What to measure? And how? – mapping current and future needs for water quality monitoring in urban areas

Que mesurer ? Et comment ? – Évaluation des besoins actuels et futurs en matière de surveillance de la qualité de l'eau urbaine

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RÉSUMÉ

Les réseaux d'eau urbains évoluent vers des modèles circulaires et durables. Cette transition nécessite des données complètes sur la qualité de l'eau afin d'identifier les points critiques de pollution, de planifier des stratégies d'atténuation et d'évaluer leur efficacité. Les méthodes de surveillance actuelles sont coûteuses, génèrent des données fragmentées et sont insuffisantes pour des applications à l'échelle urbaine. Le projet URBAN M_2O permettra de relever ces défis en développant des solutions intégrées de surveillance et de modélisation adaptées aux besoins des utilisateurs finaux, notamment les services des eaux et les autorités environnementales. Cet article présente les résultats préliminaires d'une analyse des exigences actuelles et futures en matière de surveillance à travers l'Europe, réalisée à partir d'examens législatifs, de questionnaires destinés aux parties prenantes et d'ateliers de co-création. Les résultats révèlent des divergences importantes entre les réglementations européennes et nationales, des lacunes dans le partage des données et des besoins émergents en matière d'indicateurs à haute résolution couvrant les contaminants chimiques, microbiens et microplastiques. Ces informations guideront la conception d'outils de nouvelle génération pour une surveillance rentable à l'échelle du système, permettant ainsi la mise en place de stratégies solides de contrôle de la pollution.

ABSTRACT

Urban water systems are transitioning towards circular, sustainable models. This transition requires comprehensive water quality data to identify pollution hotspots, plan mitigation strategies, and evaluate their effectiveness. However, current monitoring methods are costly, generate fragmented data, and are insufficient for city-wide applications. The URBAN M_2O project addresses these challenges by developing integrated monitoring and modeling solutions tailored to end-user needs, including water utilities and environmental authorities. This paper presents preliminary results from mapping current and future monitoring requirements across Europe through legislative reviews, stakeholder questionnaires, and co-creation workshops. Findings reveal significant discrepancies between EU and national regulations, gaps in data sharing, and emerging needs for high-resolution indicators covering chemical, microbial, and microplastic contaminants. These insights will guide the design of next-generation tools for cost-effective, system-wide monitoring, enabling robust pollution control strategies.

KEYWORDS

Water quality monitoring, urban water systems, stakeholder engagement, data integration, investment costs

1 INTRODUCTION

The transition of urban water systems from traditional linear approaches towards circular, more sustainable approaches (described by the "Water Wise Cities" concept, IWA n.d.) requires curbing the pollutant emissions from urban areas. Policies like the EU "Zero Pollution Action Plan" aim at reducing the impacts to the natural water environment, protecting water resources and ensuring clean water for both humans and the environment.

The implementation of these pollution control actions requires a great amount of water quality data for (a) identifying pollution hotspots, causing high environmental and health risks, (b) planning pollution control actions to reduce the impacts (including both end-of-pipe treatment and source control), and (c) monitoring the implementation of these actions for assessing their effectiveness. However, the available water quality monitoring methods typically fail to provide adequate information to support city-wide pollution control actions. Indeed, current lab-based sample analysis and sensors target only a few contaminants, are costly, difficult to install and maintain, require intensive data validation, and have limited spatial and temporal resolution.

The URBAN M_2O project aims at developing new monitoring and modelling solutions to provide urban water managers with all the necessary information to address current and future threats (including trace organic chemicals, microbial contaminants, microplastics) to water quality in urban areas. However, the developed solutions need to be tailored to the needs of end-users (water utilities, environmental authorities) to ensure a broad application of new monitoring technologies and thereby support a successful implementation of pollution control actions.

This study presents the first results of the activities performed by URBAN M_2O to map the current and monitoring future needs for a wide range of European stakeholders. The mapping involved reviewing the monitoring requirements defined in the current and future legislation, as well as co-creating "User Stories" together with end-users, describing their water quality needs. The results of this study will guide the development of a new generation of monitoring and modelling tools, enabling the implementation of more cost-effective water quality monitoring across urban waters.

2 MATERIAL AND METHODS

2.1 The Urban M_2O project

URBAN M_2O (www.urbanm2o.eu) is an EU Horizon project aiming at creating and demonstrating tools to merge and integrate data from different sources across the urban water system, supporting a 'whole system monitoring approach' addressing the multifaceted pollution threats to water quality. The project involves 20 partners across Europe, developing and testing (a) monitoring solutions targeting different water quality indicators, (c) modelling tools to track pollutant fluxes across integrated urban water systems, and data management systems for sharing the available information across multiple organizations.

End users and stakeholders involved in urban water quality monitoring (water utilities, environmental authorities at local, regional, and national scale) are essential for developing user-friendly tools, tailored to the different water challenges that are found across Europe. Their needs have been mapped by URBAN M_2O by (a) reviewing the current and future EU and national legislations, and (b) holding several co-creation workshops resulting in the so-called "User Stories", i.e. document describing how stakeholders envisions a future where they have access to all their necessary data to plan and implement pollution control strategies for various urban water matrices.

2.2 Mapping current and future monitoring needs

2.2.1 Legislation requirements

Relevant European directives for the various urban water matrices found in cities (drinking water, groundwater, surface water, treated water, bathing water) were reviewed, and their monitoring requirements (in terms of chemical and microbiological indicators) were compared with the corresponding national legislation of six European countries. This comparative approach provided an overview of alignment, deviations and gaps between the current national and EU regulations. Further, strategies outlining the future of urban water systems (such as EU Water Resilience Strategy and the IWA Principles for Water Wise Cities) were reviewed, to identify new monitoring needs that might arise in the future.

2.2.2 Current monitoring practices

An online questionnaire was launched to collect information on current monitoring activities across Europe. The questionnaire focused on monitored water matrices and quality indicators, but also aimed at collecting data on the resources (both financial, but also workforce) that are currently invested in operational monitoring programs (i.e. research activities were not included in the questionnaire). As of December 2025, over 50 responses from end-users spread from 12 European countries were collected.

2.3 Describing the water quality monitoring needs

URBAN M_2O will hold several co-creation workshops in four countries (Denmark, Italy, Spain, Switzerland), integrated by online workshops in the period from December 2025 to February 2026. The participants from these workshops include end-users (employees from water utilities, environmental authorities, consultants) dealing with different water matrices and dealing with various water challenges. During the workshops, participants reflect on their current needs for water quality data, and they are then grouped by water matrix and role. Subdivided in groups of 4-5 people, the participants synthetized their vision on the data needed by their role in developing and implementing pollution reduction actions. Their input from the multiple workshops is then summarized in the so-called “User Stories”, i.e. informal descriptions of the features that an effective water quality monitoring system should provide (e.g. spatial and temporal resolution, access to data, type of monitored indicators).

3 PRELIMINARY RESULTS

3.1 Current and future needs

3.1.1 Legislation requirements

The review of the existing regulation highlighted as mismatch between the national implementation of the EU regulations, with countries including additional indicators for specific matrices. For example, over 90 chemical indicators are added in the Dutch groundwater regulation compared to the corresponding EU directive, 55 in the Italian drinking water regulation, etc. These differences create barriers for the development and use of monitoring technologies across European countries. Further, the review identified inconsistencies between the regulations of water matrices sharing interfaces (e.g. treated wastewater/surface water, stormwater/bathing water). For example, different chemical indicators are defined for treated wastewater and surface water. Bathing water regulation is primarily focusing on microbiological indicators, which are not considered by regulations targeting wet-weather discharges (stormwater and Combined Sewer Overflows). These discrepancies, which can be tracked back to a linear vision of the water cycle, create a legislative barrier to the implementation of effective monitoring strategies. New legislation will continue to enforce monitoring based on current approaches, but there will also be the expansion to wider system functions, focusing on water reuse, ecological health and risk-based monitoring. Finally, current data sharing is very limited and does not allow for a full exploitation of the information from the collected data. Future monitoring activities thus need to fully embrace the FAIR (Findable, Accessible, Interoperable and Reusable) approach, ensuring data transfer across organizations.

3.1.2 Current monitoring practices

The responses from the questionnaires show clear economy of scales for the resources invested in water quality monitoring programs (Figure 1). Establishing large monitoring programs (in terms of monitored sites or amount of collected data) decreases the investments needed by the data collection activities. Based on the currently available data, the initial costs for a site with the current monitoring technologies exceeds 20,000 EUR. This might represent an important investment for small organizations with limited budget for monitoring activities and hundreds of potential sites to be monitored.

3.2 Users’ needs

The elaboration of the User Stories will be completed by April 2025. Preliminary results from the workshops held by December 2025 identified the following monitoring needs:

- *Compliance assessment of discharges to the natural environment*: local and regional authorities need data with high-time resolution data on indicators causing acute and chronic impacts (e.g. concentrations on event-basis for micropollutants from separate systems).

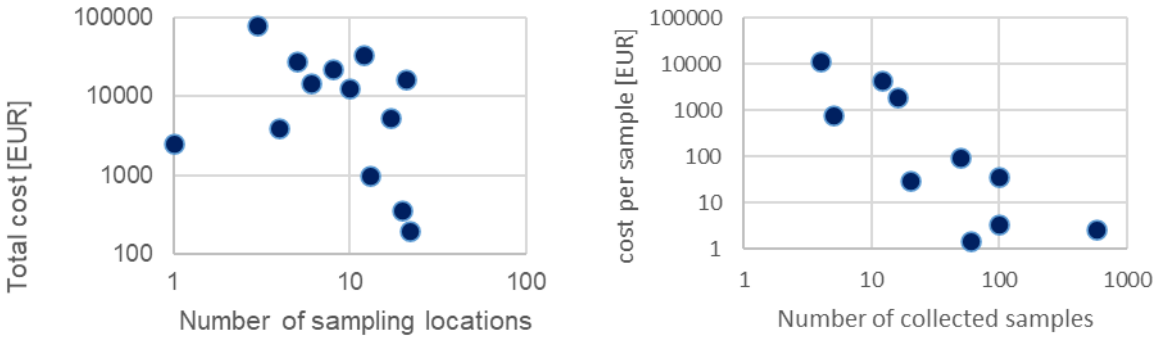

Figure 1. Overview of estimated monitoring costs based on response to the online questionnaires. Left: total cost (considering both site installation and analyses costs) as function of monitored locations. Right: unitary sample cost against number of collected samples

- *Performance assessment for decentralized infrastructure*s: hundreds of Nature Based Solutions are being built across urban areas. Water utilities need to continuously monitor performance indicators (including proxies for pollutants of interests) for this diffuse infrastructure on a monthly/seasonal basis, in order to plan maintenance
- *Pollutant source surveillance and tracking*: water utilities managing the collection network need to ensure that households and activities generating storm/wastewater comply with their permits. There is need for constantly monitoring anomalies (e.g. high polluted flows discharged by industries to WWTPs) and performance of treatment solutions (e.g. from households with polluting materials, such as copper roofs).
- *Warning for public health*: water utilities promoting water reuse for non-potable purpose, environmental authorities responsible for recreational use of urban water, need to obtain microbiological data at high resolution (daily or sub-daily) and short lag time to protect human health. A robust data validation is necessary to avoid false alarms and build trust in the citizens.

4 NEXT STEPS

The co-creation process carried out by the URBAN M_2O project together with end users from all Europe will provide an overview of the current and future monitoring needs in terms of (a) needed water quality indicators, (b) spatial and temporal resolutions; (c) intended use (planning, design, performance evaluation), (d) level of data sharing and (e) visualization needs. This information will by synthetized into “User Stories”, which will

- Help tailoring the sensor and model development to the actual needs of the urban water sector throughout the URBAN M_2O project duration (2025-2029)
- Guide the benchmarking of the developed solutions against the current monitoring methods, identifying the indicators for a comprehensive assessment going beyond CAPEX and OPEX
- Enable water authorities to better describe their monitoring needs, guiding their investment in new monitoring activities (e.g. in choosing the most appropriate technology and spatial and temporal resolution for their water challenge).

The overall development of the sensors and digital tools in the URBAN M_2O project will continue until 2029.

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