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Editorial: Developments and applications of IoT-based sensors for wastewater and drainage systems

The Internet of Things (IoT) has brought about transformative changes across various industries, offering numerous benefits that enhance efficiency, productivity, and innovation. In numerous sectors, there is a growing availability and capability of novel sensors and devices based on information and communication technology, operating in a decentralized manner. In many businesses, from manufacturing to logistics, agriculture, and healthcare, IoT devices generate extensive data, which enable analysts to make well-informed decisions based on real-time insights. In terms of operational efficiency, IoT facilitates automation and process optimization, leading to heightened operational efficiency and cost reduction. IoT sensors and applications have also significantly contributed to improved customer experiences by enhancing interactions and personalizing services. Moreover, the IoT plays a crucial role in safety and security by fostering the development of robust surveillance systems, ensuring the well-being of people and assets, particularly in smart cities.

Achieving comparable transformative changes in the water sector has been recognized for quite some time. Policymakers emphasize the significance of the digital water industry to expedite sustainable development, as exemplified in the context of a green Europe (Wencki *et al.* 2021). Nevertheless, there is a notable lag between the water sector and service providers in Europe in embracing IoT solutions and integrating digital services and automation to improve their operational and management responsibilities (Stein *et al.* 2022). Among other things, these technologies are primarily applied in centralized facilities such as wastewater treatment plants and storage units. Also, in the drainage network, monitoring and control opportunities for distributed system components are currently often concentrated on key points, such as overflows, main shafts, and pumping stations. However, decentralized urban water management techniques (e.g., green infrastructure and nature-based solutions) are increasingly deployed in urban areas, enhancing both system complexity and efforts for accurate management. Particularly, the evolution of low-cost sensors in combination with innovative and wireless data transfer technologies will enable large-scale implementation of measurement equipment, even in remote or underground structures. This advancement opens up new possibilities for the management of urban stormwater and wastewater infrastructure. Targeted IoT approaches enable us to integrate these solutions more efficiently with overall control strategies and utilize their potential for efficiency, performance improvements, and a better customer experience. Moreover, lessons learned from the COVID-19 pandemic underscore the need to enhance the understanding of the systems in a distributed manner, particularly for epidemiological surveillance, and to better comprehend infection dynamics through wastewater analytics.

The objective of this special issue in *Water Science and Technology* is to gather contributions and review articles advancing scientific methodologies, technologies, and best practices in the context of IoT sensors for urban wastewater and drainage systems. This special issue includes, in total, seven papers that cover a wide range of advances that can be categorized into four main topics: (1) opportunities for advancing digitalization in wastewater management, (2) real-life potentials of monitoring and control of drainage infrastructure, (3) data validation and model development, and (4) advances in wastewater-based epidemiology.

Firstly, the potential for advancing digitalization in wastewater management through the implementation of building information modelling (BIM) is explored in the work of Kretschmer *et al.* (2023). This study employs expert surveys to examine the extent to which current wastewater management practices integrate BIM, shedding light on both its advantages and limitations. Notably, from the survey, it became evident that essential components are already in place, although not always as originally intended. Moreover, the aim of the digital transition is not to replace existing procedures but rather to prompt re-evaluation and optimization, necessitating more integrated and collaborative approaches, along with increased political engagement. The domain of BIM also highlights the importance of data models and standards in order to achieve truly interoperable data workflows.

Secondly, the real-life potentials of large-scale implementation of measurement and control equipment in urban water infrastructure are frequently ambiguous. Oberascher *et al.* (2022) and Roosipuu *et al.* (2023) specifically focus on this research gap and concentrate on assessing and illustrating these potential advantages. Oberascher *et al.* (2022) showcased the 'Smart Campus' at the faculty of engineering sciences of the University of Innsbruck as an urban testbed for intelligent and datadriven applications in urban water infrastructure. The study includes different communication technologies and demonstrates that the quality of service is significantly impacted by the communication technology used and challenges of real-life installation locations. However, synergies in the required infrastructure can be used effectively when pursuing an integrated and cross-system approach. In a related study, Roosipuu *et al.* (2023) investigated the real-life signal quality of a specific transmission technology, Narrowband-Internet of Things (NB-IoT), for monitoring and controlling urban drainage systems. Conducting measurements in Rakvere, Estonia, the research investigates the coverage of underground signal quality by varying the installation depths of sensors with various manhole covers to define the critical NB-IoT signal strength for data transfer. To facilitate real-time control, controllable street storage units were implemented into the hydraulic model, and rule-based control strategies (RBCs) were compared with model predictive control (MPC) strategies. The findings indicated that MPC, even when relying on incomplete data, still outperforms RBC, allowing for only favourable measurement locations and the best signal quality.

Thirdly, the validation of data and the development of models based on sensor data are addressed. To prevent water pollution, the accurate measurement and control of wastewater discharges are essential. However, such sensors are often subject to malfunction, and it is of great importance to identify potential measurement anomalies before making decisions or taking action. Zidaoui *et al.* (2023) addressed this challenge by deploying artificial intelligence for automated data validation. For this purpose, two anomaly detection algorithms on sewer turbidity data are used and compared to expert validation. The investigated Matrix Profile model successfully detected the majority of anomalies with a very low number of false positives. Compared to expert validation, this analysis significantly accelerated the process while maintaining a similar level of performance. For model validation, de Morais *et al.* (2022) developed a model for predicting pH changes and ammonia desorption in polishing ponds based on process rates. Measurement campaigns in four ponds were carried out under varying temperatures and depth conditions, demonstrating good correspondence between simulated and experimental values.

Lastly, in this virtual special issue, the spotlight is on the latest findings in wastewater-based epidemiology (WBE), which has not only been a role model for putting scientific results into practice but has also greatly benefitted from effectively exchanging data and making data interoperable and reusable using digital platforms. WBE has been widely adopted by many countries since the onset of the COVID-19 pandemic as a low-cost way to monitor population health. While primarily implemented at wastewater treatment plants, the significance of decay within the sewer network is equally crucial. Mac Mahon *et al.* (2022) focus on that decay process within the network through a comprehensive review, emphasizing the importance of the sewer network and evaluating the measurement points throughout the sewer network of Dublin. The study thereby evaluates the uncertainties within the context of WBE. Therrien *et al.* (2023) underscored the significance of transparency and openly sharing data on WBE to inform the public and expedite scientific advancements. Consequently, their study introduces the Public Health Environmental Surveillance Open Data Model (PHES-ODM), serving as an open-source dictionary. The article describes, in detail, measurement protocols and data models, offering a roadmap for enhancing the interoperability of environmental public health surveillance for COVID-19 and beyond.

This special issue consolidates the latest information regarding the advancements and uses of IoT-based sensors and technologies in wastewater and drainage systems. The Guest Editors hope to raise awareness and foster recognition of the evolving multi-disciplinary field in the broader academic community through the collected findings.

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REFERENCES

de Morais, C. E. P., dos Santos, S. L. & van Haandel, A. 2022 A predictive model for ammonium removal in polishing ponds operated in sequential bath mode. *Water Science and Technology* **87** (1), 13–26.

Kretschmer, F., Franziskowski, S., Huber, F. & Ertl, T. 2023 Chances and barriers of building information modelling in wastewater management. *Water Science and Technology* **87** (7), 1630–1642.

Mac Mahon, J., Criado Monleon, A. J., Gill, L. W., O'Sullivan, J. J. & Meijer, W. G. 2022 Wastewater-based epidemiology (WBE) for SARS-CoV-2 – A review focussing on the significance of the sewer network using a Dublin city catchment case study. *Water Science and Technology* **86** (6), 1402–1425.

Oberascher, M., Kinzel, C., Kastlunger, U., Schöpf, M., Grimm, K., Plaiasu, D., Rauch, W. & Sitzenfrei, R. 2022 Smart water campus – A testbed for smart water applications. *Water Science and Technology* **86** (11), 2834–2847.

Roosipuu, P., Annus, I., Kuusik, A., Kändler, N. & Alam, M. M. 2023 Monitoring and control of smart urban drainage systems using NB-IoT cellular sensor networks. *Water Science and Technology* **88** (2), 339–354.

Stein, U., Bueb, B., Englund, A., Elelman, R., Amorsi, N., Lombardo, F., Corchero, A., Brékine, A., Aquillar, F., Ferri, M., Garcia, A., Manuel, J., Montenegro, F., Chen, A., Moumtzidou, A., Vries, D., Caradot, N., Ugarelli, R., Vennesland, A. & Vacher, A. 2022 *Digitalisation in the Water Sector. Recommendations for Policy Developments at EU Level*.

Therrien, J.-D., Thomson, M., Sion, E.-S., Lee, I., Maere, T., Nicolaï, N., Manuel, D. G. & Vanrolleghem, P. A. 2023 A comprehensive, open-source data model for wastewater-based epidemiology. *Water Science and Technology* **89** (1), 1–19.

Wencki, K., Chen, A., Englund, A., Anzaldua, G. & Elelman, R. 2021 The Need For Digital Water In a Green Europe EU H2020 Projects' Contribution to the Implementation and Strengthening of EU Environmental Policy.

Zidaoui, I., Wemmert, C., Dufresne, M., Joannis, C., Isel, S., Wertel, J. & Vazquez, J. 2023 Validation of wastewater data using artificial intelligence tools and the evaluation of their performance regarding annotator agreement. *Water Science and Technology* **87** (12), 2957–2970.