Water Europe

Technology & Innovation

SMART MEASURING DEVICES FOR EFFICIENT WATER SYSTEMS

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Prologue

Water Europe (WE) is the recognized voice and promotor of water-related innovation and RTD in Europe. WE is a value-based multi-stakeholder association that represents the whole diversity of the innovative water ecosystem. WE was initiated by the European Commission as a European Technology Platform in 2004. All WE activities are guided by its Water Vision and the ambition to achieve a Water-Smart Society.

The Water Europe White Papers and Technical Reports are aimed at informing readers about complex water-related topics in a concise and targeted way and presenting WE's vision and philosophy on the matter. They present evidence-based opinions on multiple water-related challenges and on ways to overcome them.

WE White Papers and Technical Reports are produced as part of the WE Collaboration Programme by the WE Vision Leadership Teams and the WE Working Groups. They target a wide variety of potential audiences, including the EU institutions, international organisations, the water industry, water users and water-related strategic stakeholders, the economic sectors, as well as media, analysts, regulatory and governing bodies, citizens and society at large.

Durk Krol
Water Europe Executive director

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Table of acronyms

ICT • Information and Communication Technologies

IoT • Internet of Things

SMD • Smart Measuring Devices

AI • Artificial intelligence

ML • Machine Learning

GIS • Geographic Information System

GPS • Global Positioning System

RS • Remote Sensing

NGO • Non-Governmental Organization

1. Executive Summary

Water systems represent critical, complex, dynamic human-environment coupled systems, whose management transcends individual scientific disciplines. The water system faces a plethora of old and new challenges, such as: the continuous impact of climate change and water system resilience; microplastics; nitrate and sulphate monitoring and removal; monitoring burst frequency and predictive maintenance standardization; remote valve and pump operation; leakage control; combined sewer overflow monitoring; energy efficiency; monitoring of emerging contaminants; and monitoring and automated process management (even within the framework of circular economy). Addressing these challenges requires a paradigm shift, based on holistic long-term management, to sulphate bring about a more responsible use of water and enhance resilience for a Water-Smart Society.

Nowadays, the adaptation of water management to new technologies has become a policy priority. In this regard, the definition, standardisation and implementation of efficient and effective monitoring and early-warning systems become essential to enhance the knowledge of systems and address awareness issues. In this context, the emergence of digital information and communication technologies (ICT), the development of Internet of Things (IoT), the increased use of Artificial Intelligence (AI) and Machine Learning (ML) techniques for data analytics, the availability of high-performance and low-cost smart monitoring devices, and the wide-spread use of powerful computing resources, can provide the foundation for smart water systems. The application of smart monitoring devices, IoT communication networks, and artificial intelligence techniques can contribute significantly to defining more tailored management policy for the optimal operation of water sectors. Furthermore, Geographic Information System (GIS) Technology, Global Positioning System (GPS) Technology, Remote Sensing (RS) Technology, collectively known as 3S technology, can strongly improve the monitoring of water systems.

Compared to the conventional human-based static, off-line monitoring, the application of new technologies can trigger a switch to a more accurate, safer, timelier, and smarter management of the systems. However, in the current state of affairs, there are still several challenges to be addressed. For example, concerning the quality of the water resource, measuring the high number of parameters required by the EU legislation in an affordable and accurate way requires smaller, faster, and more robust technologies than are currently available. For waters released into nature, the demand for the instrumentation to detect dissolved heavy metals, micro-organisms, or microplastics is extremely strong. And yet the challenge is still to secure water safety in a more effective way to enable real-time measurements made on-site, and to monitor the changes in water over longer periods. Citizens, NGOs and authorities can pressure the industry to control its wastewater better. Furthermore, as the water quality parameters and the specific location (through GPS) can be combined, and the information can be made freely available (through cloud service), even bigger areas can be mapped quickly. On the other hand, the resulting massive dynamic data involved in such a monitoring approach imply large spatial and temporal data. Therefore, much better accuracy, real-time capability, and intelligence of data cleaning, conversion, and analysis of monitoring data on a larger scale needs to be achieved, and tools and operational frameworks for realizing them are required.

In this regard, as reported in many scientific and technical papers, greater coordination between academia, industry, decision- and policy-makers is needed to transform traditional water systems into the new paradigm of smart water systems, i.e., into self-aware systems, enhanced with model- and data-driven management approaches for optimal operation. Therefore, to meet the demands of industry and government and to successfully make this new paradigm actionable, research and industry have to agree and collaborate on the following main aspects and key points:

- The performance required of measuring sensors is not the same for drinking water, raw water, wastewater, treated water, process water, irrigation water, industrial water and other types of water use.
- Relevant measures can be collected in different ways and used for different purposes, and even integrated into Data Analytics procedures and water utility management methodologies.
- New toolbox sensors can fill the gap between online measurements and their validation in the field.
- A effective link with Standardisation bodies must be established to assure proper integration of existing and new sensors, in accordance with current and forthcoming regulations.
- A specific process aimed at persuading the relevant stakeholders should be launched in the framework of a "smart sensors" comprehensive approach.
- There is the need to develop sensor systems that can guarantee communication quality in a complex and harsh environment, while consuming as little energy as possible.
- The development and application of tools and methodologies for the analysis of massive data involved in the system monitoring is needed.

In this document, produced by the Water Europe WG Water Sensors and Tools, after a survey of the main barriers and gaps, carried out among the different stakeholders (researchers, operators, water utilities, etc.), some ways forward are identified and proposed, such as a stronger promotion of sensors development, changes in legislation to promote SMD, and shortcomings in the market uptake.

2. Introduction

In the last decade, the spread of Information and Communication Technologies (ICT), digital technologies, and new monitoring systems assumed a key role in moving towards a Water-Smart Society (Di Nardo et al., 2021).

Smart Monitoring Devices (SMD) for water are expected to foster innovation across the Water Value Chain (WVC). In the water sector, innovative meters – able to measure quantity and quality parameters with low capital and operational costs, low energy consumption and cloud connections – can allow the identification of novel solutions to face the socio-economic challenges of water use, water quality, and management according to various stakeholder operational needs. The integration of analysers, smart meters, and biosensors with cloud computing and innovative Big Data analytics and machine learning approaches (Di Nardo et al., 2021) allows for an improvement of network management and an alignment of the water sector with other public utility sectors like energy and telecommunications. In this regard, the use of high-definition satellite image data by the RS technology, the fast acquisition of spatial location data through GPS, the storage, management, and analysis functions of spatial data with GIS, and the integration of IoT-based systems, can represent key tools to exploit and apply for the optimal management of water systems. A more effective monitoring in terms of quantity and quality variables makes partitioning of large water networks possible, thus improving customer service, quality of maintenance, and protection from accidental or intentional contamination. The performance required from SMD is not the same for drinking water, raw water, wastewater, treated water, process water, irrigation water or industrial water. This means that specific problems and aspects can vary, depending on the segment of the integrated water technological cycle, but others, such as those dealt with in this document, can be considered to be more general and thus valid for all water management levels.

Extensive deployment of SMD opens a number of interesting opportunities – some beyond the traditional ones – to strengthen the protection, maintenance or control of water networks (such as tap water distribution networks, sewerage networks, or environmental monitoring networks); to improve water treatment (tap water, wastewater, desalinated water, reclaimed water or industrial process water); and to enable a significantly better application of Water Safety Plans.

One of the most innovative applications is represented by the use of SMD in residential water consumption measurement, which can help water utilities assess detailed consumption patterns, improve leak detection, avoid significant network water storage and pumping energy costs, increase water conservation, define customized bills and improve demand forecasting (Di Mauro et al., 2021). While for customers, information on water use patterns associated with household appliances can naturally help identify post-meter leaks, increase their awareness of sustainable behaviours, prevent water waste, and generate cost savings on water bills (Di Mauro et al., 2021).

In this context, the development of end-use disaggregation techniques (Cominola et al. 2018; Di Mauro et al., 2021) of the most commonly used non-intrusive metering techniques – which permit (i) an understanding of how much of the household water use is linked to a single fixture in the home, (ii) the segmentation of household consumption data into different end-use categories, and (iii) the pre-localization of water leaks, using noise logger features sometimes integrated into the meters themselves – can provide the opportunity to develop innovative demand forecasting models, generate detailed bills, and provide personalized savings recommendations that help utilities nudge customers towards more water saving attitudes (Cole and Stewart 2013; Cominola et al. 2018), such as switching among the different exploited water sources (ground or surface waters), depending on their availability and quality. On the other hand, careful attention must be given to the privacy issues associated with smart meters, as water use can be used for occupancy detection or personal behaviour pattern identification (Salomons et al. 2020).

Therefore, special attention should be paid to data protection and security issues, in order to ensure secure data communication and protection of the consumers' (individual and business) private data (usage patterns and specific individual consumption information) against unauthorized access or hacking (cybersecurity issues). In this regard, some requirements concerning data protection must be specified. For example, personal data processing is allowed only if specific legal purposes apply, and personal data gathered for one purpose cannot be used for another purpose without permission (Ząbkowski & Gajowniczek, 2013). For these reasons, smart meters cannot transmit any sensitive data, such as customer name or address; instead, it transmits personal data through the use of a smart meter ID number, which can be associated with a customer.

Another interesting application can be in water reuse (non-drinking water), which should be encouraged in industry, municipalities, but also at the household level using appropriate devices for wastewater harvesting. A combination of water metering and water quality monitoring can promote water reuse by end-users, by enhancing their trust in the quality of the water, empowering them to make decisions on the basis of the information, and raising their awareness of ecological impacts and consumption costs.

However, further identifiable problems remain – in form of gaps, barriers, shortcomings, etc. – which hinder the full application of these technologies in the market of water distribution networks. These problems have been investigated by the Working Group WATERSET – which is made up of various qualified stakeholders, including water utilities, research centres and universities, as well as large, medium and small companies and operators – and also been reported in many scientific and technical papers.

In this white paper, the main issues are discussed with in terms of gaps and delays. We also identify some possible solutions in relation to four main aspects: (i) definition/identification of smart sensors, (ii) delays in legislation and regulations, (iii) applied research needs, and (iv) related software and IT developments.

3. Outline of the Problems and Solutions

This section provides some definitions of "smart measurement". Further, the main gaps, barriers, and shortcomings identified by the working group are defined and briefly described. Finally, some possible solutions and recommendations are suggested.

3.1 Definitions

First of all, it is useful to try to define more appropriately the meaning of smart sensors in the digitalization era, with specific reference to the water sector, given that some concepts and definitions are also valid for other application domains.

A smart measuring device is based on the digitalization of measures and consists of converting an analogue representation (measurement parameter) into a digital representation. Digitalization allows for very useful and innovative data management and control; in summary this specifically involves:

- storing information
- streaming / sending / sharing information without noise or errors
- adding further multi-dimensional information (time, location, etc.) for further processing
- treating and processing the information to control, analyse, predict, etc.
- implementing IoT, BigData, Machine Learning, Artificial Intelligence and other techniques.

Furthermore, digitizable signals can be:

- electrical signals (voltage / current), by comparison with reference.
- digital signals (frequency / time), by counting.

Figure 1 below shows the elements of the water-quantity or-quality measuring chain; it highlights that measuring devices themselves are only a part of a more articulated monitoring system.

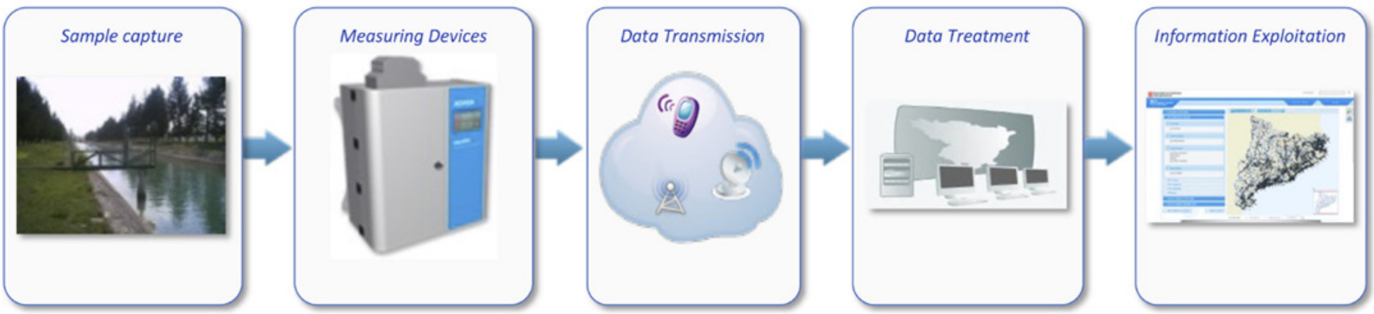

Figure 1. Elements of the water-quantity or-quality measuring chain.

What follows are short definitions of sensor, measurement device, analyser and data handling, which are presented as preliminary information, before proceeding to a definition of smart measuring devices (now also known as "smart sensors"):

- **sensor:** element that generates a digitizable signal that is a function of the parameter to be measured;
- **measurement device:** a set of elements necessary for the sensor to provide the measurement in the appropriate format;
- **analyser:** measuring device that, in addition to sensors, requires some process and reagents to obtain the desired parameter;
- **data handling:** the way measured data are processed, feed a model and/or eventually correlated with others, in order to trigger a warning to the smart sensor user.

Figure 2 presents a simple scheme of a Smart Analyser, in which the different main components are highlighted.

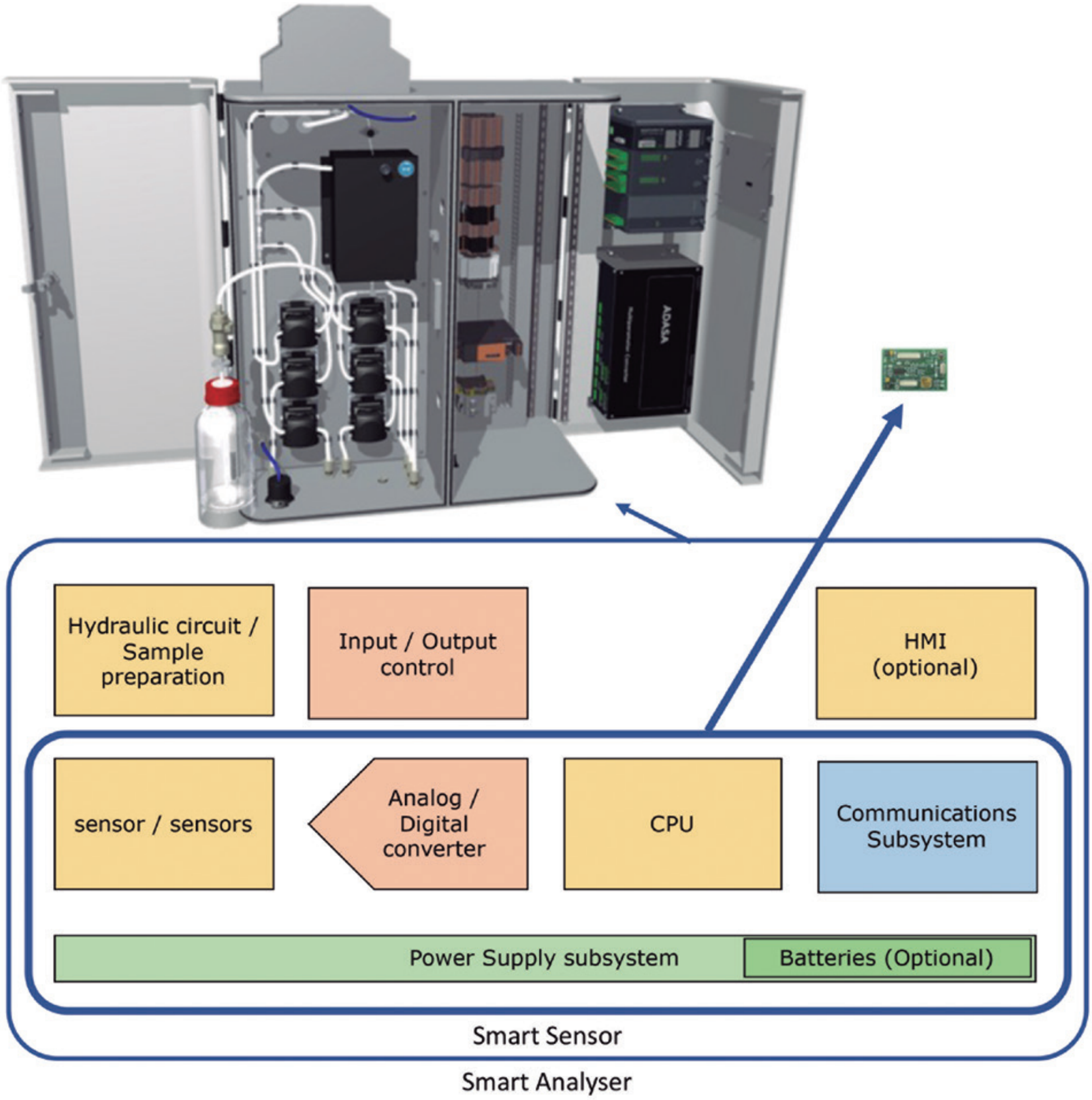

Figure 2. Elements of the Smart measuring device

The purpose of the measurement determines some of the device's characteristics: the requirements are not the same for a measuring system that verifies legislation compliance, to be used in a control system in a wastewater treatment plant, or in a scientific study. Thus, the detection limit, the range, or the interval between measurements for the SMD depend on the type or purpose of the measurement.

These instruments allow for the monitoring of water-quantity and -quality parameters, with reference to physical, chemical, and biological categories of measurements.

A short list of smart sensors is shown below, giving examples for each category, with reference to the quality or quantity parameters they are able to measure, and to the main characteristics required.

a) Physical parameters (quantity & quality) (e.g., level, flow, temperature, conductivity):

- Easy and simple conversion of measured parameter into a digitizable signal.
- The measuring device is almost the sensor.
- The devices are stable over time, they do not show excessive wear, and need little calibration.

b) Chemical parameters (Quality) (pH, RedOx, free chlorine, nutrients, ions, etc.):

- A conversion to a physical parameter must be carried out.
- The measurement device can be complex, as the sensor can work only under certain conditions, so it often requires reagents.
- Not stable over time and usually requires calibration (the conversion from chemical to physical parameter usually produces "wear").

c) Biological parameters (Quality) (BDO5, toxicity, microbiological indicators, etc.):

- A conversion to physical parameters must be carried out.
- The measuring device is usually very complex and often requires reagents.
- If the conversion of the biological parameter is done through an intermediate step of a chemical parameter, as the process of conversion from chemical to physical parameter usually produces "wear", they are not stable over time and may need calibration.

As is known, the implementation of the Smart City paradigm calls for the detection and collection of large amounts of assorted information and its placement online. In other words, it requires multiple and continuous monitoring of different parameters in each sub-domain of the Smart Cities, such as, electricity, transport, waste, internet, water, etc. With regard to the water sub-domain – bearing the integrated water cycle in mind – the required information concerns the physical, chemical and biological parameters. For this reason, Smart Cities need SMD with the following technical characteristics:

- small size in order to be spread out as "dust sensors" ;
- low CAPEX (capital expenditure) and low OPEX (operational expenditure);
- easy to install;
- easy to collect and transmit information or data (connecting to a cloud);
- low energy consumption.

Such SMD could be widely deployed in the water network, and would offer the possibility of using Big Data, Artificial Intelligence, and Machine Learning techniques, and of interpreting changes in quality and quantity measures. This would enable the prediction of system behaviour, and offer the perspective of early warning and, more generally, improve water system control.

3.2 Gaps, Barriers, Shortcomings

The scientific and technical community have been working for many years to achieve all the "ideal" SMD characteristics for the device's application in the water sector. Since the SMD requirements are application-specific – e.g., for nitrates or phosphates in WWTP effluent for legislation compliance, or flow or pressure monitoring for process control in distribution networks, or for microplastic detection in seawater knowledge advancement – some of the characteristics were achieved, while others are still the subject of ongoing challenging research. Also, some of the devices encountered difficulties entering the market due to barriers and shortcomings.

In all cases, it is clear that some delays are still occurring in meeting the Smart City paradigm. This section presents a brief description of the relevant gaps related to the technological, economic, legislation and integration issues.

The gaps, barriers and shortcomings were actually identified as a result of an internal survey carried out by WATERSET Working Group among its members and partners, as well as stakeholders, including producers, operators and water utilities. The gaps, barriers and shortcomings are shown in Figure 3, and discussed in the paragraphs that follow.

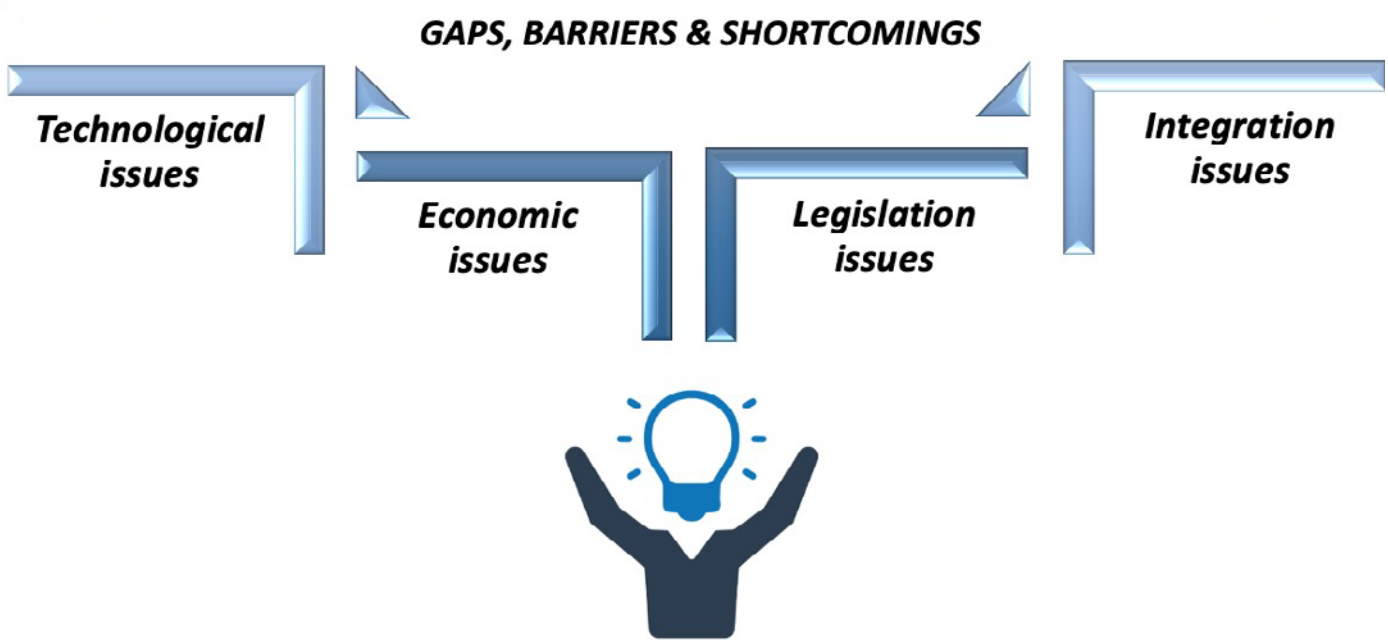

Figure 3. Gaps, barriers and shortcomings for SMD.

Technological issues

In general, it is possible to state that, over the last twenty years, the evolution of sensor technology has been slow due to physical limitations, while the evolution of ICT for sensors has been rapid. Many measuring devices are simply automated laboratory equipment, which are not ready for wide deployment due to their high purchase and maintenance costs.

The survey carried out highlighted the following main technological gaps affecting the full availability of SMD for water networks:

- Sensors (still unavailable on the market) able to detect in situ other parameters that currently require external analysis.
- Sensors with high consumption of reagents; in chemical or biological parameter measurement, reagents are usually required to perform the chemical / biological-to-physical conversion (for example, the concentration of ion to colour with a colorimetric reaction). If real-time (or near-real-time) values are required, consumption of reagent could be high.
- Measurement data validation using a proper methodology remained at the sensor manufacturer, and maybe involved using additional devices.
- Data reliability (accuracy, consistency, repeatability, etc.).
- Sensitivity. The detection limit required for some parameters in legislation (for example, in priority substances of UE Directive 2013/39/UE) is currently difficult to achieve affordably in online measuring devices.
- Selectivity. The complexity of the sensors varies according to the type of target analyte; for instance, turbidity is an aggregated parameter composed of many substances in water and requires limited sensor complexity. However, when there is a need to detect chemical compounds, and even to discriminate between analogues from the same family, such as microcystins or perfluoroalkylated compounds (DWF 2020; microcystin-LR), the selectivity of the sensor needs to include several layers of complexity. Only spectroscopic techniques with fingerprinting capabilities, such as NMR, IR or Raman, can potentially address this selectivity without using labelling.
- Connectivity in remote areas for installed SMD.
- SMD interoperability.
- Integration of data in decision support systems.
- Cybersecurity.
- Artificial Intelligence (AI) and Machine Learning (ML) - based data analytics.
- Portability and affordable devices.
- Power consumption. Another important problem faced in using SMD for innovative IoT and Big Data applications is the need to have energy-autonomous sensors for the purpose of improving the accuracy/resolution of the measurement for a given power consumption, and of increasing their operational time, or even allowing for "perpetual" operation. Thus, electronic sensors and their electronic interfaces need to be able to operate autonomously and wirelessly during a relatively long period of time from an embedded local power source. Unfortunately, batteries are typically based on lithium, which is scarce (particularly in Europe) and highly demanded, and systems for energy harvesting are still inadequate.
- Autonomy (energy harvesting systems and batteries). In relation with power consumption, the autonomy and the power consumption will define the power storage and/or supply requirements.
- Sample complexity. The need for online sample preparation to reduce noise, cross-reactivity, background and interferences. A good number of the online sensors require steps of sample preparation to achieve the sensitivities, reliability and reproducibility needed in a complex environmental matrix. Clean-up, pre-concentration or pre-treatment cartridges or modules are usually necessary to remove interferents, to increase the concentration of the analyte in the sensor surface, its accessibility or modification.

Economic issues

With reference to economic aspects, the internal survey revealed economic gaps which included:

- Cost of sensors and devices.
- Additional costs, such as installation, communications and commissioning.
- Costs of maintenance, including displacement cost in the case of remote sensors.
- Limited market, which does not favour unit-cost reduction.
- Unaffordable business models for the utilities, in terms of costs for SW licence and related data hosting in the cloud.
- Costs concerning customer data protection and privacy assurance.

Evidently, the crucial economic point is that, currently, smart sensors may be cheap, but smart analysers are not. It is therefore not possible to conceive of the wide dissemination of smart devices in the water distribution networks, or in other segments managed by water utilities.

We are already in the era of GPS, LIDAR, and other sensors, like GNSS for earth surface positioning control (and related buried asset) above the ground, whose measurements can be read using a smartphone available to most people; unfortunately, however, at the present time, a pH or conductivity measurement cannot yet be read on a smartphone.

In short, when it comes to the actual sensors presently available on the market for the measurement of certain water-quantity and -quality parameters, there are no existing low-cost SMD which could be widely disseminated. Water utilities do indeed for example use online sensors in their water plants for control and warning purposes: these are useful, but certainly not "cheap"!

Probably the benefits for the use of these devices are still low and novel rules and business models have to be investigated and proposed: Who pays for the sensors? Who profits from the information? How can we assign a value to the collected data?

Legislation issues

The legislation is, probably, the main barrier that limit the development and dissemination of SMD for water quality measurements, and more generally, for the monitoring of system performance, including 3S, ICT and IoT technologies.

The internal survey identified the following legislation gaps:

- Legal impossibility to use the data collected by water quality SMD, as only laboratory measurements using standardized laboratory methods is accepted.
- Low frequencies of data sampling, because as laboratory samples are costly and slow, only a few values are required.
- Regulating bodies are still not convinced of the benefits of SMD, so they do not require their installation.
- Guidelines and directives that regulate access to customer service data to assure privacy and data protection.

In fact, only laboratory measurements (no online or smart measuring devices) are accepted in current European legislation, and the frequency of the required measurements is very low, which excludes the need more highly performing devices and the application of big data and machine learning analysis.

So, one can confidently assert that legislation does not promote the use of water quality smart measurement devices, and constitutes the main barrier to the full development and dissemination of SMD in the water sector.

Integration issues

Another issue regards the problem of the integration of SMD in the design, management and control policies of water utilities and operators, because the possibility of having a large number of smart metering devices opens new operational and technical challenges. Questions like the following arise: Where should SMD be installed to obtain optimal performance? Which direct and indirect parameters are more useful? Once SMD are widely disseminated, could one reduce the number of direct parameters measured? Which are the optimal time-intervals required to obtain enough information for big data analysis and machine learning procedures? Which tools and software are reliable and standardized?

It is therefore clear that, in parallel with the improvement of new SMD technologies, there is a need to develop new criteria, procedures, tools and software that improve and simplify SMD application in operational contexts.

The survey underlined the following main integration gaps:

- Data models, protocols and interoperability.
- Open data management.
- Integration into decision-making processes.
- Lack of standard, reliable and standardized algorithms and procedures for big data analysis and machine learning predictions.
- Optimal SMD positioning criteria (number, locations, types, etc).
- IoT protocols.
- Limited availability of commercial software to manage big data and the placements of sensors in water distribution systems.
- Calibrated hydraulic model required by most software.
- Difficulty in defining objective functions.
- Tools to use the collected data for different purposes (etc., event detection, smart alerts).
- The efficiency of the data transmission must be optimized by improving the long-distance wired and wireless communication protocols, and through the intelligent processing technology of mass information.
- The device-manufacturing industry must work closely with regulators and standardization organizations to develop strong security standards to resolve various challenges, such as confidentiality, integrity, privacy and policy implementation.

Evidently, many of the integration gaps are related to ICT topics, which are discussed in more detail in the Working Group "Water and ICT" of Water Europe.

3.3 Proposed solutions or recommendations

The survey carried out by WATERSET WG verified that water utilities are very interested in smart measuring devices, particularly if they are tailored for a specific target (with an ROI in a reasonable time). Measurements need to be thought of as an input for a methodology used in the day-to-day management. Also, the two main uses of SMD for water utilities (i.e., process control in treatment and distribution, and legislation compliment/compliance) require different SMD characteristics, mainly concerning the required time measurement intervals, the detection limits, and the specificity of the measured parameter, mostly in water quality measurements.

After the above brief presentation of the main problems, gaps, and barriers, this section puts forward some possible solutions and, above all, recommendations. These are presented in the bullet list below:

- Promote research and innovation projects to develop new SMD technologies, and technology transfer projects to simplify migration from research to market.
- Promote compliance with the EU Environmental Technologies Verification pilot programme (ETV), from the initial steps in the development of the technology (>TRL5), to verify that performance claims put forward by technology developers and vendors are complete, fair and based on reliable test results. With ETV, manufacturers of technologies receive a Statement of Verification, which can be used in their marketing efforts to build a trustworthy business relationship with potential customers and investors.
- Place demands on electronic reporting that are in line with municipal, national, and European open data initiatives. This would make it a lot easier, for example, for construction companies, which would not have to adapt to each city´s specific reporting requirements and instead use the open data portal, from which the city (and citizens also) can access the data.
- Change the water monitoring legislation allowing the use and collection of quality data with smart metering devices.
- Change legislation to increase the frequency of data sampling and collection, and thus strongly promote the use and reduce unit costs of SMD.
- Set legal requirements for online monitoring of pollutants: it is clear that, in the event of pollution incidents, the time window for intervention in water systems cannot be efficiently used by conventional offline water quality screening, which only produces information hours/days after the incident. Online sensors are the only systems able to provide highly valuable (almost) real-time information, but they are relatively expensive assets. Hence, if the information they provide is not required by legislation, only those associated with a high levels of cost savings or competitive advantage to companies will be implemented.
- Stimulate the creation of a volume market for sensing technologies. Policy action needs to focus on this because the upscaling of a fragmented market is a major barrier for many of the digital technologies in the water market. Initially, the focus should be placed on areas where the greatest demand could be expected and where the motivation is strongest, such as the optimizing of OPEX/CAPEX. For example, predictive maintenance of wastewater systems (sewage, stormwater, and combined sewage water and stormwater) is an aspect for which Pre-Commercial Procurement (PCP) has successfully addressed the upscaling in fragmented markets to another sector. PCP challenges industry from the demand side to develop innovative solutions for public sector needs, and it provides a first customer reference that enables companies to create competitive advantages on the market. PCP enables public procurers to compare alternative potential solution approaches, and filter the best possible solutions that the market can deliver to address the public need.
- Define guidelines to employ sensoring systems for predictive maintenance and flood control of wastewater systems, and start to work with standardization when the market becomes more mature.
- Create competence development programmes on advanced data management for the water sector. These should be directed at both technical staff and management at utilities, urban administrations as well as at data experts, in order to raise awareness regarding digital solutions and to attract them to the water sector. Both technical data skills and the management and analysis of data need to be focused on. It is most essential that competence development on advanced data management be directed at drinking water utilities, where data management is far less developed than in wastewater treatment plants, which are more accustomed to handling data from many sensors and instruments in real-time.
- Promote the use of artificial intelligence and big data analysis in the water sector based on real-time datasets, where the correlation between different kinds of data (geospatial and time operational, hydraulic) is strong but difficult to understand.
- Improve the regulation of Water and Sanitation Safety Plans, promoting SMD deployment where more reliable and redundant measurements enable greater awareness and reduce the failure risk in the whole chain.
- Promote activities to facilitate the cooperation of stakeholders in specific working groups with the aim of implementing WSP in the first aqueduct.
- Make different methodological requirements and parameters to be measured necessary for online monitoring, in contrast to offline monitoring in the lab.
- Include ETV in regulations as a complementary approval for on-line methodologies.

4. Findings and Conclusion

The growing global population and resulting ever-increasing demand for water, combined with resource constraints and the simultaneous call for an ever-more-efficient service (both from a quantity and quality point of view), in addition to the unavoidable consequences of climate change, all exert strong pressures on the water sector in its current state, and highlight the imperative necessity of a monitoring and management paradigm shift. In this context, it is necessary to define and apply innovative, sustainable and smart perspectives for the analysis, modelling, monitoring, operation and management of water systems.

This explains why the application of emerging technologies (smart metering devices, IoT-based communication, artificial intelligence, big data and machine learning tools) has become a key policy issue for water management. In this paper, following a brief description of the advantages of adopting such a novel approach for the management of water systems, based on the potentialities offered by the new monitoring and communication technologies (and a description of their main components), the focus was then directed on listing the current gaps and possible solutions, with the aim of reducing the distance and time that separate research and market, and thus strengthening the dissemination of innovative smart measuring devices for water.

The survey carried out in preparation of this white paper verified that water utilities are very interested in SMD. Nevertheless, in spite of the enormous advantages offered by the application of these new tools – compared to the conventional human-based monitoring, smart metering is more accurate, faster, safer and timelier – they raise various issues that need to be understood and addressed. In this regard, several gaps and challenges have been identified, which concern producers, operators and water utilities. At a more detailed level, the issues were categorized into four main clusters: technological issues, reflecting the reality that smart metering devices are still in an embryonic and experimental stage, and not yet commercially available; economic issues, having to do with the high costs of realization, installation, commissioning, maintenance and communications; legislation issues, which concern the lack of specific guidelines and directives for the standardization of the implementation and usage of devices and the data recorded; and integration issues, which have to do with the need, together with the improvement of new technologies for smart metering, to develop new criteria, procedures, tools, and software to define an integrated framework for the application of these new technologies in operational contexts.

On this basis, some possible solutions and recommendations have been delineated to address the issues raised by the survey.

- Technological: there is an imperative need to promote research and innovation projects to develop smart metering technologies. Because of the massive volumes of recorded data available, it has become crucial to promote the use of artificial intelligence, big data analysis and machine learning tools for the data management in the water sector, in order to better understand the system behaviour and allow for predictions and early warnings.
- Economic: there is a need to reach the market with the technologies that have already been validated, and thus to stimulate the creation of a volume market and assure the migration from research to market.
- Legislation, there is a need to change the water monitoring legislation with regard to the legal requirements for online monitoring, and data privacy and security, which will stimulate the market for the technologies that have already been validated.
- Integration, it is also important to define guidelines for the employment of sensing systems with a view to achieving a unified standardization.

Naturally, the realisation of these improvements involves another crucial component, namely: the strong cooperation between the stakeholders, research groups and national and community governments.

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SMART MEASURING DEVICES FOR EFFICIENT WATER SYSTEMS

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