International Water Association

BOOK OF ABSTRACTS

13TH IWA UK Young Water Professionals Conference

18-20 April 2012
Exeter, UK

http://events.exeter.ac.uk/YWP2012/index.htm

Organised by:

University of Exeter
Centre for Water Systems

South West Water

Wessex Water
a YTL company

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WELCOME TO UK YWP 2012

It is our great pleasure to welcome you to the University of Exeter for the 13th UK IWA National Young Water Professionals Conference.

This is the first time that Exeter has hosted the conference, and we are proud to do so. For 2012, we have compiled a varied programme mixing talks and posters covering a wide range of topics from academia and industry with a fantastic social program including a welcome reception and gala dinner and two exiting final-day tours. We are also including a Careers Forum for those who wish to find out more about the potential opportunities open to them within the water industry and a 'Disaster Management Forum'.

We wish to take this opportunity to extend our thank to this years' conference sponsors: South West Water, Wessex Water, Atkins and FWR. Without their support and generosity, this conference simply would not happen. In addition, the support of industry is critical to attracting our next generation of gifted young scientists into the water sector, a sector which in the current national and global landscape is centrally important.

We hope you enjoy the conference, and we look forward to meeting you over the coming days!

The 13th UK IWA National YWP Conference organising committee.

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SOUTH WEST WATER

CONTENTS

HOST ORGANISATION AND ENQUIRIES

UNIVERSITY OF EXETER
Centre for Water Systems

International Water Association

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COMMITTEE

Organising Committee

Dr. Sarah Ward	University of Exeter
Dr. Diego Gomez	University of Exeter
Mr. Ross Smith	Wessex Water
Dr. Guangtao Fu	University of Exeter
Dr. Janez Sušnik	University of Exeter

INVITED SPEAKERS

KEYNOTE PRESENTATION

Prof. Dragan Savić - Centre for Water Systems, University of Exeter

Professor Savić is the first Professor of Hydroinformatics in the UK holding this post in the College of Engineering, Mathematics and Physical Sciences at the University of Exeter since 2001. He is also Head of Engineering in the College.
Dragan is a founder and co-director of the Centre for Water Systems recognised as one of the leading research groups in the UK. He is a Chartered Civil and Water Engineer with over twenty-five years experience in research, teaching and consulting.
Prior to 1994 he worked in industry and was appointed Lecturer at the University of Exeter in 1995, where he was promoted to a Chair in 2001.

KEYNOTE PRESENTATION

Dr. Julian Dennis - Director of Compliance and Sustainability-Wessex Water Services Ltd

Dr Dennis is a microbiologist and studied for his PhD while with the Public Health Laboratory Service at the Centre for Applied Microbiology and Research at Porton Down before joining Thames Water in 1988. In 1999 he was promoted to chief scientist.
He is a director of UKWIR and is an affiliate member of the NERC peer review college. He has previously chaired BSI, ISO and CEN technical committees and is currently chairman of the CIWEM Scientific Group.

GALA DINNER PRESENTATION

Dr. Stephen Bird - Operations Director: South West Water Ltd

Dr Stephen Bird is South West Water's Operations Director and is responsible for all aspects of operations and maintenance for the Company, as well as its scientific services and Asset Management.

Stephen is Chairman of a number of national and local groups focusing on water industry research and business.

Prior to joining South West Water, he held posts in the Welsh Water Authority, National Rivers Authority and Wallace Evans Consultants. Stephen is a Fellow of the Chartered Institute of Environmental Managers, holds an MBA and is a Chartered Director.

IMPORTANT INFORMATION FOR DELEGATES

TECHNICAL PROGRAM

Posters:

- Posters can be displayed from arrival day (18th April) until the end of the conference. Boards on which to pin your poster will be available from the start of the conference. Materials to fix your poster to the boards will be made available.
- The main poster session is from 15:00 - 16:15 on Thursday 19th April. But posters will be available for viewing for the duration of the conference.

Presentations:

- Please prepare your talk in either PowerPoint or PDF format
- The lecture theatre is equipped with Windows 7 and Microsoft Office 2007.
- Please bring your talk on a USB memory stick so it can be uploaded at the beginning of the session.
- All oral presentations are limited to 15 minutes. This consists of 10 minutes for the talk and 5 minutes for questions.

TECHNICAL TOURS

This year, we have two technical tours:

- a half-day tour exploring two-thousand years of Exeter's water supply network followed by a tour of the current Water Treatment Works in Exeter. This tour will finish by 13:00 on Friday 20th, allowing people to take early transport home.
- a full-day tour visiting Roadford Lake and Dam in Devon, with a site visit and a talk detailing the latest in so-called 'upstream thinking'. The tour then moves to Tolcarne Beach, Newquay in Cornwall where the recently completed 'Clean-Sweep' program will be discussed. This will be followed with a lunch on the seaside! Note that this tour will not return to Exeter until 17:00 (approx.).

Both tours will depart from the University of Exeter Streatham Campus.

SOCIAL ACTIVITIES

Welcome reception - 18th April

This is your opportunity to break the ice and get to know your YWP colleagues at the 13th IWA YWP conference. The reception will be held at South West Water. Transport to and from the venue will be provided, as will drinks and nibbles once at the venue.

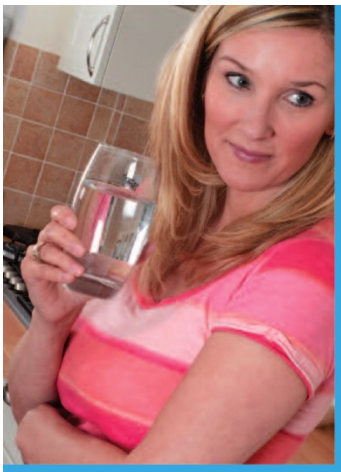
Following from this, an introduction to the City of Exeter is available for those who wish to carry on later into the evening. If you wish to carry on into Exeter, please note that you will need to make your own way back to your accommodation. Streatham Campus is approx. 15-20 minute walk from the city centre.

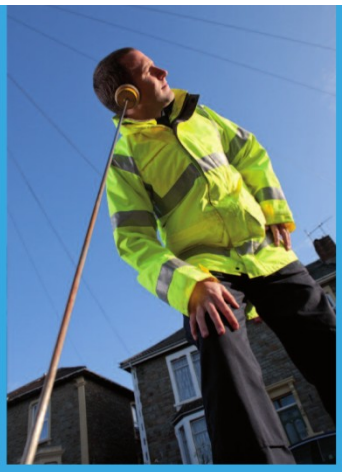
UK YWP Gala Dinner - 19th April

The conference dinner will be held at Sandy Park - home of the Exeter Chiefs rugby club. The event will begin at 19:00 and transport will be provided from the University of Exeter Streatham Campus. A keynote talk will be given by Dr. Stephen Bird of South West Water.

Following the dinner, prizes will be awarded and entertainment will be provided. The evening will end at 00:00. Transport back to the University of Exeter Streatham Campus is provided.

We would like to take this opportunity to thank our Dinner Sponsors: **South West Water**






Wessex Water

Wessex Water is the regional water and sewerage company that serves an area of the south west of England, covering 10,000 square kilometres including Dorset, Somerset, Bristol, most of Wiltshire and parts of Gloucestershire and Hampshire.

The company is committed to giving all of its customers excellent standards of service by providing high quality water and environmental services that protect health, improve the environment and give customers good value for money.

It is recognised by the water industry regulator, Ofwat, as one of the most e cient water and sewerage companies in England and Wales. Last year the firm was named "Utility of the Year" at the utility industry achievement awards.

Wessex Water firmly believes that customers are stakeholders in the company along with the environment, our employees and shareholders.

To find out more visit www.wessexwater.co.uk or download our free app.

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CONFERENCE PROGRAMME

PROGRAMME

Wednesday 18th April 2012	
14:00-14:30	REGISTRATION – Harrison Foyer TEA/COFFEE Harrison Foyer
14:30-14:40	WELCOME The 2012 IWA YWP Exeter Organising Committee
14:40-15:00	IWA YOUNG WATER PROFESSIONALS Programme Overview Frances Lucraft (IWA)
15:00-15:45	**KEY NOTE SPEAKER: Professor Dragan Savic (University of Exeter)** **"Global Water Challenges"**
15:45-16:15	*COFFEE BREAK – HARRISON FOYER TEA/COFFEE*
SESSION 1 - WATER SUPPLY INNOVATION **Session Chair: Chris Rockey (South West Water)**	
16:15-16:30	A stochastic sampling design algorithm for the calibration of Water Distribution Systems *Kyle Thompson (University of Exeter)*
16:30-16:45	The Design of Wessex Water's Water Supply Grid *William Mudahemuka (Atkins)*
16:45-17:00	Quantifying and reducing urban water system model prediction uncertainty through sequential Monte Carlo sampling *Chris Hutton (University of Exeter)*
17:00-17:15	Advanced Oxidation for Surface Water Treatment in Cornwall *Tim Ball (South West Water)*
17:15-18:00	*CHECK INTO ACCOMMODATION AND PICK UP FOR TRANSPORT TO SOUTH WEST WATER*
18:15-19:15	**COCKTAIL RECEPTION AT SOUTH WEST WATER**
19:15-LATE	**RETURN TO CITY OF EXETER FOLLOWED BY INTRODUCTION TO THE CITY OF EXETER EVENT. RETURN TO UNIVERSITY AVAILABLE**

Thursday 19th April 2012	
09:00-09:30	TEA/COFFEE Harrison Foyer
09:30-10:00	**KEY NOTE SPEAKER: Dr. Julian Dennis (Wessex Water)** **"UK Water Companies - A Monopoly or Bound By Regulation"**
SESSION 2 – WATER AND THE ENVIRONMENT **Session Chair: Dr. Sarah Ward (University of Exeter)**	
10:00-10:15	Bubbleless Aeration: How to dramatically reduce energy consumption in Aerobic Biological Wastewater treatment *Eoin Syron (University College Dublin)*
10:15-10:30	Alternative filter media in rapid gravity filtration of potable water *Phillip Davies (Loughborough University)*
10:30-10:45	Evaluation of remote sensing precipitation products over the tropical Andes, for use in water resource management in Ecuador *Neill Brauders (Mott Macdonald)*
10:45-11:00	King Abdulaziz International Airport Extension and Upgrade *Conor McLornan, (Atkins)*
11:00-11:20	*COFFEE BREAK - HARRISON FOYER TEA/COFFEE*
SESSION 3 –WASTEWATER TREATMENT TECHNOLOGIES **Session Chair: Dr. Diego Gomez (University of Exeter)**	
11:20-11:35	Enhancing nitrogen removal and effluent quality by limited filamentous bulking and partial nitrification *Jianhua Guo (Beijing University of Technology)*
11:35-11:50	Optimizing Methane Production in Wastewater Treatment Plants via Co-Digestion of Algal Biomass and Sewage Sludge *Oladipo Adewale (University of Leeds)*
11:50-12:05	A study of humic and tannic acids: Optimum coagulation conditions and resulting floc characteristics *Siobhan Mcgrath (Cranfield University)*
12:05-12:20	On-line Wastewater Monitoring Technologies: A Review and Step Change Proposal for In-Sewer Implementation *Gary Black (Severn Trent Water)*
12:20-13:20	**CAREERS FORUM** **University of Exeter (Chris Woods and academics), Arthur Thornton (Atkins), Helen Richards (South West Water)**
13:20-14:00	*LUNCH*

SESSION 4 – FUTURE WATER CHALLENGES Session Chair: Ruth Barden (Wessex Water)	
14:00-14:15	Is The Supply For Indirect Potable Reuse (IPR) A Solution For Water Scarcity? *Yanet Basulto (University of Leeds)*
14:15-14:30	Exploring climate change uncertainty in Deployable Output Estimations *Lan Hoang (University of Exeter)*
14:30-1445	THM Reduction by Surface Aeration– A practical example of Innovation in a Regulated Industry *Eva Linell (Aktins)*
14:45-1500	Can the Introduction of Local Water Distribution Systems to Rural Cambodian Communities Prove Successful? *Douglas White (University of Edinburgh)*
15:00-16:15	**POSTER SESSION**
15:00-16:15	*COFFEE BREAK - -HARRISON FOYER TEA/COFFEE*
16:15-17:45	**FORUM – Water Industry Disaster Management** **Helen Clay-Chapman (Wessex Water) , Ross Smith (Wessex Water)** **Ruth Barden (Wessex Water)**
BREAK	
19:00	***GALA DINNER & ENTERTAINMENT*** ***SANDY PARK – HOME OF EXETER CHIEFS RUGBY***
19:15-19:30	**KEY NOTE SPEAKER** : **Dr. Stephen Bird (South West Water)** **"Facing the global water supply challenges - A local Water Company's perspective"**
19:45 – 00:00	**Gala dinner followed by awarding prizes and entertainment** **Excellent local food and live music**

POST-CONFERENCE TOURS (Friday 20th April)			
Roadford Lake and Dam, Devon and South West Water "Clean Sweep" Coastal Water Quality Programme – Newquay, Cornwall		**History of Exeter's Water Supply over two millennia followed by a tour of the current Water Treatment Works**	
09:00	Pick up Point at Holland Hall	09:30	Pick up Point at Holland Hall
10:15-12:00	Tour of Roadford Lake and Dam. Upstream Thinking catchment presentation	10:15 - 12:00	Presentations on the fascinating history and future of water treatment in Exeter and the South West
13:30	"Clean Sweep" Coastal Water Quality Programme presentation – Tolcarne Beach , Newquay Followed by lunch at Tolcarne Beach Bar.	13:00	Return to University of Exeter
17:00	Return to University of Exeter		

POSTERS

Sustainable Phosphorus Removal *Flint Walter (Wessex Water)*
System Dynamics for the assessment of climate change impacts on water resources management in the Rosetta region, Nile Delta, Egypt *Janez Sušnik (University of Exeter)*
Solids Monitor for Sludge Treatment Optimisation *Miguel Cano (Cranfield University)*
Estimation of greenhouse gas emissions for development of adaptive wastewater treatment plant carbon management strategies: A literature review *Christine Sweetapple (University of Exeter)*
Challenges of Sewerage Data Collection In A Seaside Urban Area *Dnyanesh Karmarkar (Wessex Water)*

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PLATFORM EXTENDED ABSTRACTS

Optimizing Methane Production in Wastewater Treatment Plants via Co-Digestion of Algal Biomass and Sewage Sludge

O. Adewale[1], M. A. Camargo-Valero, N. J. Horan
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[1] Corresponding author. E-mail: cnoaa@leeds.ac.uk; Postal address: 6 Carr Mills, Buslingthorpe Lane. Leeds LS7 2DD; Telephone: 07576740081; Fax: 0113 3432265.
Keywords: anaerobic digestion; carbon sequestration; biogas

The UK water industry is currently facing a series of challenges driven mainly by stringent water quality regulations, population growth, climate change and its mitigation, and an increasing debt in order to meet such commitments (Palmer, 2010). Over the last 20 years, UK water companies have been in debt with increasing borrowing from zero to around £33bn; as a consequence, water bills have also increased up to 45% in real terms (Ofwat, 2011). In regards to Greenhouse Gases (GHG), it is estimated that this sector contributes with up to 1% of the national emissions and in order to meet current targets set by the UK government (i.e., reducing GHG emissions by 34% based on 1990 levels by 2020), water companies in England and Wales should reduce their annual GHG emissions to approximately 3.5Mt CO_2 by 2020 (STW, 2010).

In terms of energy requirements, up to 3% of the UK's total energy is consumed by the water industry. This energy demand is not negotiable as the society increasingly demands intensive treatment to remove nutrients and chemicals from wastewater, before it is discharged back into water bodies or is reused. The industry is regulated to meet increasing stringent water quality and reliability standards but as a result of energy use scrutiny, financial cost and environmental cost, there is need to advance into a sustainable wastewater treatment with qualities aimed at reducing carbon footprint, energy use and optimizing renewable energy production (STW, 2010).

One of the solutions to the stipulated problems could be the generation of more renewable energy efficiency measures within the sector, which has the potential to reduce GHG emissions. Even though strategies in that line have been already implemented, wastewater companies currently provide just 8.5% of its energy use from renewable sources, majorly via sludge combustion and anaerobic digestion. However with novel innovations, wastewater treatment companies could increase renewable energy generation to produce 25% of energy from renewable sources (STW, 2010).

Presently in the UK, anaerobic digestion infrastructure is set to treat at 66% of the total sewage sludge produced. However these digesters in operation are underexploited having overcapacity of at least 25% which is not utilized as well as poor feed source (sludge) containing high Nitrogen and low Carbon content (Kim et al., 2004) leading to ammonia toxicity and reduced methane yield. Thus to increase renewable energy generation within the wastewater treatment works, utilising the digester capacity with the use of additional feed substrate as well as optimizing the quality of the substrate used to one which is readily biodegradable and has high carbon content to support co-digestion with sewage sludge will be a potential pathway to enhance methane yield.

Algal biomass could be considered as an alternative for co-digestion with sewage sludge as it grows well in wastewater and have additional benefits such as carbon capture and nutrient uptake. Microalgae are photosynthetic microorganisms which are termed as a 3rd generation fuel with a noticeable feature as a result of their high lipid, starch and protein content, having its growth not linked to human food or land consumption. Also, its recognition as a potentially good source for bio-fuel production, ability to grow in wastewater and most importantly its ability to convert solar energy into biomass in a relatively short time, highlights its well acknowledged environmental credentials. Algal biomass can be converted to biogas,

bio-ethanol or bio-hydrogen amongst few others (Singh et al., 2011). However the environmental as well as economic costs for supplying nutrients and CO_2 have been reported as the most significant limitation to the energetic and carbon balance of alga production at large scale (Lardon et al., 2009).

The incorporation of algal biomass production in wastewater treatment seems to be a "win-win" situation as microalgae play the role of carbon sequestration – i.e., taking up the CO_2 produced in the industry as well as simultaneously producing biomass which can be used for methane production. This technology would also fit into the existing industry flow sheet without any major modifications. However challenges in the use of microalgae as feedstock for anaerobic digestion also exist, such as cell wall resistance which is dependent on microalgae specie, ammonia toxicity and sodium toxicity from marine species.

Therefore the submission of the full paper will highlight:

1) the opportunity to grow algae in wastewater to recover nutrients and reduce wastewater treatment costs,
2) the use of produced biomass for biogas production,
3) the challenges in the optimization of methane production via co-digestion of algal biomass with sewage sludge,
4) the evaluation of the impact that different pre-treatment processes (e.g., ultrasound, mechanical compression and enzymatic and thermal decomposition) may have on algal biomass to improve its bioavailability of resistant compounds and ultimately increase its potential for methane production.

The contributions from the final document will lead to a better understanding of sustainable wastewater treatment in terms of the cost-effectiveness of using algal technology, as well as possibilities of increasing methane production in the wastewater industries without any major modifications in the existing flow sheet.

References

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Advanced Oxidation for Surface Water Treatment in Cornwall

T. Ball, C. Tinkler, C. Rockey, A. Kolch, A. Royce

Keywords: Drinking water treatment; Advanced oxidation; Organic micro-pollutant control.

In this pilot study, Advanced Oxidation (AOP) denotes the combination of ultraviolet irradiation (UV) utilising low pressure lamps and hydrogen peroxide (H_2O_2). This technology has undergone a rapid development in the US where numerous projects have been installed, consisting mostly of standalone pump and treat technology, predominantly in the ground water remediation area.

In contrast, Europe has not yet embraced the trend towards this form of AOP technology. However, one of the most prominent projects of this type has been pioneered by PWN in the Netherlands, where the UV/H_2O_2 AOP is used within a surface water treatment plant to provide a universal barrier for a range of organic micro-pollutants.

South West Water, UK (SWW), is currently working on an AOP project to realise one of the most modern treatment trains of this type in Europe to ensure compliance with the UK pesticide standard. The new treatment units will consist of an AOP prior to Granular Activated Carbon (GAC) contactors. Other significant treatment benefits, are likely to include an improvement in the acceptability (taste and odour) of supplies, an additional treatment barrier for cryptosporidium, reduced disinfection by-product formation and improved biological stability. This is likely to have a huge impact on the course of water treatment plant design over the UK in the next 5 -10 years.

During the AOP/GAC pilot investigation, SWW worked with Trojan Technologies, who also supplied the UV system, and PWN, who provided piloting and operational expertise. The piloting work was conducted to provide proof of concept of the emerging technology for the treatment of the acid herbicides 2,4-D, mecoprop, MCPA and triclopyr and the neutral herbicide linuron. In addition, work has also been conducted targeting treatment of the taste and odour causing compounds of geosmin and 2-methyl-isoborneol (MIB).

From the pilot evaluation Electrical Energy per Order of destruction (EEO) values were calculated and compared to those predicted by Trojan's models. The use of low pressure lamp technology and good quality water (high UV-Transmittance (UVT) and low scavenging potential) has resulted in an energy efficient and low peroxide use barrier against the target range of organic micro-pollutants.

Table 1.1 Micro-pollutant EEO Comparison

Parameter	Trojan EEO prediction (kWh/m^3/order)	Measured EEO (kWh/m^{3}order)
Geosmin	0.14	0.17
MIB	0.18	0.22
2,4 D	0.33	0.20
MCPA	0.19	0.13

GACs of different ages were assessed in terms of their ability to quench peroxide and remediate any potential by-products when subjected to different empty bed contact times (EBCT) and surface loading rates (SLR). Peroxide was suitably quenched in all situations and the limited data available indicates that no significant by products would pass forward into supply.

In summary it can be concluded that the combination of AOP and biologically active GAC will achieve effective removal of all of the above mentioned substances enabling SWW to proceed as planned; upgrading the existing plant to one of the most sophisticated surface water treatment streams in Europe.

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Is The Supply For Indirect Potable Reuse (IPR) A Solution For Water Scarcity?

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*Faculty of Engineering. Autonomous University of Yucatan. Merida, Yucatan, Mexico.
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Academics, institutions and policy makers have been working to solve current water management issues from different perspectives, facing questions concerning about why conventional urban water management is failing and what needs to be done to achieve worldwide water challenges such as the 10 target Millennium Development Goal of reducing by half the proportion of people without sustainable access to safe drinking water and increase basic sanitation (WHO/UNICEF, 2010; IWA, 2011).

Introduction

Wastewater reuse is nowadays been applied to supply different demands such as agricultural irrigation, industrial (cooling towers) and urban (garden irrigation, toilet flushing) applications, groundwater recharge, and energy generation, all of them so called Indirect-Potable Reuse (IPR). For instance the current experience in South-east London, where Thames Water is working on Indirect Potable Reuse (IPR) to close the water cycle by implementing a sludge incinerator at the Crossness sewage works, where the electricity will be generated (Hills, 2009; Kalavrouziotis et al., 2011).

On the other hand, from a global perspective many countries have groundwater as its only reliable drinking water source; therefore the European Water Framework Directive (WFD) has sets new groundwater quality standards and preventive measures of pollutants into groundwater for the 18 European countries with karstic (limestone) presence (European Commission, 2008; Liu et al., 2008).

The current water management practice for the case study of this research: Yucatan aquifer, located at the South-east of Mexico, which is a karstic aquifer, and on which the city of Merida is totally dependent for its source of water supply, shows the increased need to implement an adapted new water management system.

Methodology

The aim of this research was to develop a more comprehensive water management plan to achieve the increasing water demand of the Metropolitan Area of Merida (MAM), with an efficient planning, designing, and operating system for Indirect-Potable Reuse (IPR) for the greatest water consumption activities identified: agricultural irrigation (AI) and aquifer recharge (AR).

Case study

The Yucatan aquifer has particular characteristics that involves geological nature (karstic/limestone groundwater), social (overpopulation in the urban area) and economical development (intensive socioeconomic activities), overlap in a small area rapidly developed and currently called Metropolitan Zone of Merida since 2008.

For the development of the water resource assessment of this case study and according to the literature, it was necessary to take into account local hydro geological conditions, together with the cultural and political scenario that influences the strategies of accessing.

The SWMM take into account different perspectives from the water cycle, such as the integral urban/rural management, policy and institutional arrangement, the role of different government levels, water facilities (urban drainage, water supply, solid waste and sanitation) and stakeholder participation to close the water (Fig. 1.1).

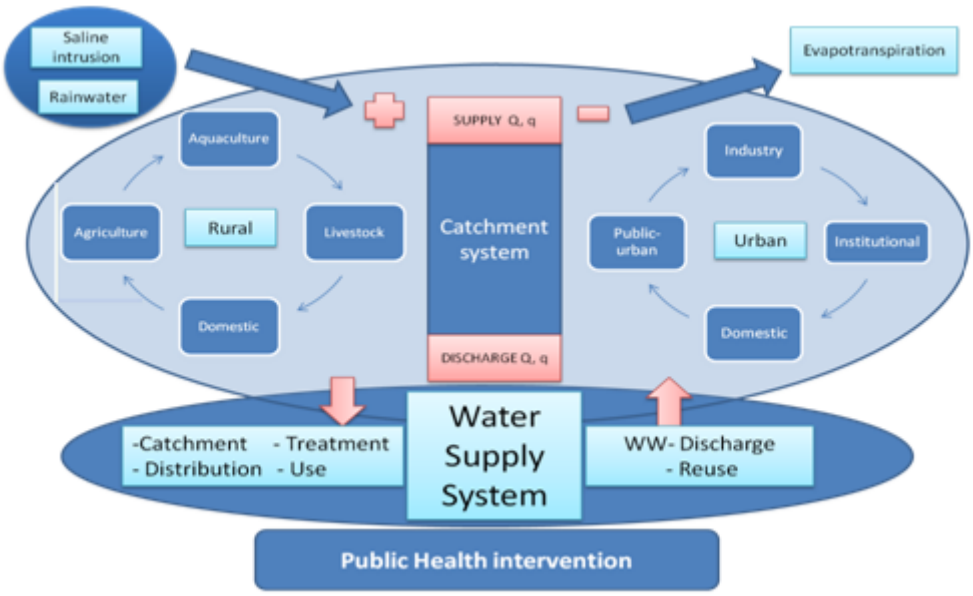

Figure 1.1. Sustainable Integrated Water Management Model (SIWMM) with a water cycle perspective.

Conclusions

The rapid growth of population in urban areas has generated a new challenge to provide efficient strategies adapted to the rapid development of metropolitan areas.

Assessments on physicochemical and microbiological status of groundwater are required to identify and reverse trends of pollutant concentrations.

The environmental legislation must be re-evaluated and adapted into the current environmental context. The development of a sustainable water management model was an effective strategy that could be applied to different areas with endangers drinking water supply to find global solutions.

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On-line Wastewater Monitoring Technologies: A Review and Step Change Proposal for In-Sewer Implementation

G Black*, G Dotro, E Cartmell****

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Keywords: Monitoring; Sewer; Toxicity

Water companies have a history of accepting discharges from various industrial operations ("traders") for treatment at the wastewater treatment works (WWTW) (Farre and Barcelo, 2003). In addition, the diurnal nature of human behaviour and variable wet weather flows directly affect the composition of the wastewater accepted by the WWTW (Bourgeois and Stuetz, 2002). With this, comes the inherent risk of undesirable events (e.g. a toxic plug) at the WWTW. This can have major implications to the accepting watercourse such as fish kills and damage to the ecosystem. Pollution events such as these can result in major fines to the parties responsible (be it the wastewater treatment company or a third party trader) and can severely damage public perception of all parties involved (Stasinakis et al., 2003).

The Urban Wastewater Treatment Directive (Directive 91/271/EEC) sets out stringent regulations for toxic and above consent discharges into watercourses, thus, the development of on-line monitoring technologies has subsequently accelerated (Vanrolleghem and Lee, 2003). The most interesting use for on-line wastewater monitoring equipment is to protect the WWTW from impending toxic plugs. Nitrifying bacteria (found in the WWTWs nitrifying processes such as the activated sludge plant) are particularly sensitive to variations of influent composition (Jönsson et al., 2001). Nitrification failure may result, subsequently leading to ineffective ammonia removal and an "above consent" discharge of ammonia, nitrite and partially treated sewage to the accepting water course (Dalzell et al., 2002). In addition, on-line monitoring equipment could be used to improve plant efficiency and identify areas where excessive use of treatment equipment can be reduced to treat sewage more closely to consent (i.e. reduce overspend and energy use due to over treatment) (Guwy et al., 1998).

In-sewer monitoring at present is mainly limited to physical properties (such as flow and level). There is no widespread implementation of equipment designed to monitor the quality and toxicity of wastewater within the sewer network (Love and Bott, 2000; Vanrollegham and Lee, 2003). At present, wastewater quality and toxicity is monitored either at the WWTW, or at the traders discharge point (by the trader or in a policing manner by the water company). Solely monitoring wastewater at the WWTW does not provide an adequate early warning of a toxic plug, and monitoring effluent at every trader site is potentially unviable from a financial standpoint (Love and Bott, 2000). This work is designed to evaluate commercially available monitoring equipment applied to wastewater (for quality and toxicity analysis) in order to propose a step change to implementation in the sewer network.

The reviewed monitoring equipment is broken down into six discrete categories, namely; respiration inhibition, nitrification inhibition (liquid phase), headspace gas, heavy metal, wastewater quality parameters (e.g. pH and dissolved oxygen) and detailed microbial activity (e.g. Flow cytometry). To date, respirometric devices have attracted the largest level of interest (30%) for academic study. However, monitors based on liquid phase analysis are inherently prone to sensor fouling. In addition, the high costs of respirometric methods, brings a limiting step for deployment on a large scale (Butler et al., 2009), (Pedersen and Petersen, 1996).

Monitoring nitrification via the liquid phase, has also proved popular, with 14% of the work focused on this, however, there is a clear lack of work in the field of headspace gas

monitoring (related to nitrification inhibition, e.g. nitrous oxide monitoring), having only 3% of the focus (allowing further scope for development). Monitoring devices based on headspace gas analysis offer excellent sensitivity at present, are generally more compact than liquid phase analysis monitors and have low maintenance intensity (due to lower sensor fouling, and no consumable requirements) (Pedersen and Petersen, 1996). Translation of this format into other monitoring techniques could subsequently allow widespread deployment of in-sewer monitoring equipment.

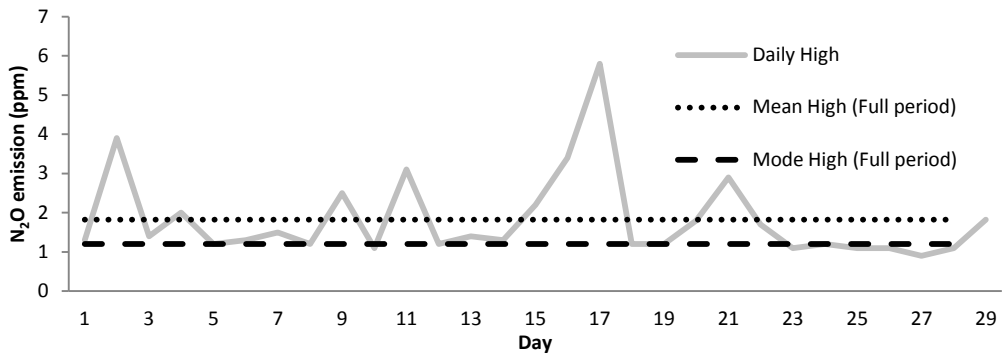

Figure 1.0 In-sewer N_2O highest daily emission collected by the N-Tox over a 29 day period.

Nitrous oxide (N_2O) is released as a response of stress to nitrifying bacteria, and can be regarded as a reliable indication of a toxic plug (Butler et al., 2009). The N-Tox® monitor (Water Innovate, Cranfield, UK) has been employed as part of this study to collect baseline N_2O emissions over 29 days within a sewer network (at a sewage pumping station). The standard deviation (1.12 ppm) in the daily high emission (figure 1.0) shows a random variation in the baseline (with peaks up to 5.8 ppm). These peaks could be indicative of undesirable wastewater conditions, and (if verified) could provide an adequate early warning to the WWTW. This justifies the use of in-sewer N_2O headspace gas analysis for wastewater toxicity monitoring.

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Evaluation of remote sensing precipitation products over the tropical Andes, for use in water resource management in Ecuador

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Keywords: Remote Sensing; Precipitation; Water Resource Management

It has been widely documented that the density of rain gauge networks throughout the globe are predicted to fall in coming years. As the global demand for water and fuel rises with a growing population, so too does the need for more effective water resource management. However, such effective management will require better understanding of the spatial and temporal variation of water as a resource, which will be mired by reducing gauge network densities. As a result, recently there has been much investment in the study of remote sensing techniques to quantify the spatial and temporal distribution of precipitation and therefore local water resources.

This study evaluates the potential application of the Tropical Rainfall Measurement Mission (TRMM) 2A25 algorithm for water resource management in the South American region of Ecuador, with specific interest in the ability of the algorithm to produce spatial and temporal average precipitation maps. This was done by comparing annual and seasonal LTA (LTA) TRMM estimates from 1998-2008 with LTA gauge observations from 1922-2008. This was made possible by highlighting the stability of the rainfall regimes in the region over the last 90 years.

Ecuador has a highly variable climate with some prominent geophysical features, such as the Andes and the Amazonian rainforest, which control precipitation patterns. However, TRMM has previously shown good performance in similar conditions elsewhere in the globe, and more recently in South America. This study strives to expose and understand the spatial and temporal variations in TRMM's performance, to highlight the existence of any bias in the estimations and to present these in a manner that will allow future studies to correct for such inconsistencies.

Findings show that TRMM PR 2A25 has good ability to reproduce spatial and temporal rainfall distributions, but encounters problems in quantifying rainfall amounts. The good performance of the satellite is noted in seasons and regions of heavy rainfall, contrastingly poorer performance is exposed in low rainfall and orographic scenarios. The need for spatial interpolation of the gauge observations is highlighted in order to better understand TRMM's behavior over the Andes. A general trend of underestimation is exposed in Ecuador, but it is recommended that a separate correction factor be applied to the Amazon, as it displays a more accurate trend of estimation. Furthermore, seasons JJA and SON highlight a more severe trend of underestimation in rainfall less than 300 mm/season, and so are also recommended to be corrected separately.

Alternative filter media in rapid gravity filtration of potable water

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Keywords: Filtration, Sustainability, Turbidity

Sand has been the prominent filter media used in rapid gravity filtration since their emergence in the 19th century. This dominance is due to its low cost, availability and dependable and predictable performance based on this extensive experience. Over recent years multi-media filters have become the typical filter arrangement. Sand still remains the preferred filter medium in the lower layer with typically anthracite used in the upper layer.

New media are becoming available and with a drive towards sustainability materials recycled from the waste of other industries such as glass and slate have started to be considered as alternative media. This work has progressed from laboratory testing to a pilot study at a local water treatment works that allows for scale-up data of real raw water variation to be compared with the results found in the laboratory. Overall this has allowed corroboration with both theory and UK practice. The media ultimately used in the pilot study were Sand, Glass, Filtralite and Slate.

Each of the alternative filter media offers different physical parameters that allow a comparison of the fundamental mechanisms that affect the performance indicators of head-loss and particle removal. Most current studies on alternative filter media do not consider the fundamental reasons for performance variation such as particle size, particle shape, zeta potential, retention time and surface area etc.

Sand – The standard filter media for comparison

Glass – An angular filter media with a the lowest surface area

Filtralite – A highly porous media surface with the highest surface area

Slate – Plate-like particle shape leads to a variable flow path through the filter

The pilot studies were used to compare the performance of the alternative filter media with regards to the requirements of head loss, turbidity removal and energy use during backwash as well as head loss and turbidity removal monitored at laboratory scale. A greater understanding of the fundamental reasons for this performance variation will allow a better choice of filter media in the future that can exploit a specific water chemistry to optimise performance.

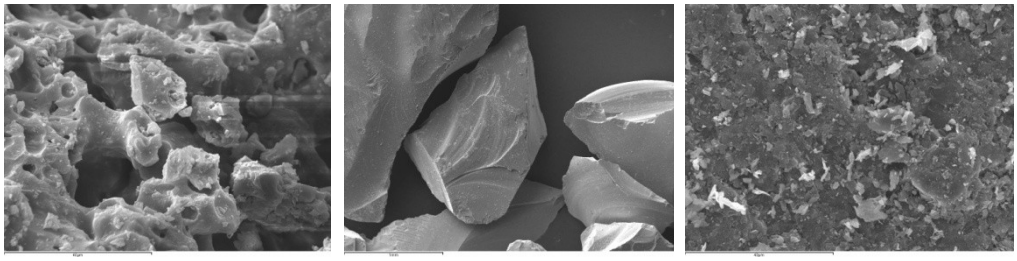

Figure 1.1 SEM images of Filtralite, Glass and Slate at various magnifications

The pilot study is reported on 4 filter columns each with a 150 mm internal diameter and a bed depth of 600 mm of mono-media (Fig. 2.1). The clarified water to the filters is produced by standard hopper bottom clarifiers with Iron coagulant typical of the majority of water

treatment works in the UK. The filters testing a combination of reservoir, stored river water and groundwater were run continuously as in the case of the laboratory units but allowing comparison of the more reliable data on expected run times for each filter media which the shorter laboratory trial did not.

Initial laboratory work was to determine the variation in key characteristics affecting filter performance. These tests included Specific Surface Area, Zeta Potential, Particle Size, Sphericity, Density, Bed Porosity, surface topography and Scanning Electron Microscopy (SEM) (Fig. 1.1) etc. From the laboratory performance the relative importance of each of these parameters were determined. The laboratory scale filter tests were of a limited run-time of 12 hours which limits the determination of the true filter run-time that the pilot plant will overcome as it will be operated to break through or maximum head-loss.

In the laboratory scale tests the turbidity removal performance of the filter media was tested at a range of flow rates (8.6, 11.1 and 13.6 m/h) and turbidities (10 and 35 NTU) these turbidity values are higher than expected in a water treatment works (typically < 2 NTU) and this was to condense the filter run down into a smaller timeframe as there was insufficient water storage to operate the filters for longer than 12 hours. The pilot study which allows full filter runs at a more representative turbidity generated by the clarifiers that falls into the expected range of < 2 NTU.

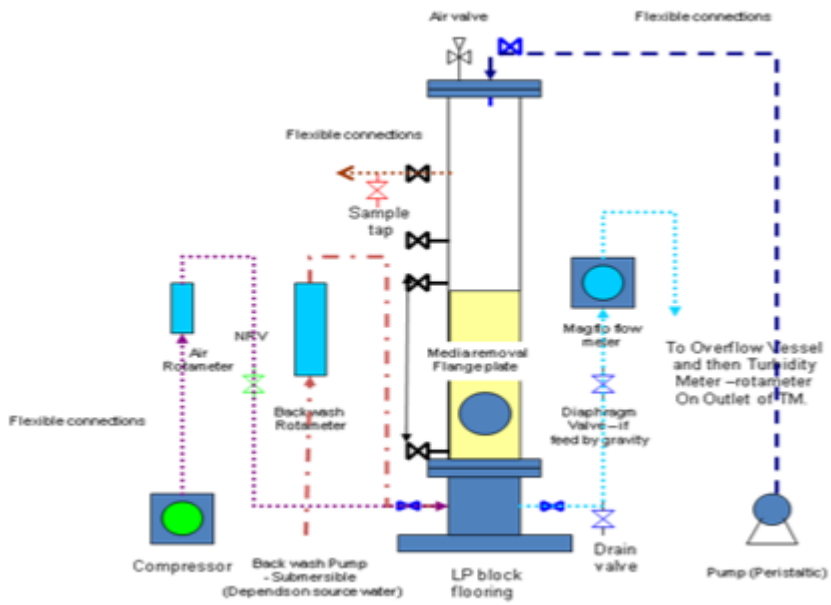

Figure 2.1 Pilot Plant column diagram

With the continued quarrying of quality sand likely to be an unsustainable practice there is an incentive to find more sustainable filter media. In addition with increased chemical coagulant costs and increased risk of cryptosporidium and higher solids loads on water works, it is worth developing better alternative filter media. Replacing the filter media it offers a cost effective solution to improve performance of a relative low-energy treatment system.

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Enhancing nitrogen removal and effluent quality by limited filamentous bulking and partial nitrification

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Keywords: Partial nitrification to nitrite; · Limited filamentous bulking; · Filaments; · Ammonia-oxidizing bacteria (AOB); · Energy saving; · Biological wastewater treatment

Introduction

Reducing energy consumption and achieving high pollutant removal efficiency are very critical for Wastewater Treatment Plants (WWTPs) worldwide. To the best of our knowledge, there are mainly three pathways to achieve the aims of lower operation cost and higher removal efficiency: (1) modifying or optimizing exiting configuration or process; (2) adopting novel biological nutrient removal processes, such as shortcut nitrogen removal via nitrite, simultaneous nitrification and denitrification and Anammox processes (Schmidt *et al.* 2003); (3) developing and installing process control system in WWTPs.

Anoxic-Oxic (A/O, i.e. predenitrification) process, as one of the most commonly used processes in China, is facing to be upgraded. When A/O process is used to treat wastewater with a low C/N ratio, it is difficult to achieve higher total nitrogen (TN) removal efficiencies due to insufficient carbon source in influent. Moreover, it is not easy to reduce operational costs generated by aeration consumption due to high DO concentration. It is necessary to develop feasible methods or strategies to solve these two problems. Based on our previous studies, a method of energy saving achieved by limited filamentous bulking (LFB) had been proposed (Guo *et al.* 2010), which offers a method for reduce aeration consumption without decreasing the quality of the effluent discharged by allowing optimal filamentous bacterial population at low DO condition. However, ammonium removal efficiency would be compromised under the state of LFB. Considering that nitrite accumulation was often built-up by controlling DO at low levels (lower than 1.0 mg/L) (Blackburne *et al.* 2008), it is possible to enhance ammonium removal efficiency with the use of partial nitrification to nitrite. If the combination of partial nitrification to nitrite and limited filamentous bulking can be achieved, it is expected solve these two problems mentioned above. In this work, the combination process of nitrogen removal via nitrite and limited filamentous bulking was achieved by process control in a lab-scale A/O reactor treating domestic wastewater. The nitrite accumulation was monitoring and nitrifying bacteria community structure was analyzed by fluorescence *in situ* hybridization (FISH) throughout the whole operation period. Furthermore, sludge settleability under low DO condition was also investigated by monitoring SVI and identifying dominant filaments.

Materials and Methods

The pilot-scale A/O reactor made of plexiglass with a working volume of 66 L and an upright clarifier with a working volume of 20.5 L were used. The feed was collected once per day from an on-campus sewer line. The detailed information of wastewater characteristics can be found in our previous study (Guo *et al.* 2009). The detailed operation conditions were summarized as Table 1.

Table 1. Operation stages and experimental procedure

Phase	Run	Duration (days)	Control mode	DO (mg/L)	HRT (h)	SRT (d)
I (Continuous operation)	1	0-60	Constant high DO	2.34±0.27	8	12
II (Batch operation)	2	61-90	Real-time control	0-4.0	4-6	60
	3	91-164	Real-time control	0-4.0	4-6	30
III (Continuous operation)	4	165-234	Constant low DO	0.56±0.17	8	12
	5	235-318	Constant low DO	0.71±0.19	9	15

Preliminary Results

According to the previous studies (Peng *et al.* 2004; Yang *et al.* 2007), partial nitrification to nitrite could be achieved quickly by using real-time aeration control with pH or DO as critical control parameters. During Phase II, aeration was turned off by an on-line control system prior to or at the point when ammonia oxidation had completed. Nitrite accumulation ratio ($NAR=NO_2^-\text{-}N/NO_x^-\text{-}N\times100\%$, $NO_x^-\text{-}N= NO_2^-\text{-}N + NO_2^-\text{-}N$) increased gradually after adopting aeration duration control. Stable partial nitrification to nitrite during continuous operation was established after switchover from the batch start-up. An overview on the following long-term results is given in Fig 1. The results showed nitrite accumulation ratio reached above 80% during Run 3 and maintained above 85% during Phase III at dissolved oxygen (DO) of 0.5-1.0 mg/L. The combination process of nitrogen removal via nitrite and limited filamentous bulking was successfully achieved by process control during Runs 4 and 5. Low DO resulted in to some extent the proliferation of some filaments. However, the sludge settleability of activated sludge was not deteriorated distinctly and sludge volume index was kept to be in the range of 150-250 mL/g. SS concentration in effluent and turbidity were distinctly lower than those during Run 1 under no bulking. It was also demonstrated that LFB caused by low DO could be used to reduce aeration consumption.

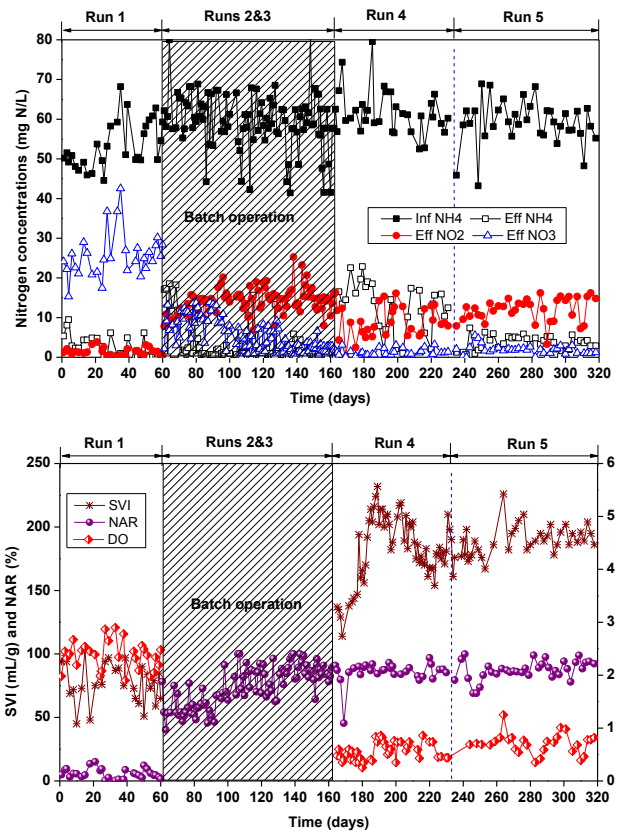

Fig. 1. Overall operation performance of the combination process of nitrogen removal via nitrite and limited filamentous bulking in A/O reactor

The stability of partial nitrification to nitrite mainly depends on the nitrifying bacteria structure. The primary reason for higher nitrite accumulation in the A/O reactor was the significant dominant ammonia-oxidizing bacteria (AOB) over nitrite-oxidizing bacteria (NOB) by real-time aeration duration during batch operation. Moreover, the control of low DO was another favorable condition, which prevented from the recovery of the NOB activity. In order to verify the assumption, the relative abundances of AOB and NOB in the reactor were monitored by FISH throughout the experimental period. In addition, the dominant filaments were identified by staining reaction and FISH. The results demonstrated that the first and second dominant filamentous bacteria were Type 0041 and *M. parvicella*, respectively (as shown in Fig. 2).

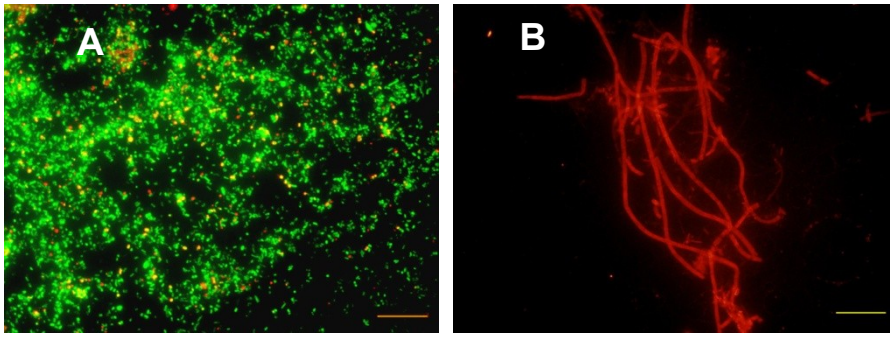

Fig. 2. *In situ* identification of AOB and filamentous bacteria in activated sludge (A: AOB image, EUBmix (FITC, green), NSO190 (Cy3, yellow); B: the first dominant filament Eikelboom Type 0041; bar=20um.)

Acknowledgements

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Exploring climate change uncertainty in Deployable Output Estimations

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Keywords: water resources; climate change; uncertainty

Water resources planning has been relying on historic climate data for future conditions, using the assumption of climate stationarity (Arnell et al., 2001; Hirschboeck, 2009; Milly et al., 2008). Yet, the impacts of climate change are introducing more uncertainty into the water systems, changing streamflow regimes and affecting the water supply-demand balance. These impacts make traditional planning based on a single projection of future less robust and efficient. Deviating from that tradition, this study uses the 10,000 scenario sets of the UK Climate Projections 2009 (Murphy et al., 2010) to perturb historic data, thus create multiple probable futures. The chosen study is North Sussex (southern England), an area likely to experience climate change disturbances. The paper aims to study the extent of uncertainty in current Deployable Output (DO) estimations when climate change impacts are included.

The study mirrors the baseline estimation procedure of the UK water industry, as shown in Figure 1.1. The UK Climate Projections consists of 10,000 sets of monthly change factors, which are used to perturb the historic 1961-1990 climate data. All other model parameters and data input are kept identical to the reference models. Structural uncertainty due to using different water resources models is acknowledged and considered in the final uncertainty analysis. The proxy water resource model has demonstrated a similar performance to the reference model AQUATOR, with a Pearson correlation coefficient of 0.78.

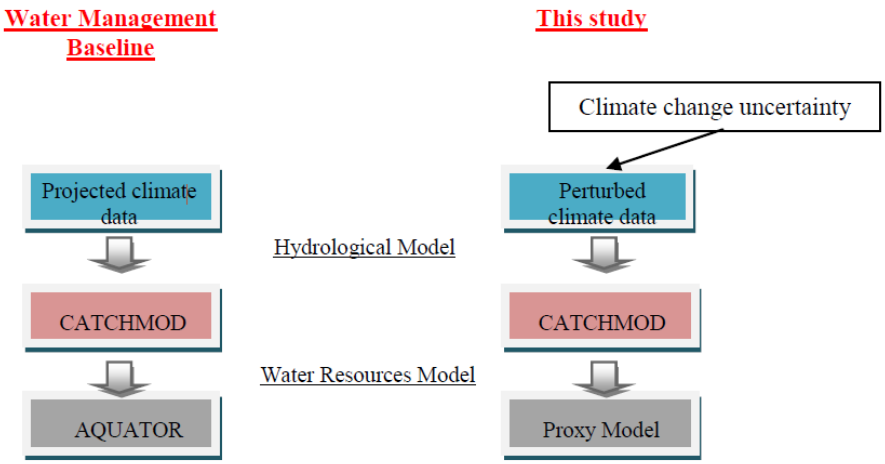

Figure 1.1 A comparative view of modelling process in existing water management plan baseline studies (without any options implemented) and this study: The latter follows the structure of the former, with the exception of climate change impacts inclusion and the proxy model

The mean estimations of the projections show a reduction in DO over time. The current DO estimation, without climate change impacts (63.73 Ml/day for 2035), is contained within the projections; however the inclusion of climate change uncertainty greatly expands the bounds of DO Estimations (Figure 1.2). These bounds include both natural variability and climate change, and often exceed the targeted headroom. The figure implies that the headroom is not a robust concept to deal with climate change uncertainty. Furthermore, it shows that the water system might be unable to meet future water demand in various cases. While the water resource management plan has outlined various options to address this potential deficit, the options need to be further tested under the whole sets of projections.

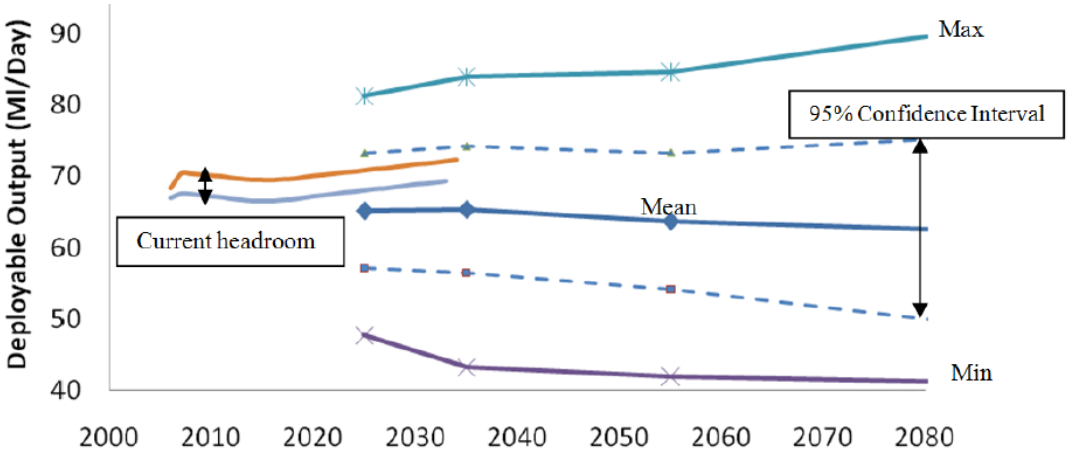

Figure 1.2 Modelling results which show the expanding bounds of uncertainty for four time slices: 2020, 2030, 2050 and 2080. These results are shown in reference to the demand side, namely current estimation of demand and targeted headroom as estimated from the Water Resource Management Plan 2009 (Southern Water, 2009). It is evident that the headroom cannot accommodate the range of uncertainty from climate change impacts and the system needs larger in-built capacity to cope with variability.

Overall, the study depicts a large uncertainty within DO estimations due to climate change impacts. There is a need for more thorough scenario analysis of climate change impacts and enhance water management options under such deep uncertainty.

Acknowledgements

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Quantifying and reducing urban water system model prediction uncertainty through sequential Monte Carlo sampling.

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Keywords: Model Uncertainty; Data Assimilation; Monte Carlo Sampling.

Abstract

This paper presents an innovative particle filter, which has been applied to a water distribution system model in order to quantify and reduce uncertainty. Uncertainty is present in all models applied to quantify and simulate urban water systems, specifically in model parameter values, input conditions, and in model structures themselves, which all then impact on model prediction uncertainty. Most past approaches for dealing with model uncertainty have focussed on reducing parameter uncertainty through the application of optimisation-based Parameter Estimation (PE). Though such methods have been effective in reducing parameter uncertainty, relatively little effort has been made to quantify errors associated with optimal parameter sets and subsequently derived predictions. This is particularly the case when such models, once calibrated, are applied in real-time State Estimation (SE).

Particle Filtering is a Sequential Monte Carlo sampling method, applicable to nonlinear non-Gaussian state-space models. Posterior probability distributions are represented by a series of state-space models (particles), each with an associated weight. Particles are propagated forwards in time until an observation becomes available, which is then assimilated to reweight each particle. A modified stochastic universal resampling particle filter was applied to a water distribution system model from the literature, using EPANET2, for the PE problem, real-time SE problem and Joint State and Parameter estimation. The re-sampling method duplicates better performing particles (states and/or parameters) at the expense of poorer performing particles, and evolves the posterior distribution of states and/or parameters as each observation becomes available. Initial application of the method shows promising results for quantifying posterior model uncertainty in both states and parameters, whilst avoiding restrictive assumptions of model linearity and Gaussianity.

The work presented in this paper is part of 'PREPARED, Enabling Change', an ongoing European Commission Seventh Framework funded large scale integrating interdisciplinary project (2010-2014). PREPARE targets the urban infrastructure for waste water, drinking water and storm water, aiming to improve its ability to cope with new scenarios on climate change in an optimal way.

THM Reduction by Surface Aeration– A practical example of Innovation in a Regulated Industry

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Keywords: THMs; Aeration; Noise

Two of Bristol Water's treatment works are fed from the Gloucester and Sharpness canal. During summer, water that is taken from the canal is immediately chlorinated, to prevent Zebra Mussels colonising the intake works, raw water tanks and pre-treatment process. Aside from killing Zebra Mussel Larvae, the chlorine is also reacting with organic compounds to form Trihalomethanes (THMs), which are harmful to health and carcinogenic. As part of PR09, Bristol Water identified exceedences in the regulation levels of THMs in the treated water. The risk posed by the mussels to reduce or disrupt the output of Purton (165 Mld, Bristol's largest and most versatile Water Treatment Works) and Littleton (65 Mld) had to be balanced against the risk of exceeding allowed limits of THMs. It was decided to continue chlorination to control the zebra mussel risk, and to implement surface aeration to remove THMs from the raw water tanks at both sites.

The decision to use Aerators represents a novel solution to an unusual problem, as most UK water companies do not chlorinate raw water. There is a general trend in the water industry towards lower chlorination, for example by using UV for Cryptosporidium removal, followed by only marginal chlorination, reducing chlorination by-products such as THMs. However, the regulation level of THMs is likely to be tightened in the future (this has already occurred in the USA), which would make this a pertinent issue for many water companies.

More generally, this project demonstrates the conflicting pressures that can lead a seemingly straightforward project to become complex. Particularly in this heavily regulated industry, the regulator is often the main focus, when in fact there are other powerful factors which can be very disruptive if not considered early.

Project Development

Through a series of laboratory-scale trials investigating alternatives, aeration emerged as a viable option for THM removal. Having approached many suppliers of different aeration systems, only one had any experience of air stripping (of CO_2 rather than THMs). This supplier was invited to carry out a trial and, due to the demonstrated success in removing THMs, became the planned solution.

8 months before the DWI compliance date, it was decided to run a trial of a different surface aerator which appeared to offer savings in capital expenditure. Upon completion of this second successful trial, Atkins was brought in to complete detailed design of the preferred option.

It was at this stage that wider environmental issues were considered in more detail (noise, ecology, planning and operations) which had not been part of the initial feasibility process, and practical aspects such as access and lifting began to be considered. At this stage multiple risks were manifest, and the compliance date jeopardized.

Conflicting Pressures

1. Environmental

A noise assessment revealed that surface aeration was very likely to cause disturbance, both to residential neighbours but also to migrating birds using the adjacent special protection area (SPA) protected by European law. Any significant effect may trigger the need for an Environmental Impact Assessment (EIA), which would take up to a year to complete. Hence it became necessary to find noise attenuation measures such as fencing or noise covers.

Figure 1.1 Surface aerator trial in raw water tank. Note limited space around tanks for access; large spray diameter is responsible for noise

2. Water Quality

A local noise cover will trap THMs as they are released into the air, greatly reducing the efficiency of air stripping. DWI Reg.31 relating to materials in contact with potable water is onerous, and applies even to raw water reservoirs. This significantly slows down the design process and limits suppliers available.

3. Operability

Noise covers would be incredibly difficult to manoeuvre in and out of the tanks.

The balance to be struck between environmental protection and delivering value to the customer is a tricky one; a solution must be found which complies with OFWAT, who want financial value, the DWI, enforcing statutory water quality obligations, and the EA, local authority and Natural England, guardians of environmental legislation.

How can Innovation and Value best be delivered within the context of this heavily regulated industry? The experience and wider view taken by a consultant should help to deliver value, but this relies on early input to enable a more informed decision to be taken. What is the best trade-off when faced with different environmental impacts- in this case embodied energy, transport, electricity costs, noise, future flexibility and employee safety. A more in-depth discussion will be available upon project completion in December 2011.

Chlorination by-products are a pertinent issue to public health and environmental protection agencies. In the future, it is expected that closer monitoring will allow chlorine to be dosed according to risk. An increasingly regulated environment makes effective multi-disciplinary working vital. It is hoped that this project provides some experience on which future projects will build.

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A study of humic and tannic acids: Optimum coagulation conditions and resulting floc characteristics

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Keywords: coagulation; flocs; climate change adaptation

The character of natural organic matter (NOM) in raw drinking water has been shown to vary seasonally depending on precipitation events such as rainfall and snowmelt (Goslan *et al.* 2002). The proportion of humic acid and tannic acid, which are significant components of NOM, also vary with precipitation events. NOM causes turbidity and colour problems in potable water, provides a substrate for microbes to grow on and reacts with chlorine to form disinfection by products (DBP) which have been linked to cancer in animals (Singer, 1999). Operational problems caused by NOM include corrosion of the distribution network and increased frequency of back washing during rapid gravity filtration. The increasing variability in seasons and weather in many parts of the world means that water companies need more information on how to manage NOM removal.

Coagulation is the most common form of treatment for NOM rich waters. The study of how NOM can be removed by coagulation is important not just for NOM but also other particles. NOM can attach to the surface of other particles in raw water thus controlling their surface charge properties (O'Melia *et al.,* 1999; Edzwald, 1993). The speciation of humic matter and coagulants depends on the solution conditions, for example pH, hardness and temperature (O'Melia *et al.*, 1999). In this study jar tests were carried out on commercial humic acid (50 mgl^{-1}) and commercial tannic acid (50 mgl^{-1}) using ferric sulphate as a coagulant at doses between 0 mgl^{-1} and 20 mgl^{-1} as Fe. The pH was varied between 3 and 9 at 1.5 increments and the optimum coagulation dose found for each pH condition. The resulting water was analysed for UV absorbance at 254 nm, total organic carbon (TOC), turbidity and zeta potential.

Seasonal variations in NOM character have been shown to impact on floc structure and strength (Jarvis *et al.* 2004). The physical properties of flocs are an important factor in coagulation as the flocs need to be robust enough to survive flow turbulence and the solid-liquid separation process. In this study the optimum ferric sulphate dose for each pH condition was used to study the flocs formed by coagulation. Floc size distributions, fractal dimension and settling rate were examined.

The results of this study increase understanding of the removal of humic acid and tannic acid by coagulation and the resulting floc characteristics. This information can be used in the development of an effective response to climate change in drinking water treatment.

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King Abdulaziz International Airport – Wet Utilities Abstract

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King Abdulaziz international airport (KAIA) is the main airport of Jeddah, Saudi Arabia. KAIA currently receives 15 million passengers per year, many of which participate in the annual Hajj. The airport expansion has been split into 3 phases. Phase 1 of the new passenger terminal complex will handle up to 30million passengers per annum and is expected to be completed by 2014. Phase 2 and 3 will increase the airport's capacity to 45 and 80million passengers respectively.

Our paper will concentrate on the design of the wet utilities for the development including potable, grey, fire and foul water provision as well as irrigation to the site. The work has been undertaken by Atkins Limited working with a leading Saudi Contractor in a design and build contract and draws upon technical staff and resources from all round the world.

Key design considerations included: Designing to US and local Saudi design codes, seismic events, aggressive soil conditions, and high water table and client stipulation of 100year design life. During planning, special consideration had to be given to the existing airport. The design and phasing allowed the current airport to function with minimal impact on airport operations. In addition to the building and runway extensions/upgrades, the supporting utilities network had to be upgraded in parallel. The proposed airport facilities will all be served from newly designed utilities networks, including, potable, chilled, grey, fire fighting water, sanitary network, electrical and communications systems.

Potable Water Network

A desalination plant west of the site is the single source of water to the existing airport. This same supply is used for the proposed potable and fire fighting networks. The utilities design had to consider failure in the network and provide a practical and efficient backup. Water is distributed to three separate load centres that in turn will supply the three zones of the airport. In the event of a supply failure, redundancy has been built in to allow 7 day back up storage at each load centre. There is also interconnection between load centre zones via normally closed valves that can be opened automatically in the event of a load centre failure.

Grey Water Network

The proposed grey water network is designed to provide water for toiet flushing to the new facilities and also provide irrigation water for both the new facilities and existing irrigation networks. The treated sewage effluent from a new on-site Sewage Treatment Plant (STP) is source of grey water for the development. Grey water demand is broken down into building demands and irrigation. A single pumping station supplies the entire site and in the case of pump or network failure a backup is provided for the critical building demands from the potable water network. Cross contamination and sufficient supply was given consideration at these locations and an acceptable solution provided.

Fire Fighting Network

A strategic fire strategy was considered for the site fire water network was designed to provide adequate fire coverage to facilities and connections to buildings for sprinkler systems and hose reels. External to the buildings networks of fire hydrants were located to provide fire coverage at key locations in accordance with the requirements of the US NFPA Codes

and Standards. Design issues of this network included, access constraints, instantaneous high demands and providing adequate coverage/backup over the network.

Sanitary Sewer Network

The KAIA site is generally very flat. There is a slight increase in ground level towards the southeast corner of the site. Because the site is 12km long, any back draining on gravity sewers would have resulted in excessively deep sewers. In order to drain the site to the STP, which is positioned at highest elevation at the southeast corner of KAIA, 10 sanitary pumping stations were required.

Whilst the gravity sewers flow in a general northwest direction (with the grade), a series of pumping stations convey the sanitary water via long rising mains (up to 8km) up to the STP. Of the 10 new pumping stations, 7 of them pump part way to the STP and discharge into nearby gravity systems, where flows are then pumped to the STP via the remaining 3 pumping stations. This reduces the length of rising mains required without directing all the flows through a single pumping station.

Due to the size and grading of the site, gravity sewers had to be laid at minimal falls to reduce the number of pumping stations required. In order to achieve a daily flush reaching self-cleansing velocity an automated flushing chamber is required at the head of many of the systems. These flushing chambers are either supplied via the grey water system or the potable water system. The incoming flow rate is regulated such that the chamber flushes once per day. A flush is triggered by a siphon which is actuated by the high water level within the flushing chamber.

Throughout the project, coordination was critical; the significant amount of proposed utility networks must share 30m wide utility corridors and 11m wide tunnels throughout the airport. 3D modelling of all utilities proposed at Phase 1 KAIA ensures site corrections were kept to a minimum.

Overall the project provided various technical and coordination challenges for the designers involved. This was exacerbated by a very demanding delivery programme but once completed, this state of the art airport will act as an international hub connecting East and West and a clear gateway to the Holy Cities of Makkah and Madinah.

The Design of Wessex Water's Water Supply Grid

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Introduction

Wessex Water has appointed Atkins as the framework consultant for the design of their Water Supply Grid. This scheme, which will be Wessex Water's largest and longest ever project, will help manage water more effectively around the region and ensure future demand is met. The multi-million pound project will take eight years to complete and is divided into 28 individual engineering schemes.

Work, which will include new trunk mains, new service reservoirs and new or refurbishment of existing pumping stations, will take place in Dorset, Somerset and Wiltshire with construction expected to start in 2013 and continuing through to 2018.

As well as allowing water to be moved around the region without having to develop new sources, it will provide alternative water supplies to areas that are currently supplied by sources which suffer from seasonal or occasional water quality problems without the need to build new water treatment works. In conjunction with catchment management to deal with deteriorating water quality, it will provide a sustainable approach to the delivery of water services to Wessex Water's customers.

Key Drivers

The four key drivers highlighted by the PR09 Business Plan (Wessex Water 2009) to be addressed by the Grid are listed below:-

- Improving the security of supply to customers, even in the event of a catastrophic source failure,
- Meeting Wessex Water's customers' demand for water over the next 25 years,
- Meeting the reductions in abstraction licences required by the Environment Agency to improve flows in some rivers and protect their ecology,
- Dealing with deteriorating raw water quality, particularly increasing concentrations of nitrates at some of Wessex Water's groundwater sources

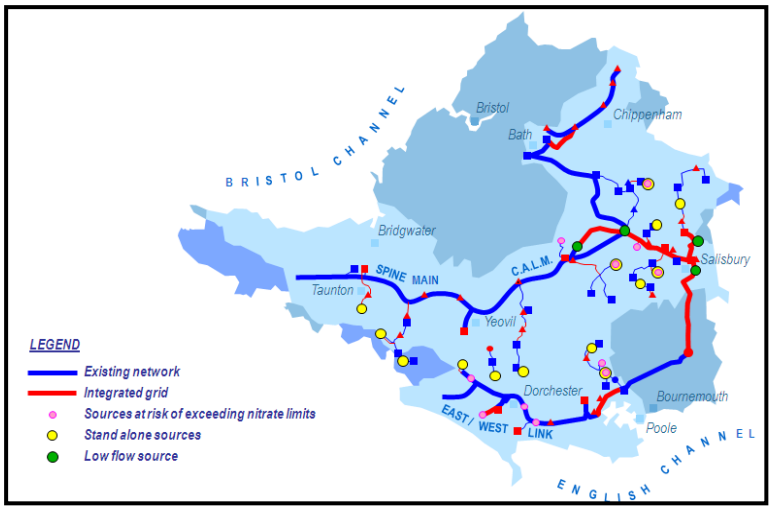

Diagram 1: How the Grid addresses the key issues

Concept Development

A range of concept solutions were considered by Wessex Water in the development of the Water Resources Management Plan; these concepts and a few additional ones were put through a screening process that identified the business plan option and an alternative option with a different route and configuration as the preferred solutions. These solutions were put through a detailed appraisal process.

The MISER water resources model of the region was used to understand the resource needs and the required capacities of the links for the two concept options. In parallel with this work, we helped develop a robust methodology for the definition of forecast nitrate levels and the consequential blending requirements for "at risk" sources.

The appraisal of the Grid concept options looked at a wide range of issues, including synergies with other Grid schemes, construction and environmental constraints, and operability, as well as cost. The options and issues were discussed at a series of stakeholder workshops. The alternative concept option was agreed as the preferred option and is currently being taken forward through detailed optioneering.

Design Challenges

The design of the Grid has brought a range of technical challenges.

The major Grid links will generally only be required to meet peak demands or manage major source outage events, with normal required flows generally low. These unusual operational needs have required us to challenge the Wessex Water's design standards, particularly in terms of reservoir storage requirements, and to develop an operational methodology that maintains satisfactory water quality during the normal low flow conditions, both in terms of turbidity and chlorine residual.

We are currently appraising options for the implementation of a control system that will allow the automated operation of the Grid with scheduled pump operation that minimises operational costs.

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Bubbleless Aeration: How to dramatically reduce energy consumption in Aerobic Biological Wastewater treatment

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Key Words: Biofilm, Bubbleless Aeration, Energy Efficiency

Introduction

Energy Usage in water treatment is becoming increasingly important year on year as the water industry attempts reduce its carbon footprint. For Wastewater treatment plants there is the added incentive of achieving an energy neutral wastewater treatment plant by maximizing the energy being produced and minimizing energy used. In municipal wastewater treatment plants the single largest user of energy is the aeration of the biological treatment processes. The current standard technology of using bubbles created via blowers and diffusers, has been studied for many years and despite many improvements being made throughout this time, the process remains highly inefficient, with only 40% of the oxygen actually being transferred to the wastewater.

The membrane aerated biofilm reactor (MABR) shows enormous potential as an alternative technology for the biotreatment of low-to-high strength wastewater. The principle benefit of the MABR is the ability to minimise the energy required to supply the oxygen for the aerobic bacteria. Due to the ability to achieve over 90% Oxygen Transfer Efficiency, it significantly reduces the amount of air needed and because the oxygen is directly supplied to the biofilm, all liquid/gas interface mass transfer can be neglected.

Technical background

The membrane aerated biofilm reactor uses diffusive membranes to supply oxygen to a biofilm which is attached to the surface of the membranes. Therefore the oxygen/air does not enter into the liquid phase once a biofilm has been established on the surface of the biofilm. Due to the fact that oxygen and wastewater are on opposite sides of the biofilm the nutrient reaction profile in the biofilm is unique and the location of the aerobically active region is within the biofilm as opposed to on the surface in other biofilm reactors.

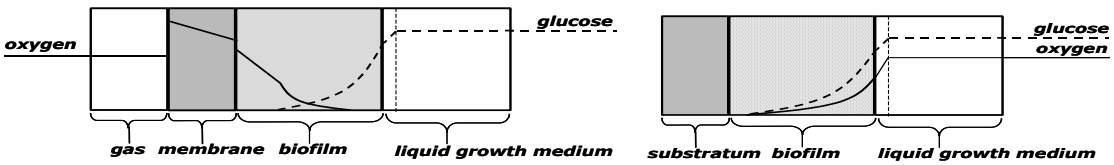

Figure 1 Configuration and indicative concentration profiles in the (a) Membrane Aerated Biofilm and (b) Conventionally Aerated Biofilm.

Modern membranes are also able to supply oxygen at high rates so much so, that the required volume for the treatment tank can be reduced by 50% from a conventional activated sludge.

Technical issues

The major drawback to the MABR is the lack of a suitable membrane for this process, because of this all membranes used to date have been adapted for use in the lab and pilot tests, eg microporous membranes are designed for water filtration which are susceptible to clogging and wetting reducing the oxygen transfer rate or diffusive membranes which have been designed as degassing membranes or gas separation membranes. These designs are not suitable to the growth of biofilm on their surface and lead to clogging and inefficient reactor performance. It is also critically important for the Biofilm thickness to be controlled. Unlike other biofilm process where the carriers move freely in the wastewater, the membranes must be attached at least at one end for the supply oxygen. Therefore to prevent the reduction in rate of reaction due to excessive biofilm growth the biofilm thickness must be effectively controlled.

Case Study

In this work, two case studies will be presented documenting the potential energy and cost savings which can be achieved with an MABR. The first, documents the treatment of typical municipal secondary wastewater, while the second examines a concentrated Ammonia rich waste stream e.g. digester centrate which by being treated separately by an MABR instead of returning directly to the head works of the wastewater treatment plant achieves significant energy and cost savings.

A stochastic sampling design algorithm for the calibration of Water Distribution Systems

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Keywords: Water Distribution Systems; Sampling Design; Sensitivity; Calibration; Stochastic

Numerical models of water distribution systems (WDS) face numerous sources of uncertainty in model and parameter specifications and must be calibrated before they are considered viable in practical applications. Calibration procedures rely on data collected from an operating WDS and are constrained by uncertainties in those data. The selection of a sampling design, a subset of the spatial and temporal locations in the system, chosen to optimise data quality and the subsequent calibration effort, is instrumental in efficient and effective WDS modelling.

The optimal placement of a limited number of sensors for the calibration of WDS models is typically approached with A, D or V optimality criteria, derived from relevant parameter or prediction covariance matrices, or with simplified criteria based on parameter sensitivity or node coverage. A common feature and weakness of many existing algorithms is the reliance on an estimate of the initial parameter vector and the inability to take into account prior probabilities of those estimates. Stochastic design algorithms are able to sample from a distribution of initial parameter guesses, thus removing this limitation. However, they are more computationally demanding than single-run procedures, within which the uncalibrated model is used as an estimator for the behaviour of that model subsequent to its calibration.

This paper presents a stochastic approach to sampling design, applied to the sensitivity-based MAX-SUM method (Bush and Uber, 1998), in order to ascertain the susceptibility of this well-known and computationally efficient algorithm to uncertainties in the initial parameter vectors for a typical water distribution network. Stochastic sampling is introduced with the aim to increase reliability of sampling designs in the absence of accurate initial parameter estimates.

The small computational demands of this popular sensitivity design are well suited to stochastic methods within which multiple design calculations are necessary. In this paper, stochastic solutions are compared with those from a range of deterministic runs, along with sets of well-known and accepted solutions from the literature. The clear benefits of a stochastic extension are presented in terms of increased reliability of sampling designs obtained (when compared to a deterministic case). The downside is the increased computational overhead involved.

The work presented in this paper is part of ‘PREPARED enabling change’ an ongoing European Commission 7th Framework funded large scale interdisciplinary project (2010-2014) that aims to analyze the impacts of climate change to urban water supply and sanitation systems.

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Can the Introduction of Local Water Distribution Systems to Rural Cambodian Communities Prove Successful?

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Keywords: Local Water Distribution; Rural Drinking Water Networks; Water treatment in Cambodia

Abstract

This paper addresses problems with the provision of safe drinking water by the water treatment industry in Cambodia. The government of Cambodia seeks to achieve the global Millennium Development target of halving the number of people without sustainable access to safe drinking water by 2015. One effective, and government supported, way for this to be achieved is the widespread implementation of Local Water Distribution Systems (LWDS) rather than applying traditional household methods. This work reviews the present uptake of LWDS in rural Cambodia, and identifies key demographic, economic, geographic and social factors within rural communities that directly affect the implementation of these systems.

Introduction

The Human Development Index (HDI) is a comparative measure of life expectancy, literacy, education and standards of living for countries worldwide (UNDP, 2010). Cambodia is currently ranked 124th out of 169 countries. This is comparable to the neighbouring nations of Thailand (92nd), Vietnam (113th) and China (89th). However, regardless of their position on the HDI, the rural population of Cambodia suffers from a disproportionate amount of water-borne diseases as compared to these countries. As of 2008, 56% of the rural population had access to an improved water source. However this still leaves almost 5 million residents vulnerable to poor health from consumption and use of contaminated water. This is very low in comparison to Thailand (98%), Vietnam (92%) and China (82%) (WHO and UNICEF, 2010).

Cambodia freed itself from decades of famine and conflict, caused by the oppressive regime known as the Khmer Rouge, in 1989. The following period has seen it become one of the fastest growing economies in the world. Between 2001 and 2010 the country displayed an average annual GDP growth rate of 7.8%, ranking it above Vietnam, Thailand and India on the global stage (IMF, 2010). However, prior to 1989 and as a consequence of the Khmer Rouge regime, almost all technical knowledge was lost due to the prohibition of education. It is only recently that this economic growth has led to a new generation of Cambodians graduating from university with science and engineering degrees (UNESCO, 2011). This means that the country has slowly developed a skilled workforce equipped with the technical ability to provide access to safe drinking water for its own population. The new influx of expertise could potentially be used to implement large-scale drinking water solutions in rural communities, which could alternate - or perhaps reduce - the support required from International Non-Governmental Organisations (INGOs) currently working towards this goal. However this depends on the viability and long term sustainability of the water supply systems that the Cambodian government is willing to support.

One of the water supply systems supported by the local government is the Local Water Distribution System (LWDS). This comprises of two stages – a central water treatment plant that draws untreated water from an available source (groundwater or surface water), and a method of distributing the water to the recipients. It differs from a centralised system in that the water is not delivered through pipes, but by collection or delivery in suitable containers. A

LWTS usually operates at a much smaller level than a centralised system, as it supplies villages and small communities rather than regional ones.

This research explores the requirements of a successful LWDS. This is achieved through both a combination of case-studies of distribution systems that supply rural communities, and a literature review defining the common requirements of any drinking water treatment system in the developing world. In particular, this research focuses on the ongoing work of an NGO *('1001 Fontaines Pour Demain')* operating in Cambodia which facilitates LWDS. This French-Cambodian organisation seeks to provide long-term solutions to the challenge of delivering safe water to remote households. It has been implementing LWDS across 39 communities in the Northwest of Cambodia since 2004.

Methodology

This paper studies the impact of the systems implemented by 1001 Fontaines in Battambang region of Cambodia. By facilitating both quantitative and qualitative surveys which review their ongoing LWDS projects, it is intended to from a deeper understanding of successful systems, potential areas of concern, as well as the local interest in such projects.

The research primarily focuses on the rural community's relationship with the Local Water Distribution Systems. The findings of the surveys are compared to the available literature on Cambodian water access such as governmental Poverty Reduction Strategy Papers (PRSPs), market research reports as well as social and ethnographic studies carried out in the project region. The study further explores the demographic, economic, geographic and social background of the community's current water supply systems. These results are then compared with the responses with residents that either do not have a system - or rejected the idea of the system.

Expected Results

It is intended that this on-going research will allow a more in-depth understanding of the factors that determine the uptake of a LWDS in rural Cambodia. It is also the aim of this research to gain an insight into the potential sustainability of the projects as well as early lessons that could affect the long term appropriateness of such a project for local communities. This will be fundamental in understanding if Cambodia, through adoption of the LWDS, is likely to achieve its target of reducing the number of people without sustainable access to safe drinking water. It will also indicate what level of outside technical support in water supply may be required in future years in rural Cambodia.

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International Water Association

POSTER ABSTRACTS

Solids Monitor for Sludge Treatment Optimisation

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Keywords: Auto-desludging; solids monitors; sludge

During the last five years Wessex Water has treated all the sewage sludge produced recycling the sludge and so utilising its high nutrient value as a fertiliser. In total, 50,000 tonnes dry solids of sludge is produced annually from the 405 Sewage Treatment Works (STW), with the sludge produced being treated in 11 Sludge Treatment Centres (STC). As part of that, Wessex Water transfers over 800,000 m^3 of liquid sludge per year between treatment works in approximately 29,000 tanker loads. In addition to tankering the total volume of sludge impacts on the proportion of the total sludge treated in anaerobic digestion and the amounts of chemicals used including polymers to aid thickening and dewatering and sodium chlorite to reduce odour issues.

The monitoring associated with sludge management is currently manually conducted in many situations and often involves the use of fixed time cycling of pumps. Consequently, adoption of on-line sensors which can switch operation to automatic and run equipment to fixed concentrations and variable times offers great potential benefits and costs savings. The current study investigates this potential by assessing the use of a commercially available solids monitor. The sensor is capable of measuring turbidity and solids using an infrared (IR) scatter light. The measuring range for turbidity is from 0.001 to 4,000 FNU and for solids from 0.001 to 150 g/l, with accuracy lower than 5%. Three specific applications were considered (Table 1.1) based around three different points within the flow sheet of a single sewage treatment works. The aim of the study was to assess the potential for automatic operation to generate substantial reduction in costs generated by reducing sludge volume and maximising sludge concentration.

Table 1.1 Summary of test operations

Location in flow sheet	Anticipated outcome	Impact
Primary Sedimentation Tank (PST).	Reduce pumping of inappropriate thin sludge.	Reduced pumping. Thicker sludge onto downstream processes / tankering.
Gravity Belt Thickener (GBT).	Automatic control.	Improve GBT performance. Enhance biogas production.
Imports.	Check and control the amount of dry solids.	Have an accurate figure of the tDS produced within the company to plan the sludge strategy.

The sensor has proven to be very accurate with primary sludge achieving an accuracy of up to 95%, even mixing the indigenous primary sludge with sludge imported has reached 93% of accuracy. The dual beam design of the sensor claims to eliminate interference from colour; tests with different colour sludges suggest that the colour is a minor factor influencing the sensor accuracy. Solids monitors have been proven as a good alternative to optimise auto-desludging in primary sedimentation tanks, producing power and chemical savings and enhancing biogas production. The cost saving at Taunton STW of using solids monitor, which was installed one year ago, was reviewed obtaining a reduction of the indigenous

sludge up to 30%. The successful results at Taunton led to the installation of a solids monitor at Yeovil Pen Mill STW, producing a reduction of the indigenous sludge of 17% so far. Further optimisation at Yeovil Pen Mill STW is required to maximise the savings.

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Next Generation Sequencing for the Water Industry

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The wastewater industry uses a number of biological technologies, yet there has been little use of contemporary biology in process improvement. Recent developments in DNA sequencing have reduced costs ten fold, and thus can now be applied in areas where cost was prohibitive. The project will demonstrate the ability of a novel next-generation sequencing platform to provide new insights in to microbiological community structure as follows:

The activated sludge secondary treatment process is used extensively throughout the world, yet the underlying biology is poorly understood. Consequently phenomena such as sludge foaming and large “safety factors” in plant design are endemic, leading to poor effluent quality and increased operational expenditure. This project will investigate variation in microbiological fauna in a number of plants in order to better understand the causative agents. In particular we will focus on functional bacterial groups of relevance to treatment processes, such as species responsible for foaming, bulking or nitrification. We will subsequently develop indicators which will allow plant operators to take remedial action proactively.

As a result of the revised Bathing Water Directive coming in to force in 2015, allowable bacterial counts will decrease. Consequently there are some bathing waters which at present will fail to meet the required standard, and thus wastewater companies must take action. This project will collect samples from a number of sites which are of concern and analyse the microbial fauna alongside samples from putative pollution sources upstream, and attempt to identify from where the organisms originate. This will facilitate corrective action in anticipation of the new requirements, as well as develop a methodology which will assist in resolving any future issues.

Challenges of Sewerage Data Collection In A Seaside Urban Area

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Key words: Sewer modelling; Street works; Confined spaces

Drainage Area Plans (DAP) are used by UK Water Companies to assess the performance of their sewerage networks. The DAP also considers sewerage improvement options with design horizons of varying return periods to assist Water Companies in their investment planning to meet objectives of a regulatory and customer service nature.

Accurate sewerage data collection is a key part of the hydraulic sewer modelling process within the DAP study.

Bournemouth lies on the south coast of England where sewerage services are provided by Wessex Water (WW). Bournemouth Town Centre sewerage catchment forms part of the ongoing DAP for the entire Bournemouth town conurbation.

Various surveys were carried out as part the process to build an accurate sewer hydraulic model for Bournemouth Town Centre.

Manhole survey. This survey involved survey of pipes, chambers and shaft sizes, cover and invert levels together with the overall condition of the structure. It also records the information of the ancillaries associated with the structure, such as weirs, screens, and flap valves.

For the sewage pumping station surveys, sump activity was surveyed at Bournemouth No 2 and Alum Chine to obtain the rate of discharge of the station. This information was needed to assess the representation of the pumping stations within the model during heavy storm conditions.

Finally a flow survey was conducted. This involved short term monitoring of flows and depths within the sewer system along with collection of associated rainfall to assess run off to the sewerage system. Data from the flow survey is used to verify or test the performance of the sewer model.

Challenges during planning of the surveys

Under the New Roads and Streetworks Act 1991, Bournemouth Borough Council (BBC) is empowered to co-ordinate and control all streetworks activities within the public highway by water companies (and other utilities). This is to ensure public safety and to minimise inconvenience caused to traffic and the pedestrians. The submission of streetworks notices to BBC allows them to perform the above.

During the manhole and flow surveys WW agreed with BBC about the type of streetworks notice required to be served. There are 3 main types of notice; “proposed” where future works are proposed, “in progress” when streetworks are taking place and “closing” when streetworks are complete at a particular location.

If any streetworks notice at any survey location was not submitted or not submitted on time, BBC has the right to fine WW or cancel / suspend future works. The challenge was to submit the correct notices for the correct stage of the survey works across multiple survey locations in Bournemouth without any penalty

Manhole surveys took place during August. Locations such as Pier Approach are very popular so contractors employed by WW were requested by the Council to avoid working during the day and required to work at night. The cost of working at night is greater than that of during the day. The challenge was to assign the survey contractor to the correct survey sites at right time thereby minimising idle time. This reduced costs and ensured compliance with the UK Working Time Regulations (1998).

Health and Safety

Gattic manhole covers are heavy duty manhole covers used in area with a high traffic volume to protect large chambers beneath. Pier Approach in Bournemouth has a number of these covers. Owing to the age of the covers some cracks occurred in the metal frame during lifting affecting the cover structural integrity. These covers were required to be immediately made safe prior to the following morning.

The Pier Approach area contained a number of manholes, the information from which was crucial to the sewer model. These manholes and chambers were deep and contain a complex arrangement of pipes and weirs. Man entry was required to obtain all the required information. Owing to the depth and complexity of the chambers, WW classify these chambers as “Class P”. This classification is based on the national “NC4” (Water UK, 2009). A signed permit from WW Operations was required before entry could be made into these chambers. The contractor produced a method statement detailing the actions they were required to perform to undertake the survey. Following completion of the method statement, a risk assessment was completed detailing the potential risks during the survey and the measures put in place to remove or minimise those risks. Following completion of the method statements and risk assessments, the manhole survey took place which obtained information essential to the sewer model.

References:

New Roads and Streetworks Act Part III (1991)

UK Working Time Regulations (1998) (as amended)

Water UK; 2009; Occasional Guidance Note – The Classification and Management of Confined Space Entries – Industry Guidance, Edition 2.2

System Dynamics for the assessment of climate change impacts on water resources management in the Rosetta region, Nile Delta, Egypt

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Keywords: System Dynamics; water management; Egypt; climate change

System Dynamics Modelling (SDM) is a methodology for studying complex systems characterised by feedbacks and non-linearity (Forrester, 1961; Ford, 1999). It is used when analytical functions do not exist, but when simulations can be developed by linking feedback mechanisms. SDM has proven very useful for simulating complex socio-economic, environmental and water systems in an integrated way. It is especially useful when building and presenting models to non-engineers, as well as for comparing the impacts of scenarios. SDM enables the implementation of unconventional or case-oriented components for the system being simulated.

SDM development is iterative, involving both the modellers and local stakeholders, ensuring that model outputs are quantifiable, relevant and useful for the end-users. Such relevance means that outputs can be used to inform policy decisions regarding the future use of water resources, even when the type of output is unusual for water systems, or aims at specific targets (e.g. evaluating water-related security threat indicators). Involving stakeholders ensures that intimate links between the water cycle and changes to socio-economic activity in the future (e.g., agricultural practices, economic revenue, population dynamics) can be captured and fully explored through the selection of relevant scenarios modelled in the system.

Egypt relies on the Nile for over 95% of its freshwater (Wichelns, 2002), as does the Rosetta region, a low-lying area on the Delta (Figure 1). Therefore, it is extremely vulnerable to changes in future Nile flows, with Rosetta water availability being directly affected by modifications in water management policies. However, climatological/hydrological models do not converge on either the direction or magnitude of potential changes to Nile flows, leading to much uncertainty (the current range of predicted changes to Nile flows is from c. -50% to + 60% relative to today, see Conway (2005)). Moreover, current estimates predict a 13% loss of agricultural land in the study area by 2050 due to sea-level rise, with subsequent effects to local agricultural activity and the local economy.

A System Dynamics Model has been developed, in close cooperation with local partners, which investigates the potential impacts of climate change on agriculture and water resources in the Rosetta region. The present-day water balance is modelled using comprehensive data provided by local partners/stakeholders, then the situation is modelled for 2050 under a range of various climate and agricultural scenarios, some of which were drawn up with the local stakeholders. Sensitivity analyses examine changes to Nile flows, different levels of land loss and water use in an attempt to account for the uncertainty in future Nile flow predictions. Tests also analyse various crop pattern scenarios to examine these impacts on water and productivity. Results show that at present, the study area is undergoing significant over-exploitation of the water resource. Even in the 'best case' future scenario which assumes increasing Nile flows, the area is still subject to water shortages.

Scenario tests indicate that only under the most optimistic forecasts for changes to Nile flows, which are also the least likely, water surplus would be attained. Greater levels of sea-level rise, while economically and environmentally not desirable, also saves water due to loss of agricultural land, reducing water demand. Assuming no change to sea-level, changing cropping patterns can save some water, but this saving is relatively minor. The results obtained will help inform policy makers, aiding them to better direct resources in mitigating the potential impact of future climate-related changes to the region. It is hoped that the results will lead to active discussion regarding the optimal policies to deal with potential changes to water and land availability, policies that not only save water, but also enhance the local agricultural production base which is very important to the local economy.

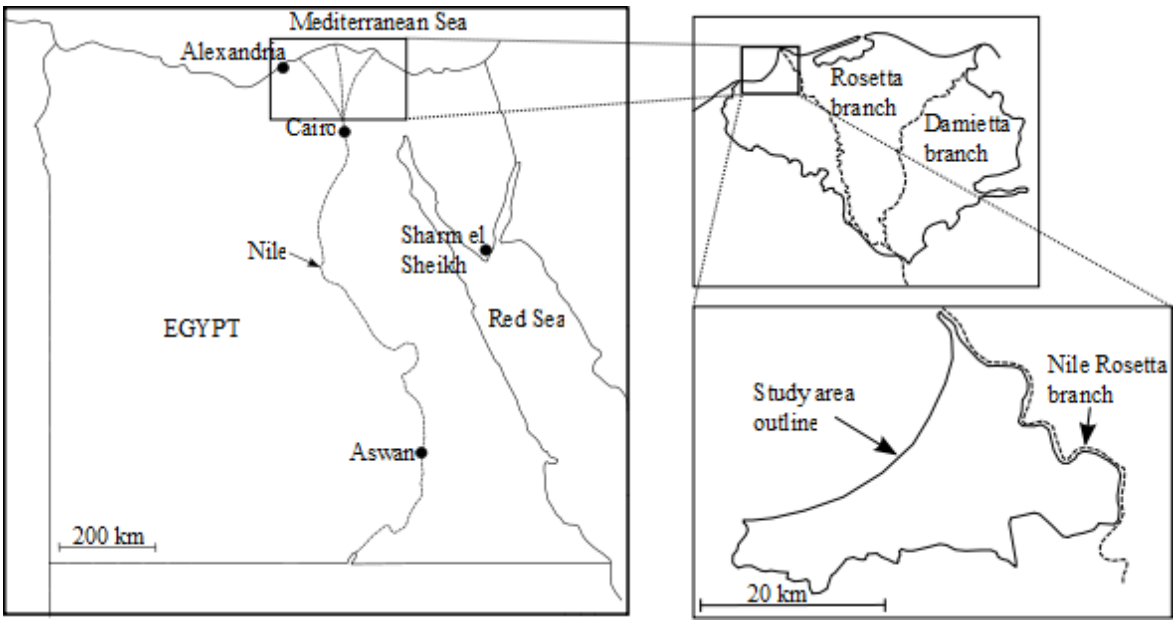

Figure 1: Location map of the Rosetta region, Nile delta, Egypt.

The work presented in this paper is part of 'WASSERMed' (Water Availability and Security in Southern EuRope and the Mediterranean), a European Commission Seventh Framework funded interdisciplinary project (2010-2013) that aims to analyse current and future climate-induced changes to hydrological budgets and extremes in southern Europe, north Africa and the Middle East under the frame of threats to national and human security.

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Estimation of greenhouse gas emissions for development of adaptive wastewater treatment plant carbon management strategies: A literature review

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Keywords: Greenhouse gas emissions; Modelling; Optimisation

This paper summarises existing methods and models for estimating greenhouse gas (GHG) emissions from wastewater treatment plants (WWTPs), focusing on emissions arising due to onsite processes and energy consumption. The methods and models identified are analysed with respect to their suitability for dynamic modelling of WWTPs for control strategy optimisation and the development of adaptive carbon management strategies.

Whilst there has been significant research into the optimisation of WWTP management strategies to reduce operational costs, few attempts at optimisation have been made with the objective of minimising GHG emissions. In order to develop a model that can be used to identify optimum carbon management control strategies, it is necessary to first identify appropriate GHG estimation methods. Many existing approaches are based on empirical formulae, using steady state calculations; however whilst these can provide a useful indication of the likely emissions they are unsuitable for use in optimisation as they do not allow for the effect of changing operating conditions and influent load to be modelled. Models used must also allow the contribution of individual processes to direct and indirect GHG emissions to be determined.

It is well known that wastewater treatment processes can result in the generation of GHGs, and studies have been undertaken to record emissions and develop estimation methods. Monteith *et al*. (2005) published a rational procedure for the estimation of methane (CH_4) and carbon dioxide (CO_2) emissions from municipal WWTPs, based upon the concepts of mass balance and stoichiometry. This procedure was intended to be applicable to a range of different WWTPs and it has been applied in the development of a model for the benchmarking of wastewater treatment plant control strategies (Flores-Alsina et al., 2011). However emission factors calculated from field test data (Toprak, 1995) can differ greatly from those predicted using stoichiometry.

Knowledge regarding nitrous oxide (N_2O) emissions during wastewater treatment is less complete. There have been recent investigations into the factors influencing N_2O emissions (Kampschreur et al., 2009, Foley et al., 2010, Rassamee et al., 2011), but there is no consensus on a method which can be used to estimate emissions with any degree of certainty. The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* proposed an emission factor of 0.0032 kgN_2O/year per capita for WWTPs with controlled nitrification and denitrification (IPCC, 2006). However it has been shown that nitrous oxide generation is affected by process conditions such as dissolved oxygen concentration in the nitrification stage and COD/N ratio in the denitrification stage (Kampschreur *et al*., 2009) and varies considerably between WWTPs.

There is also uncertainty regarding the effects of methane formation in the sewer network and dissolved methane in the WWTP effluent. Guisasola et al (2009) stated that if all dissolved methane in the WWTP influent is stripped to the atmosphere, then this could increase methane emissions from the WWTP by 12-100%.

Models have been developed to estimate GHG emissions resulting from wastewater treatment, although the scope of each is restricted. Shahabadi et al. (2010) developed a

model using their previously published methodology (2009). This was intended to be an improvement on existing models due to its versatility and inclusion of off-site GHG emissions and nutrient removal activities. However a significant omission is the lack of N_2O emission estimation, which was attributed to an absence of reliable data. A mathematical model has been developed for estimation of nitrous oxide production (Ni et al., 2011); however this is unlikely to be suitable for optimisation purposes in its existing form due to its complexity.

Modification of the IWA Benchmark Simulation Model No. 2 by Flores-Alsina *et al*. (2011) found that the implementation of controllers can simultaneously reduce overall carbon emissions and operating costs and improve effluent quality. However further research and development is required in this area as, whilst the performance of several different control strategies was investigated, no attempt was made at optimisation. There were also limitations to the emission estimation methodology and several potential sources of emissions not included in the model were identified.

Further work is necessary to develop a model which incorporates existing methodologies for estimation of CH_4, CO_2 and N_2O emissions and is suitable for dynamic modelling. Whilst existing models include CO_2 and CH_4 process direct emissions, onsite energy consumption, biogas flaring or energy recovery, sludge disposal and embedded emissions from chemical use, the incorporation of N_2O emissions would be beneficial. There is also scope to include more flexibility in terms of control strategies and to improve estimation methods where empirical formulae are still used.

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Sustainable Phosphorus Removal

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Keywords: Phosphorus, sustainable, Water Framework Directive, adsorption, pilot scale trial.

Rational

Phosphorus (P) is the limiting nutrient in the freshwater environment and when present in sufficiently high concentrations can lead to eutrophication of surface waters resulting in reduced biodiversity. In an effort to reduce our negative impact on the environment it has now become a major focus to reduce anthropogenic discharges of phosphorus to surface waters. The implementation of the Water Framework Directive (WFD) requires that further P removal be achieved, described recently as being: “the singly most challenging aspect in achieving compliance with the WFD” (UKWIR, 2011).

In order to achieve this elevated level of treatment existing sewage treatment works are being placed under greater pressures with many works requiring extensive retrofitting or the installation of new equipment. Currently the most widespread method for P reduction involves the dosing of metal rich (Fe, Al) chemical additives the cost of which has increased substantially over the last number of year. Taking these factors into account it is clear that there has never been a better time to develop and implement more sustainable alternative P removal methods.

Reed bed investigation

In an effort to address this issue a dedicated project is currently underway focused on the development of low energy treatment processes specifically for the reduction of P. Six horizontal flow pilot scale reed bed systems were constructed at Somerton STW, Somerset. The trial commenced in July 2010 and is due to continue until the end of 2012 at which point a final report will be published.

Each of the beds was filled with a separate active substrate which had previously showed promise and was planted with the reed: *Typha latifolia* (Table 1) (Cooper, 1990; Brix et al, 2001; Arias et al, 2003). An extensive monitoring campaign is currently being undertaken in an effort to determine the extent and effectiveness of this type of treatment process. Samples are taken from the inlet and outlet of each of the six pilot reed beds in order to ascertain respective P removal rates.

Name	Origin	Dominant chemical constituents	Physical characteristics
Xylit	Coal industry	Carbon and cellulose	Porous, high surface area
Red mud	Aluminium industry	Calcium, iron and aluminium	Very porous, high surface area
By product A	Steel industry	Iron, calcium and magnesium oxide	Very dense, highly resistant, medium porosity
Limestone	Local quarry	Calcium	Dense with low porosity and surface area
By product B	Steel industry	Calcium, magnesium and aluminium oxide	Very porous with high surface area
Gravel	Local quarry	Calcium	Medium density and surface area

Table 1: Showing the six active materials trialled during this investigation with name, origin, chemical makeup and physical properties.

In order to reduce short circuiting and optimise surface to liquid reactions water levels, flow rates and retention times have been adjusted. Hydraulic conductivity measurements have been taken to asses the extent of clogging within each wetland which could reduce the overall hydraulic performance of the system. Mass balance calculations are being employed to determine the respective removal rate of each of the uptake mechanism (vegetative uptake, bio film and chemical reactions). As part of the investigation laboratory scale batch experiments are being carried out to determine the P removal mechanisms and the maximum Phosphorus Sorption Capacity (PSC) (Drizo et al, 1990).

Performance data

Pilot plant results from the past 14 months show that certain substrates have the potential to actively react and remove phosphorous from domestic sewage. One material in particular (by product A) was shown to be capable of over 70% P removal (Figure 1) a sufficient amount to meet a <2 mg/L consent (95%ile) at current concentrations and dosing rates.

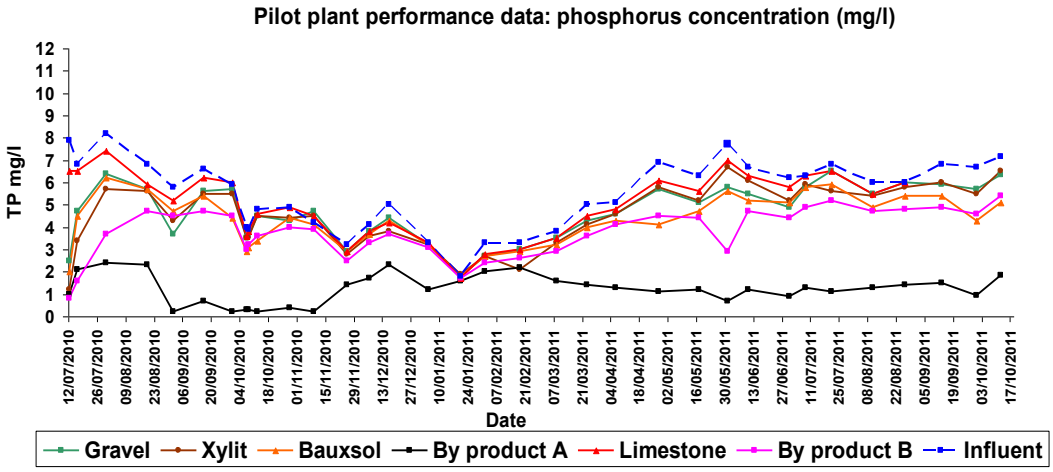

Figure 1: showing influent and effluent total phosphorus concentrations (mg/L) for the six reed beds.

Laboratory tests carried out using the materials in their natural state showed that red mud had the highest P removal rate followed by product A and by product B. This high level of removal however is not being replicated in the pilot plant due to the physical nature of the material which causes the flow to short circuit.

In their normalised state (<2mm diameter), by product A had the highest P removal capacity (2.81 mg/g) followed by red mud at 2.5 mg/g (table 2). These results support those of the pilot plan for by product A and highlight the great potential of this material for future full scale applications.

Material	Q_{max} (mg/g)	R^2
Xylit	0.02	0.70460
Red mud	2.50	0.95100
By product A	2.81	0.95000
Limestone	0.05	0.81410
By product B	0.14	0.87400
Gravel	0.10	0.84400

Table 2: Experimentally derived removal rate mg P per gram of normalised material with the relationship coefficient (R^2).

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