contamination with Nitrate. It also demonstrates the link between drinking water supply and sanitation services and an obvious reason to improve both in order to improve general urban health and wellbeing [2].

I am now planning to forecasting the future water demand and the projected availability (e.g. through dam building) for different development scenarios. Approaches to offset the scarcity will be discussed and evaluated in a workshop-type meeting with local stakeholders. This will be the second pillar of the project whereby the need to follow a different approach rather than building new dams will have to be implemented. To get more information about the project please scan the QR-code (Fig. 2).

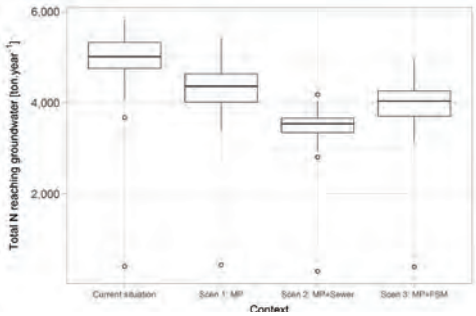

Fig. 1. Nitrogen reaching groundwater each year for the current situation and for three improvement scenarios, depicting median, upper and lower quartiles, minimum and maximum; outliers are presented as circles.

Fig. 2. Scan this QR-code or surf to https://sustainablewatermz.weblog.tudelft.nl/ for more information about the project.

Scientific relevance

The project will allow studying water reclamation from an integrated socio-technical. Simultaneously it will be possible to develop new technologies for a sanitation-based circular economy. Finally, the project aims at helping to implement policies for sustainable development of freshwater supply and inclusive sanitation services, both on large and small scale, making use of innovative combinations of public and private service providers.

Social relevance

One of the projects objectives is improving the current situation regarding water and sanitation in Maputo the livelihood of its dwellers. This will be done through capacity building and by providing a platform where novel approaches to water management can be discussed. Ideally, the technologies, tools and models developed for Maputo can be implemented in other Mozambican cities and elsewhere, helping to improve the lives of millions of people worldwide.

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Key words:
Water reuse, wastewater treatment, digestion, sewer mining, governance, ecosan, fecal sludge management, sustainability

Cooperation with other institutes:
UNESCO-IHE, Erasmus University, Universidade Eduardo Mondlane (Mozambique), FIPAG, VitensEvidesInternational, Royal HaskoningDHV, DNA, CRA, Municipality of Maputo, WSUP, WSP, Pamodzi

Yasmina Bennani (Postdoc)

AdOx – a next generation adsorption-oxidation process for removal of CECs from municipal wastewater

Research objectives and approach

The objective of this project is to realize an innovative adsorption oxidation process for organic micropllouts (OMPs) removal from municipal wastewater based on the use of zeolites as adsorbent and the chemical regeneration of exhausted zeolites with ozone. As zeolites provide a framework of micropores which well matches CECs' molecules, adsorption of background organic matter, will potentially be excluded.

Project outline

Introduction

Current wastewater treatment plants (WWTPs) are designed to remove macro pollutants (COD, BOD, TSS) and nutrients (phosphate, nitrate) and are not equipped for removal of OMPs, (Luo et al., 2014).

Over the last years, posttreatment to remove OMPs from treated wastewater has gained much attention (Vergouwen et al., 2011; Mulder et al., 2015). State of the art techniques include dosing of powdered activating carbon, granular activated carbon filtration, ozonation and biodegradation. In all cases, the focus was on a single process step or combinations of process steps. The costs of these treatments are high and are characterized by a high environmental impact. In this research an innovative approach will be investigated: combining adsorption with ozonation (AdOx), using zeolites as an alternative adsorbent. The AdOx process integrates adsorption and ozonation, and is expected to result in the removal of a wide range of OMPs as compared with the single process steps. The process is also suitable for a cost-effective and sustainable alternative regeneration technology of exhausted adsorption material.

Approach

In this research two approaches are introduced:

- Zeolites will be tailor-made to be effective and efficient for non-selective OMP removal from wastewater treatment plant effluent, avoiding the adsorption of background organic matter (BOM);
- Chemical regeneration of the exhausted adsorbent (zeolites) with the use of ozone will result in cost savings and a lower environmental impact compared to the thermal reactivation of activated carbon. As ozone can be made available at the wastewater treatment facility applying the AdOx process, regeneration may be carried out on-site, minimizing transportation costs and minimizing CO2 emissions. With chemical regeneration of zeolites the oxidant only reacts with the adsorbed organic substances. As BOM is not adsorbed by the zeolites, this potentially results in a low chemical use.

The combination of these two innovations will lead to an innovative treatment concept that is small in size, because of the short contact-times; can be regenerated frequently, because of on-site generation of ozone; and does not require continuous dosage of ozone, thus not reacting with BOM and OMPs in the full stream, avoiding the formation of by-products and metabolites.

Scientific relevance

Removal of OMPs from wastewater treatment plant effluent is becoming more and more important. Current wastewater treatment plants are not equipped for removal of OMPs. Much research is carried out into the removal of these compounds by oxidation, adsorption, biodegradation and combination of these processes. However, these processes are characterized by high costs, a large environmental impact and limited selectivity for OMPs. In the AdOx project an innovative process will be developed based on adsorption of OMPs with zeolites, and chemical regeneration of exhausted zeolites with ozone.

Social relevance

There are increasing concerns about OMPs regarding their health effects and frequent occurrence.

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Key words:
Organic micropollutants, Pharmaceuticals, Adsorption, Ozonation, Zeolites, Regeneration

Cooperation with other institutes:
Waternet, Waterschap De Dommel, Hoogheemraadschap Rijnland, Hoogheemraadschap Delfland, Witteveen + Bos,
Xylem Water Sollutions Nederland BV Funded by: Stowa, KWR, Topsector Water, STW Partnership

Mathieu Lepot (Postdoc)

FOULC: Fast Over-all scanning of Underground and Linear Constructions

Research objectives

The FOULC project (in the TISCA program) aims at obtaining information on some of the main functionalities of a sewer using non-intrusive techniques. Information can be gathered in-situ to quantify the actual hydraulic capacity, the presence and the amount of sediments and biofilm, detailed 3D information on the actual sewer geometry and information on the locations where and the amount of infiltrating groundwater. To this end an aquatic drone is developed as a platform for the sensors and the data-acquisition system. The development of this sensor platform is dedicated to sewer systems, but the application is not limited to sewers since it can also be applied for obtaining information on hydraulic capacity of and the presence of sediments in ditches and canals.

Project outline

Introduction

CCTV is known to be inaccurate and subjective. In order to deliver reliable data to sewer manager, new inspection techniques are needed. Recent advantages in this field showed that sonar, laser profiling or acoustic measurement can be used for such purposes.

Approach

This project (in collaboration with CT2MC) will combine several sensors: laser profiler, Infra-red Camera, velocity/turbidity profiler and a sonar. All these sensors will be set up on an amphibious drone that can inspect sewers pipes with service disruption. CT2MC is in charge on the drone design and construction based on the selected sensors and the required data acquisition system. Both data acquisition and processing software are under development.

Results

Preliminary results are quite promising:

- the laser profiler is able to detect any shape of deformation above the free surface with an uncertainty lower than 2 mm,
- the IR camera can detect active lateral connections with a discharge of minimum 2 % of the main discharge,
- the velocity/turbidity profiler has been improved by the supplier to reach our objective. The reconstruction of the 3D velocity and turbidity fields are now feasible.

Scientific relevance

This project already encounters some positive feedbacks from practitioners waiting the prototype to be ready for testing and then on the market. From a scientific point of view, this project is quite challenging (specially for the data treatment) and will be able to deliver reliable data for asset management and decision-making research projects.

Social relevance

The do-it-yourself end product (by just combining the platform and the selected sensors) and the expected open-source software and hardware (data acquisition and treatment) will ensure a potential wide use of this technique during the coming years.

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Key words:
sewer, inspection, sensors

Maria Lousada Ferreira (Postdoc)

Bio-methane production from urban organic matter (BeWaMet)

Research objectives

a) Adapt fouling monitoring methods to AnMBRs.
b) Identify the most suitable flux enhancer for anaerobic domestic sludge.
c) Develop an on-line control tool for AnMBRs, able to monitor fouling, add flux enhancers and increase the operational flux.

Project outline

Introduction

The BeWaMet is an ERA-Net project, aiming at demonstrating Anaerobic Membrane Bioreactors (AnMBR) technology at demo-scale for treatment of municipal wastewater. Within the project, the goal of TUD is to develop an on-line control tool aiming to increase the flux of AnMBRs, which is currently one fourth to one fifth lower than in aerobic MBRs. The demo-scale AnMBR pilot of the BeWAMet project is located at the Vigo, Spain; is designed to treat black water and is currently at the start-up phase.

Approach

Firstly, to develop a method to quantify fouling, as the cause of flux decline in AnMBRs. Fouling, as the accumulation of material in and on the membrane, was quantified as sludge filterability. A dedicated method was developed at the TUD water lab and tested at an AnMBR pilot. Secondly, to improve the sludge filterability and consequently increase the flux, 8 flux enhancers were tested, through preliminary tests and short-term membrane filtration tests. Thirdly, to develop the on-line control tool, and taking into account that the goal would require an extended time-frame, PhD student Magela Odriozola was hired one-year ago, to proceed with the work beyond the project time-frame.

The method development and flux enhancers tests were performed with anaerobic sludge from full-scale or pilot locations. Weekly samples were collected at the digester of Harnaschpolder Sewage treatment plant (HNP STP) in Delft, during a total period of one year. An installation, previously used at the TUD to quantify sludge filterability in aerobic MBRs, was adapted to measure anaerobic samples [1], and a method comprising measurements of membrane resistance, anaerobic sludge filtration and chemical cleaning was defined [2]. The adapted installation was connected in-situ to an Aqualia AnMBR pilot, at Alcazar de S.Juan, Spain, for a period of 2 weeks, where the aforementioned method was tested and applied.

Results

Figure 1 shows the sludge filterability results obtained with the HNP STP sludge. Tests at AnMBR pilot of Alcazar de S.Juan, indicate that the cross-flow of 1.5 m s-1 provides a more accurate fouling quantification (results not shown). Figure 2 shows chemical cleaning results, where the most successful cleaning is obtained by a sequence of chemicals starting with sodium hydroxide. The weekly measurements of filterability where complemented with analysis of Particle Size Distribution, Biopolymer Clusters, Extra Polymer Substances, Soluble Microbial Products, Volatile Fatty Acids, among other parameters. The full data base of results is being analysed by advanced statistical methods, such as Partial Least Squares, aiming to explain the filterability trend in time.

Jar-tests were performed to determine optimal dosages of 1 adsorbent, 2 coagulants and 5 flocculants. Specific Methanogenic Activity (SMA) tests were performed to evaluate possible inhibition effects. Short-term membrane filtrations tests were carried out with 6 flux enhancers, at the obtained optimal dosage. The integration of the sludge filterability method with flux enhancer additions is planned to occur during the first semester of 2018, at the BeWaMet AnMBR pilot in Vigo, Spain. The results of the latter campaign will be a part of the PhD work of Magela Odriozola.

Scientific and social relevance

The goal is to contribute to explain filterability of real municipal anaerobic sludge, for which 3 scientific articles will be produced, the first concerning the method, the second flux enhancers and the third filterability trends. AnMBRs produce water free of solids and rich in ammonia and orthophosphate, particularly suitable to agriculture fertilization, with simultaneous production of methane-rich biogas. Turning fouling into a manageable issue will boost a potentially sustainable technology.

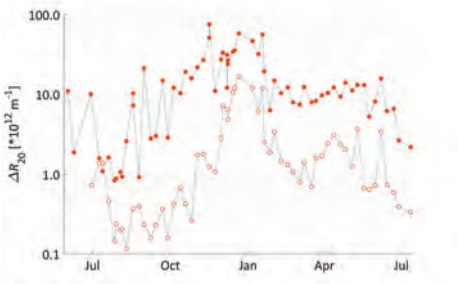

Figure 1. Sludge filterability expressed as ΔR20, obtained with a flux of 60 L m^{-2} h^{-1} and cross-flow velocities (v) of 1 m s^{-1} (full bullets) and 1.5 m s^{-1}(open bullets).

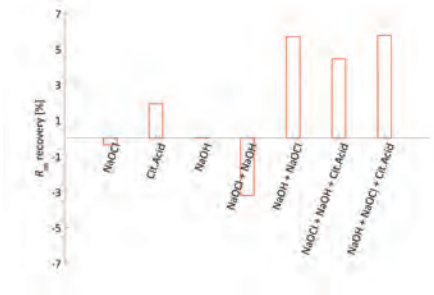

Figure 2. Chemical cleaning efficiency, measured as average recovery of the membrane resistance (Rm). Membrane resistance measured with de-mineralized water before and after chemical cleaning.

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Key words:
Anaerobic Membrane Bioreactors; Filterability

Cooperation with other institutes:
FCC- Aqualia (Spain); University of Southampton (UK)

Dhruv Mehta (Postdoc)

Computational studies on the flow of domestic slurry

Research objectives

- Use computational fluid dynamics (CFD) to simulate the flow of concentrated domestic slurry through a circular horizontal pipe.
- Use the solver to simulate the flow through bends.
- Compare the accuracies of CFD and semi-empirical models as regards to the estimation of frictional losses in the transport of concentrated domestic slurry

Project outline

Introduction

Concentrated domestic slurry results from the reduction in the amount of water used for domestic purposes. This not only helps save water but also improves the downstream recovery of nutrients and energy from biomass.

Once concentrated, domestic slurry behaves like a non-Newtonian fluid of the Herschel-Bulkley type, which has been demonstrated experimentally. As a result, existing pipes and pumps must be redesigned to transport such a non-Newtonian slurry, for which, a fundamental understanding of the flow physics of such a slurry is imperative.

Approach

- Select a Navier-Stokes solver capable of simulating non-Newtonian flows.

  1. Modify the Newtonian wall function for Herschel-Bulkley fluids.
  2. Explore relevant turbulence models.

- Use a range of experimental test cases to validate the modified wall function and the Navier-Stokes solver.

  1. Experimental data from experiments with concentrated domestic slurry.

2. Experimental data from existing literature on Herschel-Bulkley fluids.

- Use the validated solver to simulate the flow of concentrated domestic slurry through bends and elbows in pipes.
- Determine an operational envelope in terms of flow and fluid parameters within which the modified wall function is imperative for accuracy.
- Assess the accuracy of semi-empirical models in terms of estimating the wall shear stress encountered by the concentrated domestic slurry as it flows through circular horizontal pipes.

  1. Modify existing models to encompass Herschel-Bulkley behaviour, if needed.
  2. Compare CFD and semi-empirical models.

Results

- The modified wall function for Herschel-Bulkley fluids was successfully validated.
- The wall function when combined with CFD, provides an accurate estimate of the pressure loss through straight pipe sections and across elbows.
- An envelope based on the fluid and flow parameters suggest that fully turbulent flows of Herschel-Bulkley fluids that possess a yield stress that is comparable in magnitude to the wall shear stress, require the use of the modified wall function during a CFD analysis.
- Semi-empirical models do not show a recognisable trend in their accuracy as regards to the flow and fluid conditions of the Herschel-Bulkley fluid under consideration. Further, the accuracy of CFD is superior to that afforded by known semi-empirical models and more so, for the range of operating conditions that the concentrated domestic slurry would be transported under.

Scientific relevance

As opposed to Newtonian fluids, there is little known about the nature of turbulence in the flow of non-Newtonian fluids. The application of CFD to the study of such flows, merely involves the use of the Newtonian equations with a modification for the molecular viscosity (apparent viscosity in the case of non-Newtonian fluids). The development of the wall function contributes to an increased accuracy in the estimation of frictional losses in wall-bounded flows of Herschel-Bulkley fluids.

Social relevance

A thorough CFD analysis provides two benefits. Firstly, it complements experimental data with detailed information on the nature of the flow. Secondly, a good amount of detailed data provides a database to tune simple

engineering models, which are necessary to replace CFD in the analysis of large-scale sewer systems. Such an analysis is computationally expensive if done using CFD.

With a thorough knowledge of frictional losses incurred by Herschel-Bulkley fluids, civil engineers can design an appropriate sewer system for the collection and transport of concentrated domestic slurry. Finally, the implementation of such sewer systems will lead to massive savings in the usage of water and the improved recovery of nutrients and biomass (energy) from domestic slurry.

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Key words:
Comptuational fluid dynamics, non-Newtonian fluid, pipe flow, urban drainage

Cooperation with other institutes:
Deltares, Stowa, RIONED, Waternet, Waterboard Zuiderzeeland, Grontmij, XYLEM and TTW

Annemarie Mink (Postdoc)

Mobile crowd participation as innovative methodology for water research

Research objectives

1. Investigate to which extent local stakeholders, and specifically end-users, are able to monitor their own water supply systems in order to improve the sustainability, operation and maintenance of these systems.
2. Apply Mobile Crowd Participation (MCP) as an integrated research and monitoring tool for small-scale piped water supply systems in Bangladesh and India by developing a smartphone application.

Project outline

Introduction

Technologies shape and change our world and have the potential to support people in doing what they want to do and being who they want to be. However, technologies can also have unintended consequences or fail. Many failed products are unsuited to the user and / or their environment as they are either based on poorly defined needs (Donaldson 2006), or focus merely on needs instead on what people actually want (Bowman and Crews 2009). To improve the accessibility, applicability, acceptance and adoption of products and systems the end-users and other stakeholders should be included in the development and monitoring of these products and systems (Donaldson 2009; Nakata and Weidner 2012; Robertson and Simonsen 2012; Wilkinson and De Angeli 2014).

Urbanization of deltas puts a severe stress on the availability of clean, safe drinking water and therefore threatens the lives of millions, mostly affecting the poorest. In this area, centralized water supply through Small-scale Piped Water Supply (SPWS; Trifunovic 2002; Kayaga and Reed 2005) offers crucial advantages over other technological interventions, as it targets the safest source in the area, provides a degree of centralization for water quality control and treatment (<100 households), provides socially-economically desirable in-house or courtyard tap connections, and limits the number of (re-)contamination events between water collection and consumption.

To root SPWS systems into the local context, Mobile Crowd Participation (MCP) can be deployed. MCP is a novelty in water research and can be deployed to improve the users' knowledge and awareness about water quality (also by enabling them to test the water quality themselves), to enable communication between relevant stakeholders, to improve service and maintenance, and to make billing easier. According to GSMA (2013) access to mobile services in developing regions has outpaced the rate at which much of the population is gaining access to basic services such as electricity, sanitation, and banking. This is especially true for India and Bangladesh (GSMA 2016, 2017). Therefore, there seems to be scope for a smartphone application to investigate and monitor SPWS systems.

Approach

Comprehensive interviews with end-users and other local stakeholders have been conducted to get to know the local context, identify the current issues with existing piped water supply systems and propose relevant functionalities for a water monitoring smartphone application. Currently, the app functionalities are being developed in a participatory, co-creative manner with local stakeholders and local app developers in Bangladesh. This development is an iterative process in short sprints with extensive field testing.

Results

Practical results: A water application ready to use in the field in Bangladesh by end-users, caretakers, NGOs and local governments.
Scientific results: generic and context specific boundary conditions for MCP which are empirically validated.

Scientific relevance

Mobile phone applications (apps) are a novelty in water research, and by this project its relevance for researching and monitoring SPWS systems will be determined. Generic and context specific boundary conditions for MCP will be established.

Social relevance

The results of this study can be used by governments, NGOs working in SPWS projects in Bangladesh or in other urbanizing delta areas in order to improve the operation and maintenance of SPWS systems in these contexts and in that way contribute to sustainable safe water supply for its end-users.

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Start date project: Jun 2016
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Key words:
Mobile Crowd Participation, End-User Interaction, Small-scale Piped Water Supply

Cooperation with other institutes:
AN College Patna India, Dhaka University Bangladesh, National Institute of Design Ahmedabad India, Industrial Design Engineering TU Delft

Marjet Oosterkamp (Postdoc)

Microbial community analysis of anaerobic bioreactors treating extreme wastewater

Research objectives

- Detailed characterization of the microbial community present in anaerobic membrane bioreactors and an upflow anaerobic sludge blanket reactor treating (synthetic) industrial wastewater containing various concentrations of phenol and salt and under mesophilic as well as thermophilic conditions.
- Identify functional metabolic pathways employed by the variety of microorganisms in the anaerobic bioreactors under different conditions.

Project outline

Introduction

Anaerobic digestion is important for wastewater treatment, combines reduction of waste and pollutants with energy production and is low-cost compared to aerobic treatment methods. Recently, the advantages of membrane technology and anaerobic bioreactors have been combined into the anaerobic membrane bioreactor. To ensure optimal performance, a more fine-grained insight in the composition and functionality of microbial communities of bioreactors is important.

Approach

Samples from bioreactors treating wastewater with various concentrations of phenol and salt and under mesophilic as well as thermophilic conditions are studied using molecular techniques such as DNA isolation, polymerase chain reaction and high throughput deep-sequencing techniques (Illumina MiSeq, Figure 1). Advanced bioinformatics tools, such as QIIME and the R environment, allow us to get information of community composition as well as diversity. To address the functions of the community in the bioreactors in more detail, more advanced omics techniques such as RNAseq and proteomics will be used. Furthermore, single-genome sequencing and isolation of key microorganisms from the bioreactors can provide more information about the bacteria or archaea present in the bioreactors.

Influence of microorganisms on safe drinking water production

Research objectives

- Verify the importance of microorganisms in drinking water systems for the production of clean and safe drinking water.
- Study the optimal conditions under which microorganisms can contribute significantly to drinking water treatment.

Project outline

Introduction

Clean and safe drinking water is a basic human need and contributes to health and wellbeing. In the Netherlands, a major part of drinking water is produced from groundwater that contain compounds such as iron, manganese, ammonia and arsenic that are removed in drinking water production systems. Chemical interactions and conversions are important in these systems. Microorganisms may be important in mediating partly the treatment process and may be able to help refine the production of clean and safe drinking water.

Approach

Drinking water treatment systems will be sampled and the microbial communities will be studied using molecular techniques and bioinformatics approaches. Further microbial studies may be applied to gain a further insight in the importance of microorganisms for the removal of hazardous compounds from groundwater for drinking water production.

Scientific relevance

This research will lead to novel insights in microbial communities treating wastewater and involved in drinking water production. We will identify and further understand microbial specialists involved in this process, which will increase our understanding of optimal anaerobic digestion of extreme wastewater and also of optimal drinking water treatment.

Social relevance

Insight in microbial communities of anaerobic bioreactors will help to enhance the treatment of wastewater. Improvement of extreme wastewater treatment will lead to more environmental-friendly industry as it will not only reduce the release of industrial pollutants, but also increase green energy production. A further understanding of microorganisms involved in drinking water treatment and removal of hazardous compounds can help to keep drinking water clean and safe.

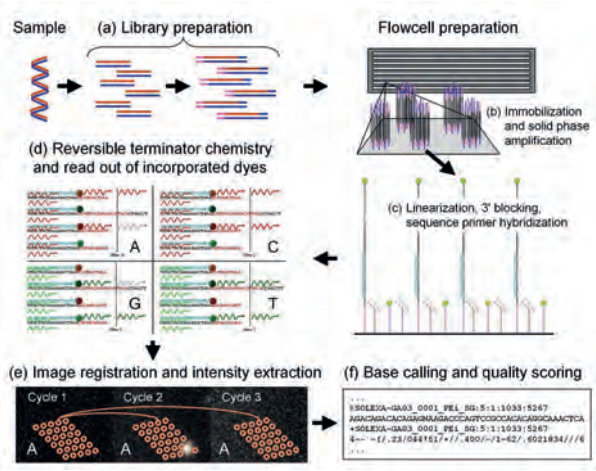

Figure 1. Overview of the Illumina sequencing workflow.

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Start date project: Jul 2015
Expected end date: Jul 2018

Key words:
Microbial community analysis, next generation sequencing, anaerobic digestion, wastewater, drinking water, recalcitrant compounds, biochemistry

Cooperation with other institutes:
Via TTW

David de Ridder (Postdoc)

Understanding iron and arsenic removal

Research objective

Improve Arsenic removal from groundwater to below 1 µg/l by enhancing the availability of its main adsorbent – iron oxide.

Project outline

Introduction

Iron oxides are known to be effective adsorbents for arsenic. Groundwaters that contain arsenic may also contain dissolved iron, which can precipitate after aeration and remove arsenic, making the groundwaters a (potentially) self-cleaning system during water treatment. Iron precipitation depends on charge interactions. The solution pH has an important influence on the surface charge of iron oxides, but the presence of anions and cations, such as Ca^2+, Mg^2+, HPO_4^2- and natural organic matter can enhance or neutralize charge interactions, depending on their relative concentrations. Also, the presence of particles may help iron oxide precipitation.

When arsenic removal is considered, both the efficacy of iron oxide precipitation (i.e. formation of the adsorbent) as well as adsorption competition are relevant.

Approach

Jar tests were carried out in demiwater in the presence of Ca^2+, HPO_4^2-, and fine particles that carried a surface charge that was either positive (ZnO) or negative (SiO_2). In additional jar tests with various natural groundwaters, the removal of iron and arsenic was followed in the waters as is, and after manipulation by adding Ca^2+, Mg^2+, HPO_4^2- and humic acid, or removing these by an/cation exchange. The influence of particle characteristics was further investigated in pilot experiments with a fluidized bed of either sand, garnet, olivine or stainless steel.

Results

The growth of iron flocs was delayed at pH 6 and pH 9, where all iron particles carry a positive or negative surface charge, respectively. This could be negated by introducing ions or particles with the opposite charge, i.e. HPO_4^2- or SiO_2 at pH 6, and Ca^{2+} or ZnO at pH 9.

In natural groundwaters, it was found that removing Ca^{2+} an Mg^{2+} resulted in limited iron floc growth, while their addition enhanced it. In two groundwaters, this enhancement was the same for equimolar additions of Ca^{2+} an Mg^{2+}, suggesting that the main underlying mechanism would be charge neutralization. In a third groundwater, addition of Ca^{2+} led to much larger particle volumes than addition of Mg^{2+}, indicating that hydroxyapatite potentially precipitated as well, or that iron flocs with a more open structure (thus larger volume, but lower density) were formed in the presence of Ca^2+. In this same groundwater, addition of HPO_4^2- led to a substantial increase in floc growth, contrary to what was found for the other groundwaters. The (Ca^{2+}+Mg^{2+})/P ratio could be used to explain floc growth for two of the three groundwaters. For all groundwaters, removal of arsenic mainly depended on the removal of iron; any competition effects, while observed, were of lesser importance. At environmentally relevant concentrations, As adsorption seemed to be hindered more by adsorption competition with Si, than with HPO_4^2-.

Iron (Fe^{2+}) removal in a high flowrate fluidized bed reactor was strongly pH-dependent. At pH>7.5, iron floc formation occurred in the water phase and the flocs were not retained in the fluidized bed. At pH<6.75, iron removal was most likely limited by the slower oxidation rate of Fe^{2+}. While this prevents floc formation in the water phase, it also prevents regeneration of the adsorbent, since Fe^{2+} needs an (oxidized) iron oxide to adsorb onto. At relatively low flow velocities, more iron was removed in the top part of the fluidized bed with the smallest particles (and highest surface), but this shifted to lower layers in the bed when the flow velocity increased. This is probably related to the effective particle surface per reactorvolume during operation.

Scientific relevance

While the importance of charge interactions has been addressed by various authors, these effects are barely investigated in realistic, multi-element conditions, and literature on the impact of charged particles therein is sparse. The concept of removing iron in a high flowrate fluidized bed reactor has only been explored by a handful of researchers.

Social relevance

Arsenic is nasty.

Literature

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Start date project: Jan 2016
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Key words:
Iron and arsenic removal, rapid sand filtration

Cooperation with other institutes:
Vitens, Brabant Water, Dunea, Pidpa, Evides, RoyalHaskoning DHV, Hatenboer Water, RIVM

Ran Shang (Postdoc)

Ceramic nanofiltration membrane modification using atomic layer deposition (ALD) (2014-2018)

Research objectives

- To investigate a new route (ALD) to prepare ceramic nanofiltration (NF) membranes with homogeneous micropores, high organic and P rejection and yet high water flux.
- Mechanisms of ALD coating in the nano-sized pores.
- To study the performance of the new NF membranes for industrial wastewater treatment.

Project description

The atomic layer deposition (ALD) is investigated as a novel method to precisely modify the pore size of ceramic nanofiltration membranes. The ALD can also be used to . The is a self-limiting gas-phase deposition method for growing atomic scale thin films on a range of inorganic materials. It can be used to coat thin layers on a mesoporous and microporous substrates in a controlled manner, resulting in the desired pore size reduction.

The ALD coating depth determines the water permeability loss after the ALD modification. The shallower coating depth leads to a higher water permeability of coated ceramic membrane. The ALD coating depth in nanopores with varied pore sizes are studied.

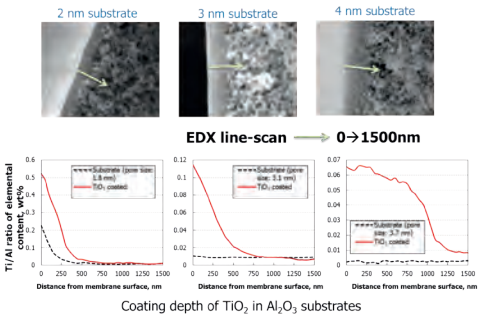

Figure 1 ALD coating depth in varied substrates

Zeolites as novel adsorbent in water treatment

Research objectives

1. To investigate the efficiency of high silica zeolites (of various pore size and Si/Al ratios) for adsorption of the organic micropollutants (OMPs) and the assimilable organic carbon (AOC) from drinking water.
2. To study the competitive adsorption between the natural organic matters and the OMPs or AOC.
3. To investigate if the zeolites can be effectively regenerated by in-situ oxidation.

Project description

Activated carbon is typically used to remove organic micropollutants from contaminated water, but during this process, natural organic matter (NOM) present in the water competes with adsorption sites and may restrict pore access. Both these effects reduce the filtration time until regeneration, and during regeneration, energy is wasted on removing NOM. Zeolites have pore sizes that are too small for NOM to enter, and initial lab tests have already shown that equilibrium adsorption of organic micropollutants on ZSM5 zeolite was similar with or without the presence of NOM [2].

The research focus will be on understanding what molecule and zeolite properties affect adsorption (both equilibrium and kinetics). Based on this, combinations of zeolites will be selected and agglomerated to granules. The adsorption capacities of these granules for a broad range of organic micropollutants and AOC will then be tested.

The regeneration of saturated zeolites will also be investigated. Since zeolites are chemically inert, oxidative techniques can be used for their regeneration. These techniques are envisioned to be more cost-effective than the current thermal regeneration used for activated carbon regeneration.

Literature

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2. de Ridder, D. J. Adsorption of organic micropollutants onto activated carbon and zeolites. Delft University of Technology, 2012.

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Start date project: May 2014
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Key words:
Ceramic NF, Sewer mining, Zeolite, Adsorption

Cooperation with other institutes:
STW, Evides, Logisticon

David Steffelbauer (Postdoc)

DASH of Water – DAta-driven Stochastic Hydraulic models of Water distribution systems

Research objectives

This project aims to develop beyond state-of-the-art methods to simulate drinking water distribution systems (DWDS) in a more realistic and accurate way by utilizing the potential of recently available smart meter technology. The aim of the project is (i) to apply data science algorithms on smart meter data using this new source of information, (ii) to develop advanced data-driven stochastic hydraulic (DASH) models of DWDS by linking this new information to simulation software and, subsequently, (iii) increase the operational efficiency of DWDS by employing these advanced models on a wide range of real-world applications.

Project outline

Introduction

Across the globe, water utilities face exceptional challenges due to ageing water infrastructure, population growth, financial and regulatory pressures, and climate change while new resources are ill-equipped to meet rising water demands (Niemczynowicz 1999). Thus, water companies are forced to operate their systems in a more efficient way.

A growing number of drinking water utilities use hydraulic models to improve the performance of their systems. However, flow and pressure sensors in these systems had only existed at larger distribution pipes and measurements are sparse even today. This results in inaccurate computer models that are not satisfactory for optimizing operations. Recently, smart water meters—devices measuring and transmitting water usage of households in real-time—are entering the market. An innovative new way of combining data from these smart meters and hydraulic models can help to quantify and reduce model uncertainties and, hence, to increase water system's operational efficiency in a wide range of applications.

Approach

The project is structured in three phases. In the first phase, data science algorithms will be developed and applied on real-world smart meters to retrieve relevant information for hydraulic modelling from the vast amount of data. The main techniques include subgroup discovery (Herrera et al. 2011), motif mining and time series analysis in collaboration with LIACS—Leiden Institute of Advanced Computer Science.

In the second phase—by linking smart meter information, stochastic demand models (SIMDEUM— Blokker 2010) and hydraulic simulation software (OOPNET—Steffelbauer & Fuchs-Hanusch 2015)—advanced data-driven stochastic hydraulic (DASH) models of drinking water systems will be developed together with KWR Water Cycle Research Institute.

During the final phase, these advanced models will be employed and tested on a wide range of real-world applications aiming to increase the operational efficiency of DWDS. These applications include leak detection and localization for reducing water losses, optimal sensor placement algorithms for placing hydraulic and water quality sensors, demand forecasting techniques for model-predictive control applications (e.g., optimal pump scheduling), etc.

Results

The project will lead to unprecedented insights in customer demand as well as novel tools to simulate DWDS in a highly realistic way—opening plenty of novel opportunities to improve DWDS efficiency through applying model-based simulation approaches. Additionally, besides scientific publications, the project will be advertised in social media and blog posts and disseminate open source developed algorithms so a wider audience can benefit from the project.

Scientific relevance

The project aims to deepen our knowledge on customer demand with highly sophisticated data science algorithms. Through coupling of stochastic demand modeling software and hydraulic models, the project will open a new and more realistic way to simulate DWDS, which will immensely increase the robustness of outcomes of optimization algorithms applied on real-world problems.

Social relevance

In the face of global uncertainty over water security, the DASH project will contribute in making DWDS more efficient in various fields of application and will assist in solving mankind's future water problems.

Acknowledgement

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Literature

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Start date project: Sep 2018
Expected end date: Aug 2020

Key words:
Drinking Water Distribution Systems, Smart Meter, Data Science, Hydraulic Modelling, Optimisation

Cooperation with other institutes:
LIACS-Leiden Institute of Advanced Computer Science, KWR Water Cycle Research Institute, OASEN drinkwater

Franz Tscheikner-Gratl (Postdoc)

Quantifying Uncertainty in Integrated Catchment Studies (QUICS)

Research objectives

Quantifying Uncertainty in Integrated Catchment Studies (QUICS) performs high quality research for developing and implementing uncertainty analysis tools for Integrated Catchment Modelling. The main aim of the QUICS ITN is to educate and train researchers capable of operating at academic research institutions, water utilities or other public bodies so as to provide them with a comprehensive understanding of water quality processes, uncertainty issues and knowledge of appropriate decision making strategies for integrated catchment management. The objective is to establish a framework for the application of uncertainty analysis in integrated modelling including definitions for the observable uncertainties in integrated catchment studies, a linkage to scientific literature and further reading on the topic, guidance for the practical application of uncertainty analysis in integrated catchment studies and practical examples for the application of the proposed framework.

Project outline

Introduction

Integrated modelling uses a set of interdependent components to construct an appropriate modelling system for a certain task. This joint modelling of two or more systems of the urban water system works by interweaving a sequence of sub-models for the various elements of the system. However, the integration of too many subsystems and processes irrelevant to the problem formulation can lead to unnecessary complexity (and errors) of the applied models. Furthermore, the decision on what is relevant for the actual question leaves room for subjective interpretation and differences of approach from the practitioners, who apply them to plan measures, to optimize systems as well as to evaluate the need of certain measures. The stepwise process of abstraction from reality to model representation with its simplifications and idealizations of the real systems comes with the unavoidable occurrence of uncertainties.

Approach

The problem is approach by implementation of existing frameworks for a global assessment of modelling uncertainties and uncertainty propagation analysis into a step-wise integrated urban water modelling approach, while expanding the scope of uncertainties incorporated. The idea is to see uncertainty analysis not as a standalone and separate process from the usual modelling workflow but as an integral part of it. The used model and sub-models need to be revised and if necessary refined with every step, creating a feedback loop for the model. Contemporaneously with this process, a thorough continuous documentation of the information, data, changes and assumptions used during the process and the uncertainties of the before mentioned should be included to enable other people to comprehend what has been done and what every bit of data means. The treatment of uncertainties is incorporated here not as one step included in model analysis or calibration, but as a continuous work accompanying the entire integrated modelling process.

Results

A key element of QUICS is the completion of publicly available reports and guidance documents which will allow practitioners to understand uncertainty and implement methods which have been developed during the QUICS project, available at https://www.sheffield.ac.uk/quics/dissemination/reports.

Scientific relevance

The project aims to examine the identification and quantification of uncertainty throughout a catchment, from rainfall to rural runoff and wash off processes, through to water and pollutant transport processes in urban areas as well as receiving surface waters. This complete coverage including both rural and urban sectors and the determination to deal with the temporal and spatial integration issues and the resulting uncertainties is unique and essential, if catchments are to be modelled effectively in an integrated fashion and the model outputs used to sensibly inform investment decisions.

Social relevance

The project will provide support for the development of abundant and dynamic world-class human resources in the European research system, taking into account the inherent international dimension of research by exposure

of the QUICS fellows to various internationally leading research centres and institutions and innovative private and public sector organisations.

Literature

https://www.sheffield.ac.uk/quics/dissemination

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Start date project: Mar 2017
Expected end date: Mar 2018

Key words:
Uncertainties, integrated modelling, decision support

Cooperation with other institutes:
University of Sheffield, CH2M

Steef de Valk (Postdoc)

Passive waste water treatment using mineral wool based bio filters

General objective

In many cities around the world there is little access to centralised waste water treatment facilities. This results in the discharge of domestic waste in open canals that eventually discharge into rivers and seas. Because the waste water also contains pathogens and other contaminants it poses a severe health risk to the communities living around these canals. Our aim is to treat waste water at the source and improve the water quality downstream while simultaneously reducing health risks. We strive to achieve this by using simple mineral wool based bio filters.

Project outline

Introduction

In New Delhi, India and Jakarta, Indonesia, only a part of city has access to centralised waste water treatment facilities. About 40% of the waste water is treated by these facilities. The remainder of the untreated sewage flows through a network of small drains throughout the city into larger canals and eventually discharges into rivers and seas.

It is estimated that by going down stream, the pollution in the drains increases due to the continues inflow of sewage as the drain flows through the city and the health risks associated with living near the drain increases. By partly treating the waste water at critical areas such as before entering a slum area or at smaller inflow points, overall water quality can be improved and health risks reduced before the water flows into higher populated areas.

Twofold approach: Biofilter cascades and vertical walls

The larger drains are originally designed to remove monsoon water and therefor have a large hydraulic capacity. During the dry season, the drain system has a large hydraulic overcapacity and due to height differences, water flows freely through the drain creating the possibility for passive aeration. These conditions can be used to passively clean the drain by constructing bio-filter cascades at (inflow) points along the drain.

By constructing small cascades, oxygen rich water is produced which in turn can be used for the biological processes inside the porous bio filters made from mineral wool. The dykes and cascades are to be removed when the monsoon period starts, to restore the hydraulic capacity of the drain and ensure the proper discharge of rainwater. During this period the filter material can be recycles and new filters constructed for the next dry season.

An alternative approach makes use of the limited space and construct the bio filters vertically. These systems can be built near the pollution source and also have a aesthetic function as plants can be grown on top of the filter.

Filter material

The filter material that is going to be used is called Drainblocks. This porous carrier material is made out of mineral wool and can be fabricated in different densities.

Partners

This research is funded by the Dutch 'Grote Giften Campagne' foundation. Knowledge transfer and cooperation is an important aspect for this foundation and thus will be focussed on during this project by close cooperation with local universities. The research is supported by Drainblocks B.V. who provides us with their expertise and mineral wool products.

Scientific relevance

This project will demonstrate that local treatment of waste streams can be achieved in an effective and simple way using mineral wool bio filter systems.

Social relevance

By locally treating waste water, the direct health impacts are lessened accordingly. This will benefit whole communities that are exposed to the waste water and could concordantly improve the water quality in receiving water bodies.

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Start date project: Jun 2018
Expected end date: Jun 2020

Key words:
Local water treatment,
Mineralwool, Biofilters

Sonja Vidojković (Postdoc)

Magnetite surface properties in the various conditions of power plant water steam cycle

Research objectives

The research intends to improve the understanding of the mechanisms governing corrosion-product deposition in water-steam cycles of power plants units and to identify the most important parameters that influence its formation. The main objective of the proposed project is to determine the effect of octadecylamine, oleylamine, oleyl propylenediamine, acetate, formate, glycolate, propionate, and aluminium on magnetite surface charge, zeta potential and the deposition rate at high temperatures.

Project outline

Introduction

Deposits have substantial negative impacts on power plant performance, reliability and availability, cause sizable economic consequences and raise the costs of electrical energy. Therefore, improvement of the understanding of deposition mechanisms in boiler tubes is defined as a high priority in power industry. However, deposition in power plant cycles is the least understood aspect of the operational cycle. The current method used to remove the deposits does not solve the problem satisfactorily. The proposed project suggests a new approach to reduce the deposition by altering the surface characteristics of the suspended particles, potentially forming deposits, in order to increase the electrostatic repulsion between the particles and the inner boiler tube wall. This will enable to identify techniques and methodologies to mitigate the process of deposition. This experimental research will focus on magnetite (Fe3O4) because it is known to be the predominant deposited compound found in water-steam cycle of fossil fuel plants and in water-cooled nuclear reactors. The surface and electro-kinetic properties of magnetite are a function of temperature, which indicates the necessity of providing results at high temperatures under the real power plant operational conditions.

The proposed project will provide the first results on the effect of adsorbed (on magnetite surface) film forming amine additives and breakdown products of organic plant cycle treatment chemicals based on film forming amines, and aluminum on surface charge up to 290 °C, zeta potential of magnetite up to 80 °C and deposition rate up to 150 °C.

Approach

The proposed experiments will simulate the processes taking place in a power plant water-steam cycle. The basic surface properties of magnetite (surface charge, zeta potential) and its deposition rate on metal surface will be systematically studied over a wide range of temperatures and solution compositions. The outputs of the proposed project will be: (1) Collections of experimental data for each variable over the temperature range up to 290 oC and determination of influence of varied solution compositions, pressures and temperatures to the magnetite surface properties and the deposition rate. (2) Establishment of the relations between the solution composition and the chemistry of the particles over a broad range of temperatures. (3) Determination of the conditions most likely to contribute to the deposition process and demonstration of how to alter the conditions in the water-steam cycle to change the deposition behavior but not negatively impact other operations within the cycle. (4) Selection of amines according to the deposition criteria. (5) Development a comprehensive model for predicting the behavior of the surface of magnetite in the presence of the examined compounds.

Results

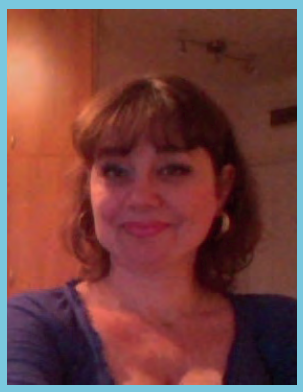
A key element of QUICS is the completion of publicly available reports and guidance documents which will allow practitioners to understand uncertainty and implement methods which have been developed during the QUICS project, available at https://www.sheffield.ac.uk/quics/dissemination/reports.

Scientific relevance

The result of this project will allow to understand and control the mechanisms leading to surface fouling and build a comprehensive mathematical model for predicting, controlling and preventing deposition.

Social relevance

The obtained results will serve as a basis for the development of tools to reduce the boiler tube failures. They will allow to enhance the reliability, availability, efficiency and performance of the power plants, and reduce the costs of electrical energy.



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Start date project: Jul 2018
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Key words:
power plant, boiler tube deposits, magnetite

Feifei Wang (Postdoc)

Bromate biodegradation during managed aquifer recharge

Research objectives

The main objective of this study was to investigate the behavior and mechanism of bromate (BrO_3-) biodegradation during managed aquifer recharge (MAR). Specially, a) the competition of nitrate (NO_3-) and BrO_3- biodegradation, b) the effect of denitrification functional gene on BrO_3- removal, c) the effect of denitrifying bacteria community on BrO_3- removal.

Project outline

Introduction

The combination of advanced oxidation process (AOP) and MAR is a potential system to remove more organic micro-pollutants during drinking water treatment processes[1]. BrO_3- formation has been observed to happen during ozonation of bromide containing water. The disinfection by-product, BrO_3-, is an issue to be considered since BrO_3- has been designated as carcinogenic to humans. Our previous study showed that BrO_3- biodegradation occurs under anoxic condition in MAR systems and probably denitrifying bacteria contribute to BrO_3- biodegradation[2]. So far, no further research about BrO_3- biodegradation mechanism during MAR has been conducted. The understanding of BrO_3- biodegradation mechanism in MAR is helpful to maximize BrO_3- removal by optimizing the operation conditions.

Approach

To investigate BrO_3- biodegradation performance in oxic zones and anoxic NO_3- reducing zones of MAR systems and to study the influence of NO_3- on BrO_3- removal, column experiments using oxic sand column simulating oxic zones and anoxic sand column simulating anoxic zones of MAR systems were carried out in the presence and absence of NO3-. The experiment was carried out for 13 months in total, including an acclimation period of 3 months before the 10 months formal experiment period.

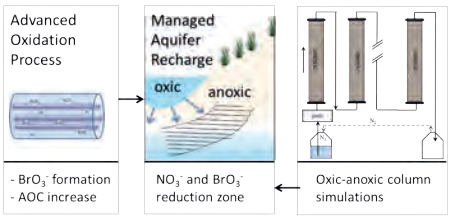

Figure 1 graphic abstract of BrO_3- removal simulation in NO_3--reducing zones of MAR

Results

The results about the competition of NO3- and BrO3- biodegradation have been collected and analyzed. Other results are being analyzed. The results of oxic and anoxic column (1 m) indicate that BrO3- and NO3- compete for reduction by denitrifying bacteria, but BrO3- reduction and NO3- reduction can occur simultaneously even if denitrifying bacteria prefer NO3- to BrO3- as an electron acceptor (Figure 2). The presence of NO3- is a precondition for denitrifying bacteria to reduce BrO3- in NO3--reducing anoxic zones of MAR systems.

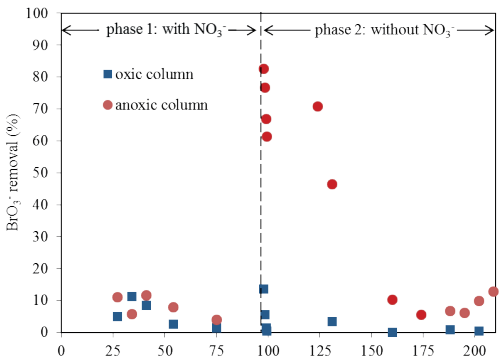

Figure 2 BrO3- removal in the 1 m oxic and anoxic columns containing acetate supplemented MAR water as influent with 10.3±1.8 mg/L NO3- (phase 1: 0-98 days) and acetate supplemented MAR water as influent with NO3- below than detection limit (0.89 mg/L) (phase 2: 98-209 days). 150 µg/L AOC from a CH3COONa solution was added to the MAR water to compose acetate supplemented MAR water. The dashed line at day 98 separates phase 1 and phase 2. Influent BrO3- was 56.6±6.45 µg/L. Influent DO in the oxic column and anoxic column was 8.52-10.74 mg/L and below 0.6 mg/L respectively. T=11.5±0.5C.

Scientific relevance

BrO_3- biodegradation mechanism during MAR has never been studied. This research will give insight into BrO_3- biodegradation behavior under different NO_3- concentrations and the impact of denitrifying functional gene and denitrifying bacteria community on BrO_3- biodegradation for the first time.

Social relevance

By understanding BrO_3- biodegradation mechanism in MAR, it will be possible to provide an efficient and environmentally friendly BrO_3- removal technology and therefore broaden AOP application in water treatment.

Literature

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2. Wang, F.; D. van Halem; L. Ding; Y. Bai; K. Lekkerkerker-Teunissen; J.P. van der Hoek. Effective removal of bromate in nitrate-reducing anoxic zones during managed aquifer recharge for drinking water treatment. Water research 2018, 130, p. 88-97.

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Start date project: Nov 2012
Expected end date: 2017

Key words:
Drinking water, AOP, MAR, H2O2, bromate

Cooperation with other institutes:
Dunea

Ljiljana Zlatanovic (Postdoc)

The urban water cycle as enabler for circular cities: New Urban Water Transport Systems

Research objectives

This aim of this research is to identify the extent to which the urban water transport systems would alter if resource recovery becomes an equally important design criterion as public health, public comfort and environmental health.

Project outline

Introduction

The engineered urban water cycle in The Netherlands is more than 150 years old and it comprises three separate domains: drinking water supply, sanitation and stormwater management. Throughout the past, all three domains have been linearly arranged, putting the priority on public health, public comfort and environmental health, rather than recognising and allowing for resource recovery from the urban water cycle. Awareness of depleting natural resources urged attention on the lack of circularity in handling the natural resources in urban environments. The engineered urban water cycle offers a huge potential for relieving the water-food-energy nexus by resource recovery and re-use, as water itself, phosphate, and organic or thermal energy can be effectively recovered and re-used in many applications. However, the resource recovery approach requires a concentrated wastewater flow, which will have major consequences for the drinking water use and the collection and transport of wastewater. To unveil the possibilities of resource recovery, the engineered urban water cycle needs to be comprehensively reconsidered as an integral system.

Approach

Our approach involves:

1) Inventarisation of best practices on resource recovery from the engineered urban water cycle that might affect current urban water transport systems;
2) Developing resource recovery scenarios based on the conducted inventarisation;
3) Building and validating an integral model by which it will be possible to simulate the hydraulic behaviour of the drinking and wastewater load in the current drinking and wastewater transport systems. This model will focus on the effect of customer behaviour on the drinking water use and consequently wastewater production (flow, compounds and concentrations) on a short time scale (seconds to minutes) and small spatial scale (tap level) (Blokker, 2010);
4) Implementing the resource recovery scenario's in the integral model;
5) Assessing the impact of resource recovery options on the current urban water transport systems and developing novel design and operational requirements for the new urban water transport systems.

Results

The outcome of this research will be a set of verified and calibrated models that represent drinking water supply and wastewater generation, collection and transport based on the behaviour of customers, both in quality and quantity. Results from these models will lead to novel design and operational requirements for the water transport infrastructure of the urban water cycle at the house, street and neighbourhood level, maximizing the possibility of resource recovery in the urban environment.

Scientific relevance

The engineered urban water cycle plays an important role in the integration of water-material-energy flows within the urban environment. However, this integration might require a new design approach towards the urban water transport systems in order to maximize the resource recovery. One of the most important issues in this new design approach is addressing the role of customers and the technological infrastructure at the house, street and neighborhood level.

Social relevance

Worldwide, urban environments face challenges to: 1) protect their citizens against water-related disasters, as droughts and floods; 2) guarantee water availability and water quality; 3) renew and upgrade the infrastructure in response to climate, demographic and economic trends (OECD, 2015). It is now the right time to start the transition towards new urban water transport systems which are targeted at the recovery of depleting resources within the urban environments.

Literature

Blokker, E.J.M. (2010). Stochastic water demand modelling for a better understanding of hydraulics in water distribution networks, PhD Thesis, Delft University of Technology.

OECD (2015). Water and cities: Ensuring sustainable futures. Paris, France: Organisation for Economic Cooperation and Development.

Stichting RIONED (2010). Riool in cijfers 2009-2010 . Ede: Stichting RIONED

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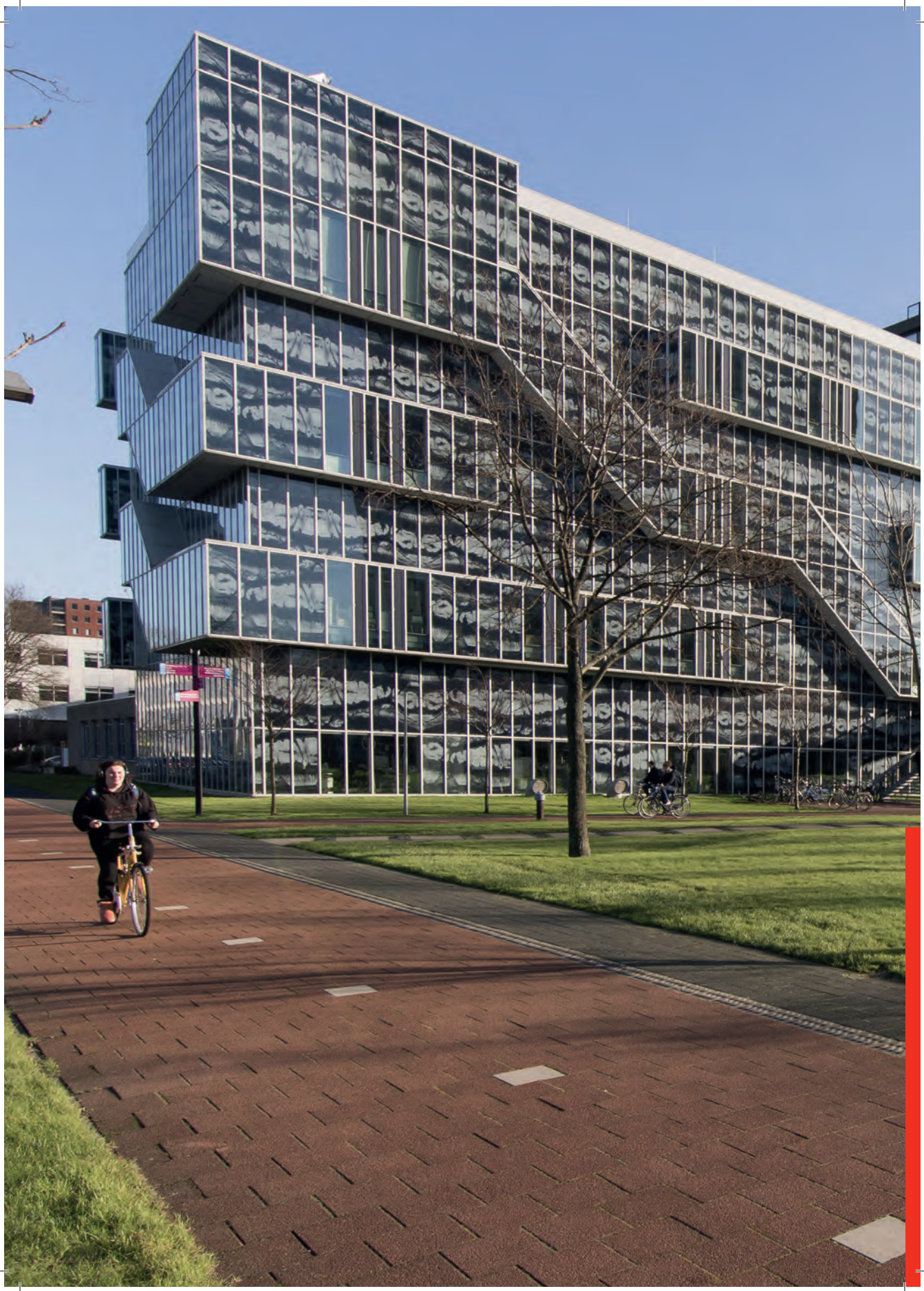
Start date project: Sep 2018
Expected end date: Sep 2020

Key words:
Urban water cycle, water transport infrastructure, resource recovery

Cooperation with other institutes:
Topsector Water, AMS Institute, Waternet, Evides, Brabantwater, WML, RoyalHaskoningDHV, DeDommel



Education

PDEng

Professional Doctorate in Engineering (PDEng)

Our society is facing various social and environmental challenges such as climate change, social and water safety challenges, water pollution, aging infrastructure, a rapid development of technology and increasing demand for mobility. The civil and environmental sector is, therefore, in urgent need of young professionals who have enough knowledge to provide innovative solutions for these challenges and enough experience to develop practical plans for application of the suggested solutions.

As a response to this market need, the faculty of Civil Engineering and Geosciences at TU Delft has started to provide a two-years (post-master) PDEng programme that will deliver highly skilled engineers to fill the gaps in the rapidly ageing population of specialists in civil and environmental engineering sector.

The PDEng in Civil and Environmental Engineering (CEE) started in February 2018 with two tracks: Water & Environmental engineering and Structural & Railway engineering. At the moment, there are three PDEng trainees in the Water & Environmental track working on the following three projects:

- Subsurface Iron removal in cooperation with Vitens water company (page 156)
- Integrated urban water risk-based asset management in cooperation with Waternet water company (page 154)
- Reclamation of nutrients from digestate after green biogas production: Development of a solid/liquid separation process: in cooperation with Host B.V. (page 158)

The PDEng in CEE is structured around an existing practical challenge, such as the abovementioned ones. The project is supported by several courses to deepen and broaden the knowledge of the trainees and to help the trainee finding innovative practical solutions in a systematic way for the project. These courses include: Advanced principle in product and process design, Techno-economic evaluation, research design, effective communication for designers, integrated design, asset management and risk management.

The candidates are supervised by a team consisting of a supervisor from the company, and a scientific supervisor, a process mentor and promotor from TU Delft, helping the trainees to obtain the desired results that are scientifically, socially and environmentally sound.

For further information about the PDEng track Water and Environmental engineering you can contact Professor Luuk Rietveld or Amir Haidari.

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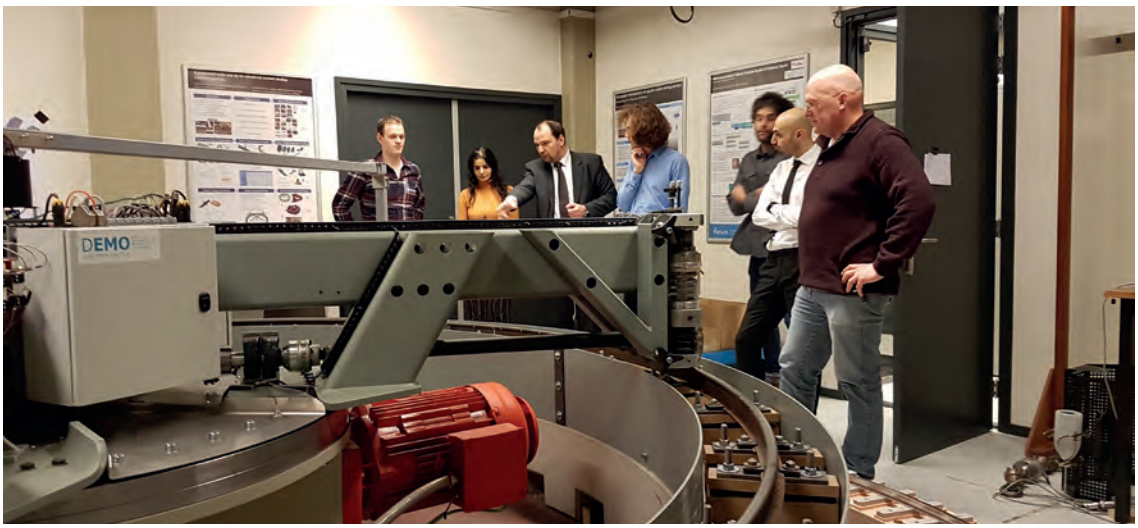

DEMO

Online Education

Online, publicly available education is regarded as part of TU Delft's social contribution and as an integral part of its goal to innovate. For these reasons, Open & Online Education was set up as a strategic innovation programme, with the overall mission to educate the world and enhance the quality of education. It seeks to create a comprehensive online portfolio, both in terms of the variety of course topics and in the type of courses on offer, while delivering an outstanding learning experience. It also aims to innovate education by conducting research into online courses and utilising the insights to benefit both online learning and teaching on campus.

MOOCs

It was back in 2007 that our section, as one of the pioneers of this university, offered its first courses on water treatment as OpenCourseWare (OCW). OCW is a free and open digital publication of high quality university-level educational material. OCW is openly licensed, accessible to anyone and anytime via the internet. A more recent and much more appealing form is a Massive Open Online Course (MOOC). A MOOC is a free online course aiming at large-scale interactive participation and open access via the web. In addition to traditional course materials such as videos, readings, and problem sets, MOOCs provide interactive user-forums that help to build a community for the learners, where professors and teaching assistants actively participate in forum discussions. MOOCs represent a form of web information systems that is revolutionising the way education is brought to people. MOOCs offer great opportunities to change how people learn, by analysing student interactions with the courseware and adapting the courseware to the learners. As per 01 September 2016, the TU Delft has reached over one million enrolments in more than 36 MOOCs in the field of science, design and engineering. Hundreds of thousands of learners from all around the world are now able to gain access to the knowledge and expertise of the TU Delft through open online courses.

WaterX series

At the Sanitary Engineering department we have two MOOCs running, namely “Drinking Water Treatment” and “Urban Sewage Treatment”. We even won an award for them! In 2018 more than 16.000 learners from more than 165 countries enrolled for our online courses. When finishing the course, learners can buy a verified certificate. A verified certificate can provide proof for an employer, school, or other institution that the learner has successfully completed the online course. In 2018 more than 500 learners bought a verified certificate. Together with the MOOC “Water & Climate” from the Water Resources section, the three MOOCs form the WaterX series. When a learner successfully completes all three MOOCs, he will receive the XSeries Certificate, which is a true achievement!

Johan, from Albania, had always been a bit sceptical of online courses, but he found that “this experience proved me wrong”. “The course helped me learn how to stick with a problem and find ways of solving it. Perhaps most significantly, this experience taught me the skills that will enable me to continue to develop my passion for the water sector beyond the virtual classroom. Thank you TU Delft for bringing into my modest Albanian home such innovative technology in the simplest way possible. You make it easy for anyone to study online.”

Online Education

Blended learning

Because of the availability of the MOOC material, campus education has changed into a more blended way of teaching. The knowledge clips, tutorials and quiz questions that were developed for an online education purposes are now being used by our own campus students as additional educational material. A type of blended learning is the "flipped classroom" strategy in which campus students are required to have read and watched the online material before attending the lecture. This way the lecturer can actively interact with the students during the lecture itself, explore topics in greater depth and creates meaningful learning opportunities. This new way of teaching has shown that not only the inscriptions to these courses but also the passing rates have increased remarkably.

What else?

Some courses of the Water Management Master track are available online, this requires customization, since the courses aren't officially available online. When a student is interested in following a Master course, please contact your online education officer, Sabrina Kestens.

New developments: ProfEd

As the university promotes lifelong learning, our section has come up with a new product: the ProfEd (short for Professional Education). This is a short and intensive course for working professionals. The ProfEd is an online education product for which learners have to pay, in contrary to the MOOCs. Learners also receive more personal guidance from the course team and the team works actively together with (water)companies in creating the course. Therefore the course has a strong practical approach; participants can apply the learning material into their working environment and get personal feedback from the professors. Combining academics and action! For example, in the ProfEd about "Nanofiltration and Reverse Osmosis" from Bas Heijman, participants engage in practical applications such as designing a reverse osmosis installation with the use of computer programs.

Developing one ProfEd would be just plain, and since the "Nanofiltration" ProfEd was such a success that we will be running it again next year, the section is creating another two more! One is from prof. Merle de Kreuk about "Aerobic Granular Sludge Technology", the other is from prof. Jules van Lier and covers "Anaerobic Treatment". As the course teams strive to give the learners the best online learning experience, they stretch all their potential, like filming on a Marine ship, incorporate Virtual Reality components and include prominent scientists as lecturers. Feeling enthusiastic? Stay tuned!

More information & registration

For an overview and the look and feel of our MOOCs and ProfEds, visit the online learning website of the TUDelft. The online courses of our Mastertrack can be found on the website of our department. Or drop by your online education officer, Sabrina Kestens, for a chat over a good cup of coffee.

In depth; how does a ProfEd work?

Now we've told you about the creation of a new online education product, the ProfEd, we would like to give you a better overview of what it really is. In the text below we explain what the "Nanofiltration and Reverse Osmosis in Water Treatment" course is composed of.

Reliable access to fresh water is one of the fundamental pillars on which a society is built. However, only a tiny fraction of planet's water is directly readily available as freshwater. The shortage of potable water, as consequence of population growth, current consumption patterns and climate changes, will be a major problem in the coming decades and will have the same social impact as that of increased energy prices. Groundwater is by far the most abundant and readily available source of freshwater. When used for drinking water, fresh groundwater sources are preferred to other readily freshwater sources because of the absence of pathogens. However, regions with sustainable fresh groundwater resources are shrinking by the day, throughout the world. A solution to this problem is the use of saline water to produce drinking water. Among different desalination techniques, Reverse Osmosis (RO) has become an attractive solution for water shortage. The purified water from RO can be used in drinking water, dialysis, power generation, pharmaceuticals and medical devices, manufacturing of semiconductors, and paper, sugar and beverage industry as well as concentrating and reclamation of wastewater. Therefore, knowing how to use the RO-technologies is important for a significant number of people.

The sanitary engineering department of Delft University of Technology developed an online course about RO membranes, to offer working professionals from all over the world a flexible, convenient way to strengthen and enhance their professional skills, increase their value as employees, and advance themselves to a higher position. The course, which is on MSc level, reached 34 learners from over 20 countries, representing Asia, Africa, Europe and North and South America. Very successful for a first run!

The online membrane professional education course focuses particularly on the Spiral-wound membrane (SWM) configuration because that is predominately applied in NF and RO. The course is divided into seven weeks and each week has its own theme. First, the course provides general information about the RO, it's principle and calculation methods. Then, it will focus on the applications of the RO on different type of water: seawater, brackish water, fresh surface water and the main problems of using RO with this type of water: concentration polarization, scaling and biofouling. Finally, some design considerations will be explained in the last week.

Each week consist of several knowledge clips, quiz questions and homework. Knowledge clips are about the theoretical matters, practical matters or an excursion to a membrane based treatment plant. Excursions are planned to a seawater RO on a ship (Karel Doorman ship), a brackish water RO (Oasen water company) and industrial water RO treatment plant (Evides water company). The homework is also very diverse. For example, the participant has to do an online measurement by the provided animated simulation or making his own SWM modules by using colored papers and glue.

Bas & Amir receive flowers for creating a very successful ProfEd

Overview of all completed MSc theses

Name	Subject
Sara Ghanbari	Pilot research and modeling of calcite contactor at low temperature for desalinated water
Anna Waque	Silica removal from presoftened reverse osmosis brine using silica gel beads
Jingwen Li	Atomic layer deposition for synthesis of ceramic tight UF membrane
Jiaxing Fang	The Study of Potential Transition Effects on Water Quality During Distribution by Smart Water Meters (SWMs)
Qiuman Tan	Potential impacts of supply water quality change on aged household connection pipes
Eleftheria Chiou	An improved model of calcium carbonate crystallization
Fajar Muhammad Rahman	Fouling control in ceramic NF membrane: Forward flush and precoating method
Wyona Boers	The corrosion behavior of mild steel in soft alkaline cooling water in relation to phosphorus-free corrosion inhibitors
Hon-Chuck Yu	Recovery of sodium sulphate from a reverse osmosis concentrate of silica-industry wastewater by eutectic freeze crystallisation technology
Tim van Dijk	Assessment of Fe(II), Fe(III) and NaMnO4 dosing for As removal <1 µg/L during aeration-filtration at WTP Prinsenbosch
Xuan Li	Assessing water quality changes and transition effects in distribution systems by online particle sampling system (OPSS)
Vera Bost	Control of biological phosphorus removal in an oxidation ditch using simple sensors
Dionysia Diamantidou	Ionic separation by Nanofiltration of spent IEX regenerant
Lotte Kattenberg	Vacuum membrane stripping of wastewater for the production of ammonia fuel gas for solid oxide fuel cells. From synthetic to real wastewater
Liying Feng	Ceramic nanofiltation membranes: Rejection of salts and NOM at high ionic strength and modification of pore size by atomic layer deposition

Overview of all completed Watermanagement BSc theses

Name	Subject
Josif Andriopoulos	Rol van de evaporometers in the peri-urbane tuinbouwsector van Rwanda
Daan van Beek	Correlation signal-to-noise ratio rainfall
Shaniel Chotkan	Microwave attenuation
Jakob Christiaanse	Analysis of plastic river pollution in Indonesia
Detmar Dieleman	Differential barometry
Jesse Dijkstra	Design instrument for sustainable development of marginal farmers
Daniel Donse	Water reclamation with ceramic membrane filtration for cooling water in industrial use
Renee Dooren	Proof of concept: een online weegschaal om totalling rain gauges continue te meten
Marc Esmeijer	Optimizing the performance of a Cubesat
Zhi Yang Fan	Het onderzoeken van de waterkwaliteit in oudere gebouwen in Delft
Abe Feenstra	Design instrument for sustainable development of marginal farmers
Brahmanand Goerdat	Dictating the frequency of occurance of sqall lines with CubeSats
Thomas Grolleman	Influence distance and spillway height on rock sour
Huck de Haas	Differential barometry
Bram Holland	Rol van de evaporometer in de peri-urban tuinbouwsector van Rwanda
Stefan Hulsbos	Conversion of measured electric energy back to kinetic energy
Pauline Janssen	Rol van de evaporometer in de peri-urbane tuinbouwsector in Rwanda
Casper Jantzen	Estimating the distribution of seepage losses along a canal
Anthonie Luteijn	Monitoring the Ayeyerwaddy river
Coco Man	Crystallization of magnesium hydroxide
Marijn Meyer Ranneft	Micro urban wetland
Frank Mols	Flocculation of anaerobic sludge
Wouter Moors	Ion exchange and coagulation
Asor Mustafa	Steady-state BOD transport in rivers - an accurate and efficient modelling approach
Laura Nougues	Arsenic removal from tubewell water with bricks in Bangladesh
Rasha al Sam	Promoting the growth of arsenite oxidezing bacteria through the use of rope
Maurice Shorachi	Roles of disinfection in the removal of antibiotic resistant bacteria
Daan Slagmoolen	Measuring evaporation on the Veluwe.
Victor Stoeten	Data analyse van een paraplu
Irene van der Veer	Leaf area index a model to predict daily values
Rik Verboeket	Low powered discharge measurement
Laura de Vries	Invloed van het klimaat op de ruimtelijke verdeling van regenpieken
Niels Walrave	Arsenic removal by Greensand plus
Kris Wijdeveld	Aquifer storage and recovery in Rotterdam
Daan te Witt	Design instruments for sustainable development of marginal farmers in Ghana
Monique Woen	Roles of disinfection in the removal of antibiotic resistent bacteria
Carolien Diederen	Drinking water softening at the tap
Omar van der Marel	Thermische energie uit afvalwater
Jasper van Duffelen	Waardecreatie afvalstroom glastuinbouwsector
Niels van Kouwen	Waterkwaliteit waterspeeltuin Delftse Hout
Esmee te Velde	Het verwijderen van arseen met ijzer
Boris Burkhardt	Ontzouten van zeewater voor irrigatie en drinkwater
Dorette Regout	Ontzouten van zeewater voor irrigatie en drinkwater

Overview of all completed Watermanagement BSc theses

Name	Subject
Jessica van den Heuvel	Duurzame watervoorziening voor verdstedelijkt Maputo
Martijn van Ruiten	Coatings van schepen
Jasper Scheijmans	Improving water quality in Addis Ababa
Jip Buis	Toepasbaarheid AKVO Caddisfly applicatie voor het detecteren van arseen
Geraldine van der Storm	Invloed meetomstandigheden op de Akvo Caddisfly applicatie
Kay van den Berg	Verwijderen van arseen uit grondwater met behulp van ijzer
Ben Bischoff Tulleken	Air flotation
Frank Mols	Anaerobic Membrane Bioreactor Chotkan Spanjers
Zhi Yang Fan	Waterkwaliteit in Delft en crowd sourcing met scholen
Daniel Donse	Duurzame watervoorziening in verstedelijkt Maputo
Razjan Baram	Trommelfilters
Marijn Meyer Ranneft	Infiltratie
Kris Wijdeveld	Wateropslag in de bodem in Spangen, Rotterdam
Wouter Moors	South West Water Treatment
Robin van den Berg	South West Water Treatment
Rasha al Sam	Arseenverwijdering uit het drinkwater in Bangladesh
Laura Nougues	Arseenverwijdering met bakstenen
Niels Walrave	Arsenic removal by Fe-Al coated pumice in (natural) groundwater matrix

Peru

On the 8th of July after a busy exam period, it was finally departure day: 12 overly enthusiastic Water management and Environmental Engineering students left to one of the biggest adventures of their lives: the GVR trip to Peru! This big group was only accompanied by one (back then still) Ph.D. student: Ricardo! Thank god he was with us, this native Peruvian helped us out in a lot of tricky situations where good bargaining skills were crucial!
More than 20 days were spent in this huge Latin-American country where we ended up visiting interesting projects, marvelous landscapes as well as cultural sights. In the beginning, we had the chance to visit Sedapal, a company that deals with the water treatment and the water distribution network in Peru's biggest city and at the same time one of the biggest cities in South America: Lima! In Pachacámac, a district of Peru, we then went to la Bio agricultural Casa Blanca, a self-sustained farm where the owners, Carmen Felipe-Morales and Ulises Moreno, both agronomists and now retired teachers of the National Agrarian University La Molina, apply the principles of ecological agriculture and scientific knowledge to develop a sustainable agriculture.

Water issues

At Sedapal we had the chance to visit treatment plants where mainly municipal wastewater is treated. It was quite interesting to hear that actually, the problems in Peru are quite similar to the ones in Netherlands and Europe, they just lack in the financial support from the government to solve them. So while in the Netherlands it is easy to just apply a UV-disinfection treatment it is in Lima not a very widely applied technique. Furthermore, we also talked about water issues in general that are there in Lima. An interesting fact about that is that Lima is actually quite a dry city. Apart from the mist that falls in winter, they have very few rainy days in the city itself.

Copper Mines and Deep Canyons

After a few days in beautiful Lima, we headed to Arequipa, the second largest city in Peru. Here we were hosted by the water treatment company - 'Suez' which had organized a day trip to one of their treatment plants located at the second largest copper mine in the world. Since the mine was located in the desert, there was an enormous lack of water. The government, Suez (contractor) and the mining company had established a collaboration to treat the domestic and industrial wastewater at the mine site. The plant treated the wastewater from the city and just a small, almost negligible, amount of wastewater from the mine. 1 m3/s of effluent went directly to the mining area and the rest was discharged into the river. This was actually very beneficial for the quality of the rivers since the treated water is of good quality. For us, it remains a mystery what happens to the 1 m3/s that went to the mine, because it does not come back to the treatment plant. The treatment plant was impressive and interesting to visit. Not only to see how they treat the water but also how the system and collaboration work there. After acclimatizing to Arequipa for one day we started early morning the next day to Colca Canyon, which is the world's second deepest canyon. The Colca Canyon was full of stepped terraces, in many shades of green, yellow and brown, and cacti. A smoking volcano (Sabancaya) was in the background, which made the views even more spectacular. We had to take some extra breaks because of the height and we had to protect ourselves from the strong sun with hats, scarfs and sunscreen factors up to 70, but this only increased the fun. We ended our hike passing ruins and then moved further to an indoor hot spring! At the canyon, the next day, the volcano's smoking crest hung over the whole valley and we learned from our guide Carlos that the local civil protection had spread an alert warning those days! Luckily, piles of stones had been erected all over to venerate the mountain gods and we felt a bit safer –knowing that this could have appeased their rage. As soon as we reached the Colca Canyon we completely forgot about erupting volcanoes and so forth. The view was magnificent and we immediately spotted seven condors! It was so surprising and spectacular, especially after the whole psychological preparation of our guide to the fact that we might not have encountered any.

Study trip Dispuut Watermanagement

Throughout the day we managed to see hummingbirds, a fox and what remained of a cow after foxes and condors had their lavish dine. Then we trekked the second deepest canyon in the world, no need to describe the beauty.

The world's highest navigable lake-Lago Titicaca

The day is an very early leave with some live, true Peruvian palm flute music. The boat took us to Islas Uros, also known as the floating islands. These islands are made purely from reed roots and reeds itself. The story goes that people fled from the Incas and Collas to live on the water in reed boats with a hut on top. About 100 years ago the people realized that a bed of roots of the reeds float and since then the floating islands have been constructed. An island lasts about 30 to 40 years and every 10-14 days a new pack of reeds need to be laid on top. Usually families live together on an island or a group of friends. The Usos islands also have their islands with a primary school, a nursery and even a little soccer field.

The whole islands lives of agriculture. The whole island is agriculture, pre Inca population built terraces along all slopes of the islands. Water cannot be extracted from the lake for irrigation as it contains a grain of salt per liter of water. A microclimate exits on the island, giving it good conditions for many crops. Including one certain plant, which if grained with water turns into a natural detergent and can also be used for increasing hair growth. One of the islands is also known for its textiles and knitting. Men learn at a young age how to knit.

The wear self knit hats, in the shape of the national peruvian plant, to indicate their social status, married or single. Having a very good knit hat indicates that one will be a good future husband. The island follows both the local religion as well as Catholicism.

The lost city and one of the 7 world wonders: Machu Picchu!

We had the full experience of travelling from Cusco to Machu Picchu, with the adventurous so called Junle Inka Trail. It was even more adventurous than it was supposed to be, because the organization that was guiding us seemed to be badly prepared for unexpected events. Therefore, on the way to Machu Picchu we got stuck on the top of a high and snowy mountain for a whole day, without any telecommunication. Fortunately we made it in the end, and it was definitely worth any extra effort, to see the impressive work of architecture that was built by the ingenious folk of the Inkas. The Inkas built the walls with a technique that is called ashlar, where stones fit together perfectly like puzzle pieces and walls are tilted with an angle of 3 degrees, which made them very stable even without cement. At least this technique kept the city intact even after the Spanish conquests 100 years after its birth. But most importantly it gave us the unforgettable chance to see it!

Machu Picchu was built around 1450, and it is thought that it was built for a royal member of the Inca empire, Pachucutec, but there are also theories that it was a ceremonial center. The truth might lie somewhere in between. Machu Picchu, meaning “Old Mountain”, is located high up in the Andes mountains at 2400m above sea level. Although it is located at such high altitude, the climate is kind of special. It is warm and humid, since it is located at the edge where the Amazon rainforest starts to expand northwards. The Andes scenery, with its high peaks of mountains, in combination with a jungle climate that vegetates and brightens up every inch of these mountains, gives it Machu Picchu a mystical ambiance. Especially in the early hours, where the morning sun rise makes a dramatic scenery and kept us in great suspense. When the freezing cold Andes morning-land is hit by the first sun rays, the land heats up immediately and gives very special lightning from the surrounding densely green vegetation. For us it was not a mystery anymore why the Inkas honoured the sun (“Inti”) and the Mother Earth (“Machamama”). Waking up with this scenery must have given Pachucutec and his family a great start of the day.

The Waterlab: where education and research meet

The department is proud of its unique laboratory facilities in the WaterLab. The WaterLab is a research and education lab providing a unique infrastructure for experimental research. We support numerous and very different kinds of permanent practical set-ups and research experiments, of course bounded by the safety regulations.

The WaterLab hosts permanent experimental set-ups for education: a gas-transfer cascade, filtration columns, bubble aeration column, the online nanofiltration, specific ultrafiltration resistance, sand columns for soil hydrology tests and a reverse osmose filtration setup. These facilities are also used by "Stichting opleiding actuele water zuiveringstechnieken bij drinkwater bereiding".

The WaterLab facilitates MSc and PhD students with the experiments of wastewater treatment in a ML-I certified laboratory. Here we study the recovery of energy, biochemicals and water from the sewer or industrial effluent, with special focus on the hydrolysis processes, granular biomass and Anaerobic Membrane Bioreactors (AnMBR).

In 2017 the WaterLab created a small 'clean-room' facility for experiments and analysis. In the open lab area of the WaterLab the majority of the experiments are located. Here we see experimental set-ups like Zero Brine to recover resources from brine water, DFCm- Delft Filtration Characterization method, Ceramic Nanofiltration membrane installation, Ceramic water filter columns for the removal of phages, Drinking Water Distribution System, high-pressure reactors for waste-water treatment, flat-sheet cross-flow module for arsenate removal. Also the research subject of generating electricity form wastewater and removal of organic micropollutants, like medicines, from municipal wastewater uusing natural materials like zeolites.

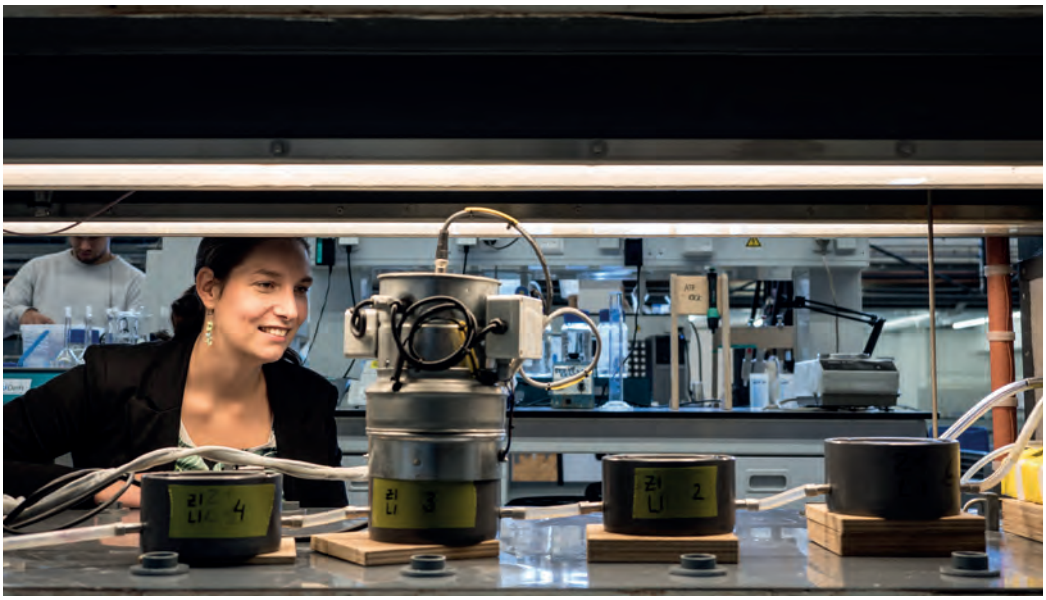
In the WaterLab we also often see proof-of-concept experiments with novel sensors or set-ups, not seldom build using huge amounts of industrial Duc tape. Examples are smart-roofs for dynamic water storage on flat roofs using small-weirs, developing temperature sensing using glass optical fibres or measuring water content in tuff building blocks using radar scanning to protect e.g. frescoes on walls. After intense testing in the laboratory, the set-ups, sensors or reactors are taken to a real-life test.

The WaterLab of our department is managed by ternary enthusiastic lab technicians: Patricia van den Bos (started summer 2018), Armand Middeldorp and Mohammed Jafar. They provide the training for analytical equipment. They provide support for designing and building experiments, safeguarding our high safety and environmental standards, purchasing equipment and consumables.

Our Water Laboratory is not a 'standard' analytical lab, but

it does possess plenty high-end analytical equipment like ICP-MS, GC, HPLC, IC, Several Automatic biomethane potential test system (AMPTS), TOC analyser, particle counter and PSD system, Solar simulator, water isotope analyser. Where possible we also try to modernise the analysing apparatus. Recently the lab purchased a modern environmental-friendly COD analyser.

A small drinking water distribution network of grey PVC pipes is built to mimic the real distribution network situation, project of Jawairia Imtiaz Ahmad. Photo by TU Delft/Frank Auperlé



The DIPool project of Marjolein Peters and Maarten Keuten looks at how the formation of harmful disinfection by-products can be counteracted. Photo by TU Delft/Frank Auperlé

Marc van Eekeren Reisfonds

Uit respect voor de bijdrage die Marc van Eekeren aan de watersector heeft geleverd en geïnspireerd door zijn passie voor het vak en zijn drive om de Nederlandse water sector internationaal te verbreden en te laten inspireren, is een fonds opgericht om Bachelor studenten van de TU Delft te motiveren en te ondersteunen om internationaal ervaring op te doen binnen de watersector: het Marc van Eekeren Reisfonds.

De TU Delft zet het Marc van Eekeren Reisfonds in als belangrijk strategisch middel om talentvolle Bachelor studenten aan de sector te binden.

Het reisfonds biedt de Bachelor studenten de mogelijkheid om binnen de Bachelor studie een reis gesubsidieerd te krijgen, welke onderdeel vormt van een watergerelateerde ervaring (stage/afstudeeropdracht/bijwonen van een congres/studiereis).

Het fonds had in 2015 een redelijke omvang (ongeveer €10.000 per jaar) en de resultaten waren erg positief. Zie hiervoor de enthousiaste reisverslagen van de studenten. Het Marc van Eekeren Reisfonds is onderdeel van een campagne Bachelor studenten van de TU Delft te interesseren in de watersector en uiteindelijk te binden en te werven voor de Mastertrack Watermanagement van de opleiding Civiele Techniek en Geowetenschappen.
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Recovery of magnesium from industrial waste streams

Coco Man

My name is Coco and for my bachelor thesis, I was very lucky to participate the experimental campaign at the University of Palermo (UNIPA) in Sicily. It is part of the European project ZERO BRINE. ZERO BRINE integrates innovative technologies to recover minerals and water of sufficient quality. The experimental campaign which I participated in was focused on the recovery of magnesium from a saline impaired stream also known as brine.

Magnesium is classified as being one of the most critical raw materials in the Europe, which means that 96% of the magnesium is imported from other countries. At the same time, it is one of the discharged ions in high concentrations in the brine streams of various industries, such as pharma, chemical, food and textile industry. This highlights the importance of the search for methods of magnesium recovery from the industrial waste streams. Crystallization is the used method to recover magnesium from industrial brine water during my research.

The challenge for my research is to shorten the filtration time of the crystallized magnesium and to obtain a good quality of magnesium. This is done by doing experiments with an imitation brine stream and using a seed suspension. The seed suspension consist seeds of magnesium hydroxide and water. The new formed crystals will 'grow' on the existing seeds, which will make the filtration time shorter.

The first step is to choose an experimenting method that is similar to the pilot system of the ZERO BRINE project and also is easy to control. These requirements are such as processing rate of the brine stream and the dimensions of the pilot system. This is why the semi batch system is chosen with a needle injection.

The second step was to obtain a good ratio between seed suspension and the imitation brine, during the crystallization of magnesium hydroxide. More seed suspension during crystallization leads to lower filtration times, but also makes the experiment more expensive. So the challenge is to find the balance between the two.

The third step is to check the quality of the crystallized magnesium hydroxide. The quality of the crystallized material has to be high, in order to have commercial values. This is done by using ionic chromatography and granulometric analysis.

This experimental study has indicated that using a semi batch system to recover magnesium hydroxide with initial seeding is promising for potential application in the experimental campaign of UNIPA. The optimal conditions were found to be a [1:10] brine to seed-suspension ratio with an injection time of 68 seconds. The produced product shows a promising purity of magnesium hydroxide of 95.8%.

What I have found in this research was promising for the future of the experimental campaign of UNIPA. My research describes only a first step in experimental campaign. The results can be optimized by further experimentation.

These two months were a wonderful experience and I have learned a lot, not only from working on my thesis but also socially from the culture and the people in Italy.

Removal of Antibiotic Resistant Bacteria in wastewater

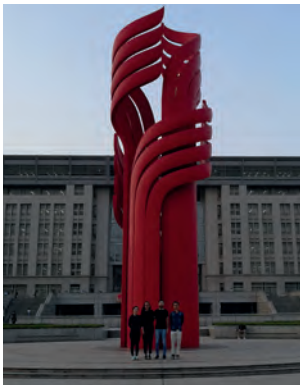
Maurice Shorachi & Monique Woen, Jinan, China

In the third quarter of the academic year of 2017/2018 we (Maurice Shorachi & Monique Woen) were given the opportunity to collaborate with the University of Jinan (UJN), China to perform a research project for our bachelor thesis. We conducted a research regarding the removal of Antibiotic Resistant Bacteria (ARB) in wastewater. This collaboration was made possible with the help of our supervisor Dr. Ir. Gang Liu (TU Delft) and our external supervisor Dr. Liping Qiu (UJN).

The use of antibiotics continues to increase significantly since the 20th century. The (over)use of antibiotics has resulted in Antibiotic Resistant Genes (ARGs) and Antibiotic Resistant Bacteria which will carry through water treatment plants without proper measures. Since public health among other industries depends heavily on antibiotics, to stop using antibiotics in these sectors will not be an option. Thus, the use of antibiotics will only further increase the number of ARGs and ARB. The objective of this thesis was to research the effects of the disinfection reagents chlorine and the combination O3/H2O2 in the removal of ARB in wastewater, originating from the campus of the University of Jinan. In the end, finding the optimal disinfection parameters for the removal of ARB in University of Jinan's wastewater.

To find out what impact the disinfection reagents have on the total bacteria and the ARB, experiments were carried out. Wastewater samples were gathered from the wastewater treatment plant of the campus of UJN. Subsequently, these samples were disinfected with different dosages of the disinfection reagents in parallel. The treated samples were cultivated on agar plates. Also, TOC analysis was performed on the treated samples. The obtained results were reviewed based on the ARB count and the TOC values. The aforementioned experiments were repeated with adjustments until the target ARB count was met, thus obtaining the optimal disinfection parameters. It was concluded that chlorine and O3/H2O2 is effective in the removal of ARB in UJN's wastewater. The found optimal disinfection dosages are respectively 120 mg Cl2/L with the reaction time of 30 minutes and 134.4 mg O3 and the ratio H2O2 to O3 of 0.15.

Our time at the University of Jinan was incredibly informative, as we have learned how to perform accurate experiments in a laboratory within a short time span. Also, it was interesting to learn about Chinese wastewater systems and which problems they face. Besides these project related experiences, we also learned a lot about the (regional) Chinese culture as we have lived as real Chinese students for a month. This includes interacting with Chinese students, experiencing the food culture and the regional culture of the Shandong province. We are very thankful to the students and our local supervisor who have accepted us with open arms in all aspects and have guided us through this amazing journey. We recommend every student to do their project abroad to challenge yourself while also broadening your perspective and learning about amazing new cultures!



Influence of spillway height and discharge on rock scour

Thomas Grolleman, Stellenbosch (South Africa)

Since the start of my Bachelor Civil Engineering I have had the dream to conduct a water research project somewhere abroad. Unfortunately I could not manage to go abroad during my Minor phase so I was extra motivated to find something for my Bachelor Thesis. During my holiday last year in South Africa I arranged a short meeting with a teacher at the Stellenbosch University, Adele Bosman. After chatting for a short while, she offered me the chance to write my Bachelor Thesis in Stellenbosch this year and to help her with her PhD project.

My research was about the influence that the spillway height of large dams and the discharge has on rock scour behind dams. The most well known case of this is The Kariba Dam on the border of Zimbabwe and Zambia, a water-retaining structure that faces the consequences of rock scour already for many years. The scour hole that has been formed is two-thirds of the total dam height and is a big hazard for the dam foundation.

In the hydraulic laboratory of the University of Stellenbosch a 1:20 scale model was set up to simulate the general case of water falling from a certain height into a plunge pool. In order to be able to do research about the influence of the height the inlet channel could be adjusted to three different heights. Besides this the discharge could also be adjusted to three different values and the water level in the basin was either 1 or 0.5 meter. Twelve layers of cobblestones (0.1m x 0.1m x 0.05m) were placed on the bottom of the basin to simulate the rock formations behind dams. After every test with a certain height, discharge and tailwater level a scour hole was formed by blocks that had been scoured away by the water flow.

Nine different tests have been executed with three different discharges (98, 126 and 228 l /s), two different drop heights (3 and 4 m) and two different tailwater levels (0.5 and 1 m). Increasing the discharge resulted in an increase in the scour depth, length and width, corresponding with was found in the literature. An increase in drop height resulted in an increase in scour depth. However, it is expected that at higher discharges increasing the spillway height would result in a decrease in the scour depth, due to the consequences of air entrainment, decreasing the scour potential of the jet.

Halfway through my research in Stellenbosch I visited the Kariba Dam in Zimbabwe myself. Here I had the opportunity to see the Dam from inside and to speak with the Swiss company that is currently doing the maintenance work at the dam. Besides talking about their strategy to fill up the scour hole and the consequences for the downstream part of the river, the chief engineer offered me an internship for next year at the Kariba Dam!

Altogether it was a life changing experience for me! Not only did I learn a lot about dams and especially its downstream part, I also learned about working in a hydraulic laboratory and a very beautiful bonus is the opportunity for me to do an internship in Zimbabwe next year.

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Van Bijnen, M. (2018) The impact of sewer condition on the performance of sewer systems

Gude, J. (2018) Arsenic removal in rapid sand filters

Gutierrez, J.P. (2018) Riverbank filtration in highly turbid rivers

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