FWR NEWSLETTER
fwr.org
...from the Foundation for Water Research
March 2024
Spring Issue

CONTENTS

ENERGY EFFICIENCY AND CARBON NEUTRALITY: POSSIBILITIES IN WASTEWATER TREATMENT

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Viikinmäki wastewater treatment plant takes a step towards carbon neutrality with the development of a digital twin

Aalto University

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Aalto University researchers are developing a decision-making support tool to help the plant operators achieve almost the impossible: cleaning the wastewaters to attain exceptionally low levels of nutrients, while maintaining good energy balance and carbon neutrality.

The DIGICARBA research project is being conducted at Aalto University (Finland) by researchers in Water and Environmental Engineering between 2023 and 2025. The main goal of the project is to develop a digital twin of the wastewater treatment plant WWTP Viikinmäki in Helsinki, with a focus on greenhouse gas (GHG) emission mitigation to improve carbon balance and promote proactive process control and operation. A digital twin could be defined as a model of physical asset with a continuous automated connection to live data of the real entity.

The project is funded by Business Finland (via the Decarbonized Cities programme) and is supported by a main partner: Helsinki Region Environmental

Generating electricity from biogas at the HSY Viikinmäki waste-water processing plant

Services Authority HSY, which operates WWTP Viikinmäki. The work is done in collaboration with companies several companies: FCG Finnish Consulting Group Oy, Valmet Oyj, Brighthouse Intelligence Oy, Mittausguru Oy, and water utilities of Turku (Turun seudun puhdistamo Oy) and Hämeenlinna (Hämeenlinnan Seudun Vesi Oy). All stakeholders participate regularly in the ongoing project development, via discussions in the steering group meetings.

WWTP Viikinmäki possesses a significant advantage for this study, as it was constructed in underground bedrock with an exhaust air pipe equipped with gas compound measurement sensor and implanted liquid phase N2O emissions sensors. WWTP Viikinmäki is the largest treatment plant in Nordic countries, and receives a load of approximately 1.2 million population equivalent as per 2023. Its average flow is 280 000 m3/day, with peak flows up to 700 000 m3/day. Influent flow constitutes domestic wastewater (85%) and industrial wastewater (15%). WWTP employs biological wastewater treatment via nitrification/denitrification and post-denitrification via biofilters for nitrogen removal, alongside chemical phosphorus removal via ferrous sulphate. Processed excess sludge from biological treatment and raw primary sludge are both used for anaerobic digestion for biogas production. The generated biogas for heat and electricity production ensures approximately 90% sufficiency for the treatment plant's electricity needs. As for the digested sludge, it is used for processing into soil products in composting fields. In addition, local energy company Helen Ltd operates a heat pump plant to produce heat and cooling from the treated wastewater.

The DIGICARBA project objective is to create a digital twin that combines a biomechanistic model with data-based information for the automated simulation of the actual wastewater treatment process. During the development, different machine learning techniques will be tested to provide influent wastewater quality predictions using the process data collected at the plant. These predictions would entirely rely on available data sources from WWTP Viikinmäki (HSY).

The digital twin will operate based on various data sources, including technical information, historical data, laboratory data, and process instrumentation data. Additionally, wastewater fractionation analysis will be performed to fine-tune the process model. The collected data will undergo pre-processing, systematisation, and utilisation in the development, calibration, and validation of the process model. At the end of the project, the developed digital twin should have automated data feeding to the process model, automated data pre-processing and automated model calibration. It should also provide useful information from simulations in the user interface.

GHG emissions from biological wastewater treatment modelling still requires comprehensive research to improve model accuracy. Nitrous oxide (N2O) is the most significant contributor to the carbon footprint of wastewater treatment plant Viikinmäki, and is therefore one of the primary variables for optimisation. Viikinmäki plant's long-term monitoring of N2O for over 10 years will benefit digital twin development with a focus on carbon balance completed during the DIGICARBA project.

The parts of the treatment plant with the biggest energy consumption are the aeration systems for biological treatment steps, pumps, mixers and centrifuges. The aeration systems require the most energy, as the nitrogen removal process requires intensive air supply for ammonia conversion into nitrates. An advanced aeration control system is already used at the Viikinmäki WWTP: however, N2O emissions are caused by a complex mixture of pathways, and aeration affects N2O emissions. Also, optimisation of the carbon use between energy production and nutrient removal is a complicated challenge. Due to the extreme complexity of these tasks, the use of real-time predictions of different operational choices will be a valuable tool for plant operators, and this will allow them to make more informed decisions. The digital twin can also calculate energy consumption and energy production potential for different simulated operational scenarios. Therefore, the development of the digital twin will also focus on providing the operators with new information that supports proactive energy-efficient process operation. The project would result in the active use of the digital twin as a proactive process control tool, and therefore, the engagement of operating team and the early establishment of guidelines for cyber security is necessary.

The DIGICARBA project is progressing in various new directions, as the synthesis of different results are required for the successful development of a digital twin. One of the crucial steps was to encourage the operating and engineering teams of HSY to participate in the project, as they are the ones putting the digital twin into active use, and benefitting from its ability to predict the process behaviour. To that end, a workshop was organised in the autumn of 2023, during which operators and engineers of the plant cooperated with the research team at Aalto University, to define what improvements could to be implemented for the digital twin (**Fig.1**).

One of the key outputs of the DIGICARBA project will be a doctoral thesis, but in the meantime, project updates will be provided on a regular basis via peer-reviewed articles and at conferences.

More information on the DIGICARBA project is available on its website[1] and LinkedIn page[2].

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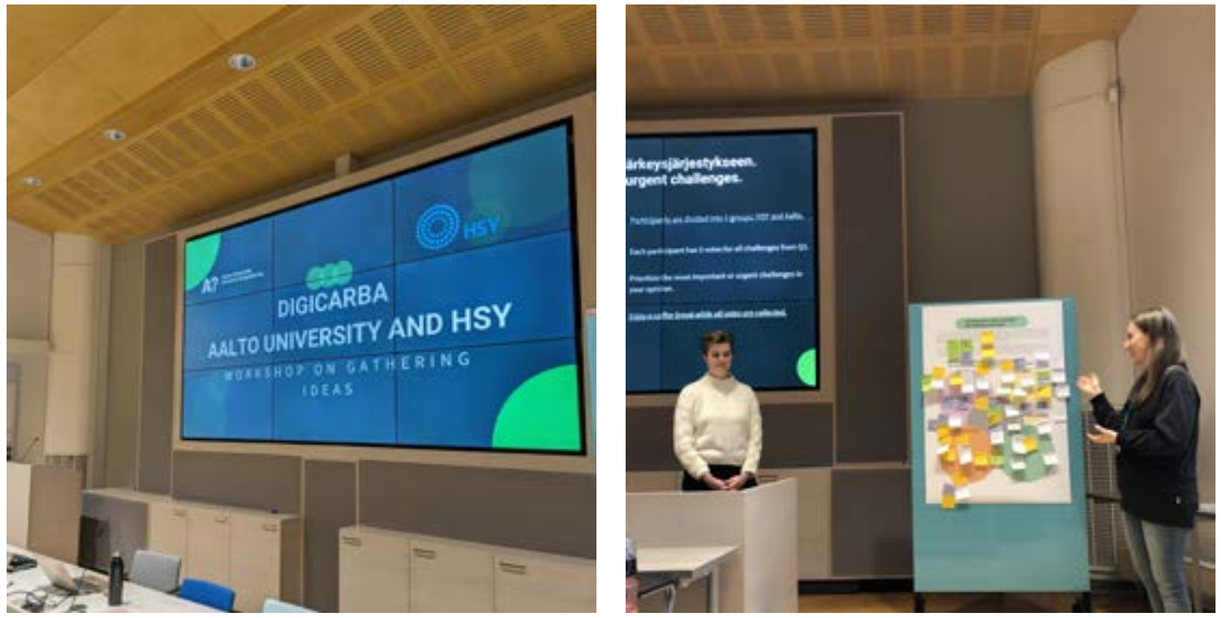

Figure 1. Workshop presentation for collaboration between HSY operators and Aalto University

Water policy and your career: Q&A with Joseph Lewis

Joseph Lewis
Policy Lead, IES

In this Q&A, Joseph Lewis responds to some important questions that anyone working in the water sector should be considering.

Q: Why is it important for professionals working in research or practical roles to learn more about water policy?

Whether we want it to or not, policy shapes our work as professionals. Unless we know about it, we cannot prepare for it, so we are exposed to more risk and uncertainty from changing social and political tides. Regulation controls the ways practitioners work, setting restrictions, guidelines, or targets.

For researchers or businesses seeking grants or tenders, government funding often relies on aligning with national or sub-national objectives. Understanding policy and the objectives of governments or funding organisations makes funding bids or research projects more likely to succeed.

Trivially, policy also has major implications for the water environment. Water is a complex natural system, but it is also bound up in social and economic systems, so understanding the ways that policy shapes our approach to water also helps us predict how the environment could and will change in the future.

The last decade has also been relatively uncertain for environmental policy in general, and UK water policy in particular. Increasing environmental challenges, coupled with diminishing enforcement resources and significant governance reform following the UK's exit from the European Union, have led to a dynamic policy environment where change is iterative, rather than occasional.

Addressing uncertainty is never easy. Water professionals with questions about the inexact future of the policy landscape can find answers by:

- Building their awareness of the policy landscape and the drivers behind change.
- Understanding the science of how water and the wider environment is changing, through resources like the FWR's Reviews of Current Knowledge (ROCKs).
- Taking a horizon scanning approach to policy risk, so that when change does take place, it is less unexpected and easier to respond.

Q: What are some of the barriers early career water professionals might encounter when trying to engage with policy matters?

The first challenge for early career professionals is knowing where to begin. The effects of policy on water and the environment are becoming increasingly mainstreamed, resulting in a vast and potentially confusing legal and political landscape. If professionals have the basic 'process literacy' skills needed to understand how policy change happens, who makes it happen, and where they can find out about specific policies, they are well-equipped to begin tackling the implications.

Q: What kinds of resources are available for professionals working in the water sector to learn more about water policy and how it influences their roles and responsibilities? Are these easily accessible?

Over the past few years, the IES has responded to the increasing need for training and resources on engaging with policy. While there are a lot of resources available on policy, the majority are not sufficiently tailored to the sector to help professionals identify the most important information. Lots of the resources are also prohibitively expensive, making them inaccessible to the majority of water professionals.

We started with regular horizon scanning briefings, helping professionals to engage with policy developments and to understand what may change in the future. Our inaugural piece looked at the water environment, and it was updated again in 2023 to address developments such as the Environmental Improvement Plan for England and the inclusion of Sustainable Drainage Systems in developments. We update the briefings annually to ensure water professionals have the insights they need to understand policy.

For those seeking to take a more direct approach, we also provide training on how to engage with water policy.[1] It starts with a session on the complex policy landscape, providing an in-depth look at legislation and the other actors involved in shaping policy. Next, participants get an insight into the different ways they can engage with policy, from an increased awareness of policy and how to understand and analyse its effects, to specific techniques for engaging with decision makers and impactful policy influence.

Q: How can policy learning be made applicable and relevant to professionals across different specialist areas within the water sector?

Increasingly, jobs in the water sector can be very specific or technical, so professionals need an adaptive approach that supports them to identify the ways that policy matters to their work directly. Most professionals develop their understanding of regulatory frameworks through practice, so our profession can be vulnerable to sudden changes.

One approach is to provide detailed analysis of regulatory change when it happens, but that does not remove the inherent vulnerability. A better alternative is to provide professionals with the skills and knowledge to understand the implications of policy changes when they happen, increasing adaptability and resilience to change.

We developed our resources with professionals in mind. We do provide the deep overviews of novel policy developments that professionals need to stay up to date, but we also champion a skills-based approach to dealing with unexpected policy developments. Our training sessions are highly participatory, so attendees have the chance to apply their own perspective to the training. We also hold the sessions with small groups, giving everyone a chance to reflect, ask questions, and interact directly with our expert trainers.

Q: How can water professionals incorporate targeted policy learning into their CPD plans?

Policy is a topic where collective competency is king: not every water professional needs to know everything about policy. A wastewater process scientist may not need to know which species are included in targets for freshwater biodiversity, and a consultant ecologist may not need to know the details

of requirements to upgrade wastewater treatment works in the Integrated Water Plan. Those competences are collectively needed across the profession, but are not needed by every professional.

Water professionals should focus their CPD on the areas of policy which will be most relevant and beneficial to their professional development. Basic process literacy will be relevant for most professionals, covering an understanding of how policy change happens, who is involved, and how to research the details of policy developments. Once professionals have that understanding, they will be well-positioned to identify targeted areas for further professional development.

The secret to effective CPD on water policy is to have a plan for what you want to learn. The policy landscape is so vast that an untargeted approach may lead to inconsistent results. That should not preclude water professionals from developing policy insights outside their immediate responsibilities: often, an interdisciplinary understanding of policy issues can be a particularly useful way to develop niche and competitive skills.

Q: Are there any particular areas of the water sector that you think could benefit from closer engagement with policy developments and policymakers?

Despite the growing public interest in clean water and the environment, widespread engagement with water policy is still relatively nascent compared to other areas of environmental policy. In the past, policy conversations have been very concentrated between the Government, regulators, and the water industry. As a result, the expert insights of water professionals have not always been recognised at the point of policy design.

As the need for water security, clean water, and thriving water environments is increasingly recognised, those insights from water professionals will be pivotal. Achieving positive outcomes for water relies on understanding how policies are implemented in practice, so water professionals will have a particularly important role to play in evaluation and sharing their insights of what policy means 'at the waterfront'.

In the wake of pressing environmental crises, policy must increasingly recognise the links between those crises and the natural systems they work within. The voice of water professionals will be particularly important to ensure that approaches to climate change also support water security and resilience, and to ensure that approaches to biodiversity loss account for key freshwater environments.

Q: How can employers in the water sector support their employees to seek a better understanding of water policy issues and how these relate to their own responsibilities?

Employers have incredible power to shape the overall competence of their profession, particularly in the water sector where many professionals are employed by large consultancies, industry, and the public sector. Recognising that providing employees with basic policy skills can be a significant asset to the team is the first step to developing a more engaged and effective workforce.

The relatively small costs of upskilling or training staff will often be lower than the benefits of better risk management, broader knowledge, and the potential to develop competitive advantages through thought leadership. For employers working in regulation-driven sectors, those benefits will be even larger.

Joseph Lewis
Policy Lead, the Institution of Environmental Science

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1. **IES Training: Making a splash: learn how to engage with water policy (2024). https://www.the-ies.org/events/ies-training-making-splash-0**

FWR's Reviews of Current Knowledge (ROCKs): Upcoming topics in 2024

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As part of the IES's commitment to continuing and building on the legacy of the Foundation for Water Research, we will be producing Reviews of Current Knowledge (ROCKs) on a rolling basis. ROCKs are medium-length briefing documents aimed at giving the public, professionals and policymakers an overview of the key components of a given topic. They are written by leading experts in the given fields. ROCKs aim to create a coherent and integrated understanding of each topic, describing key considerations in the environmental science and policy realms.

ROCK topics will be decided by the FWR Council in advance and will aim to cover some of the most relevant and stimulating topics within and affecting the water sector in the UK. The scope of ROCKs is broad, with wide and ambitious topics covered, previously including freshwater eutrophication, flood mitigation, water reuse, and water for food security.

The first two ROCKs the IES will be publishing are focused on remote sensing and wastewater epidemiology.

Remote sensing

The remote sensing ROCK will focus on the use of satellite-based earth observation and its application to both natural water systems and the management of constructed water infrastructure and services. The topic provides excellent opportunity for linking with other IES specialisms, such as Land Condition and Marine and Coastal, as well as addressing an ever-more important research approach in a rapidly changing technology landscape. The guide will also highlight core opportunities, challenges, and potential growth avenues. The aim of this guide is to illuminate the use of earth observation, alongside its applications, limitations, and how it might develop in the future. The goal that this information will be used and acted on.

The remote sensing ROCK will cover a wide range of applications, including how the technology can be used in drought and flooding scenarios, in climate change observation, and in the context of research priorities. The ROCK will be written by the International Water Association, with its Earth Observation Technologies for Water Management Community of Practice taking a collaborative, multi-author approach.

Water-based epidemiology

One of the most urgent areas of study in the water sector since the COVID-19 pandemic has been wastewater-based epidemiology (WBE). In response to the many challenges of the pandemic – such as monitoring public health, disease transmission, and COVID-19 hotspot locations – research and knowledge within wastewater-based epidemiology has accelerated quickly. The WBE ROCK will harness this momentum and examine the possibilities it presents in the context of new and existing environmental and public health challenges.

With contributions from leading experts in the WBE field from academia, government, and the private sector, this ROCK will cover established, emerging and novel

approaches in WBE. It will explore the model of WBE as a tool for public health, and offer an analysis of a range of different case study applications (including drug use and COVID-19), as well as reviewing different sampling and data collection approaches. Future opportunities will also be a key area of focus: particularly in relation to the interpretation of data, WBE fingerprinting, IoT, and systems thinking. Other key chapters in the ROCK will examine the challenges that may impede progress in the field, such as standardisation, resourcing, sustainability, and ethical challenges around the monitoring of public health data.

The ROCK will be co-written by a group of experts, from the 4 Nation WBE Group, the UK Centre for Ecology and Hydrology (UKCEH), and the Pathogen Surveillance in Agriculture, Food and Environment (PATH-SAFE) Programme, under the editorial guidance of Dr Matthew Wade (UKHSA). Along with the IES and FWR's membership base and collaboration with industry and governance organisations, this publication will be a timely addition to the growing body of WBE work, offering expert analysis of the key opportunities, challenges, and drivers for the future of WBE in public health contexts.

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Publication Nº : FWR-NEWS 44-0