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Editorial

Electronic Technology for Wastewater Treatment and Clean Water Production

Doekle R. Yntema [1,*] and Caspar V. C. Geelen [1,2]

1 Wetsus, European Centre of Excellence for Sustainable Water Technology, P.O. Box 1113, 8900 CC Leeuwarden, The Netherlands; caspar.geelen@wetsus.nl
2 Mathematical and Statistical Methods—Biometris, Wageningen University, P.O. Box 16, 6700 AA Wageningen, The Netherlands
* Correspondence: doekle.yntema@wetsus.nl

Abstract: Water is essential for society. Due to excellent distribution systems for clean drinking water and wastewater, safe and reliable water transport is guaranteed. However, due to ageing network conditions, there is a need for extensive network monitoring and replacement strategies. There is a high demand for good insight into water mains and water distribution systems. A promising way to monitor our water transport involves various types of novel sensors, including strategies for the smart placement of these sensors, maximizing performance while minimizing costs. Furthermore, processing the increasingly large amount of sensor data can be done using Artificial Intelligence and sensor fusion techniques, yielding vastly increased information about the distribution mains.

Keywords: artificial intelligence; sensor state of the art; new sensors; smart pipes; data processing; integration with other domains; sociology effects

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1. Introduction

Water is an essential part of all life, and safe and reliable drinking water is a crucial concern (as well as one of the Sustainable Development Goals). Water distribution networks are key in providing access to water for many people around the world. However, these ageing and underground networks are hard to monitor, and bursts and cracks occur frequently. Since replacing every single underground asset is not feasible, nor is inspecting each buried pipe, smart solutions are required to distinguish where to intervene. To alleviate the burden of consumers as surrogate sensors, more proactive strategies are required [1].

In the field of water distribution, smarter water grids are slowly becoming the dominant strategy. Water distribution networks, such as drinking water mains, are often compartmentalized into DMAs (district metering areas), collecting real-time flow measurements at the DMA boundaries. Based on these data streams, various applications such as water demand forecasting and leak detection become possible [2,3]. This successfully implemented framework is rapidly expanding. Due to developments such as the Internet of Things and the reduced costs of data transmission and storage, the use of more and other sensor types is becoming more viable. Novel technologies, such as crack detection or conductivity sensors embedded in pipes during casting are entering the scene as new and cost-effective measurement methods. Nevertheless, smart strategies in placing sensors are required to keep cost low and maximize the added value of the various sensors utilized to monitor the networks. Which sensors are used now, and which sensor types are emerging, and above all: what is needed? Current network sensor data allow for the better estimation of optimal placement of future sensors, with a focus on the relatively cheap and versatile pressure sensors [4–6], enabling efficient sensor placement at the lowest investment cost.

The combination of sensors and data processing offers new insights into distribution systems for drinking water or wastewater. Due to the increasing availability of data streams from various sources, sensor fusion and data integration offer novel opportunities for monitoring water distribution systems in real-time.

Besides reliable water supply, potable and safe drinking water is crucial. Contamination with toxic chemicals is to be avoided in drinking water mains, and the detection of these compounds is essential to minimize harm and help develop mitigation strategies. However, not every organic and inorganic contaminant is easily detectable; in the case of lower concentrations of harmful contaminants, especially, there are no solutions other than sampling on a regular basis and waiting for lab analysis results, which may take days to arrive after sampling. With the next-generation sequencing revolution, the role of biosensors is making a comeback. No longer are water mains fish or coal mine canary "sensors" required to measure a general level of toxicity. The potential of water microbiomes acting as fingerprint sensors describing the actual water quality is slowly taking center stage [7–9]. This effect-based monitoring strategy has many potential applications, mainly in the detection of (the combinations of) toxins, allowing real time or near real-time mitigation.

To work towards effective digital twins of the water supply, the benefits of smartly placed sensors are becoming evident. Using a data-model integration strategies, flow and pressure measurements, together with consumer demand estimates and a hydraulic model on a DMA level, allow for faster responses and proactive management of the water grid [1,10]. Smart sensors measuring flow, pressure, or household consumption help calibrate and validate these models, which in turn serve as the foundation for digital twins acting as comprehensive water quantity and quality monitoring systems [11,12].

Data can be processed by artificial intelligence, leading to a much more defined insight into water networks and water quality. Leak detection, water quality assurance, and threat detection can be significantly improved using these techniques. Integration with other systems (e.g., the energy grid) increases this information awareness even more. Which information is required for normal operation, and what is interesting for new business cases? Which information is not accessible yet, and which sensors would be needed to fill the current holes in our understanding of the water distribution process? Finally, what can the public do with the available information? For example, direct feedback regarding water scarcity and water use will likely prompt users to adapt their water use, remediating the immediate scarcity level.

2. Current Practices in Water Infrastructure

Currently, most water networks are equipped with flow sensors and some pressure sensors. These sensors are relevant and provide insight into the water distribution, but not all relevant water parameters can be monitored by these sensors alone. Furthermore, current sensor measurements are currently mostly monitored via dashboards, providing status network information. However, the pressure signal can help strengthen forecasts of water demand, as well as help with leak detection and localization [2]. These more advanced information gathering techniques as of yet only see limited use in practice but are becoming more and more relevant.

The state of the network is often indirectly monitored by malfunction reporting, with a focus on replacing entire assets if repetitive failures occur. This is often only a form of symptom control if the underlying cause of failure is not identified. This practice results in unnecessary replacements and thus higher raw material use and higher replacement costs than strictly necessary. As of yet, often no more cost-effective strategy is available. However, in-line inspection technologies offer a solution here, for many materials a reasonable solution is found, although for PVC and other plastics they are mostly not yet fully matured.

3. The Future of Infrastructure Sensing and Processing

In order to process the ever-increasing amount of sensor data and obtain good information out of it, we can no longer rely on human expertise alone, but will have to turn to computer algorithms. Where human expertise alone might not suffice, algorithms can help mine other relevant information that is still locked inside the collected data streams. Data processing can offer unprecedented information about the network, the water quality, and gives good predictions about the state of the mains as well as operating anomalies.

Artificial Intelligence seems like the right direction to go, but contrary to regular belief, for many applications the current amount of data is still not really "big", i.e., that there is even more data needed to properly train more advanced AI algorithms. It is proposed that the starting point should be the more advanced processing of currently collected sensor measurements. A required second step will be to select the optimal sensor types and the required quality of sensors, which implicitly co-define a price tag, followed by the actual placement of sensors. With the advent of new types of sensors and new ways to apply these sensors, AI may soon be delivering performance rapidly. Some examples of what is changing are the ever-increasing means of gathering measurements of the network state:

- The sensing of other specialized properties, such as optical density, color, pH, conductivity, as well as sensor fusion and soft sensoring, which combine multiple measurable properties to indirectly construct measurements for other hardly measurable properties.
- High speed measurement. High sample-rate pressure meters are, as of yet, rarely used, but are rapidly becoming mainstream as the costs are now similar to the placement of pressure sensors. Data transmission is getting simpler and faster and data storage is generally not considered to be a significant hurdle. High speed pressure data can reveal transmission-line parameters for a given segment in terms of the flexibility of the pipe, or possibly even leak detection at a distance.
- Smart pipes, employing sensors integrated in the mains material are quickly becoming a reality [13], the detection of stress-strain relations, bending effects, crack detection, excavation activities nearby, tampering and other anomaly detection will be easily possible using these systems.
- Pipe inspection technologies can be used as well but are generally costly. Combining inspection data with other failure data, replacement, geographical, and load-history data with artificial intelligence seems a promising tool to help in this area and could improve failure prediction massively.

4. Call for Insight

The activities in the area of water transport monitoring are very diverse and the level of control varies by country and by (waste)water company. A bottleneck, which can simply be described as "if it works, don't try to fix it", has always been the business model, resulting in the adaptation of useful technology at a relatively low pace. It is more important to keep the system working than to accept the risks introduced by the adoption of novel practices. Nevertheless, in this new era, both can co-exist; high-tech solutions such as pattern recognition in water delivery do not hamper the actual delivery of water. Artificial Intelligence recognizing wastewater hazards may easily help the treatment plants by providing information serving as decision support and early warning tools. It is already possible to implement this using existing data.

As the next phase, there is an urgent demand for more sensor data and the basic question of which sensors must be placed where in the network to obtain useful information. In this instance, the limiting conditions are the cost: many sensors for a low price, or only a few high-quality sensors? Furthermore, many parameters are not being recorded, such as conductivity, Ph, metal content, and biological information, which may be very relevant for the end-user and, therefore, for the water companies [14].

For this Special Issue, researchers, companies, and other stakeholders are invited to submit their work on the application of computational algorithms, developments in sensor technologies, network insights, reflections on the abovementioned vision, and case studies involving the use of sensors and computational processing beneficial to the water distribution network and its maintenance.

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