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Developing a Framework for Smart Stormwater Management in Tallinn, Estonia †

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Abstract: The recently revised European Urban Wastewater Directive 91/271/EEC has prompted a shift in urban stormwater management across Europe. The directive emphasizes the importance of improving stormwater monitoring to prevent urban water quality degradation. Larger organizations with more resources are increasing their stormwater monitoring capabilities. However, there is concern that smaller utilities might lack these resources. A methodology was developed to evaluate stormwater managers' ability to implement continuous stormwater monitoring solutions. The proposed framework was developed based on a literature review, and it considers environmental, technical, financial, and human resource factors. This proposed framework represents the first step towards putting data-driven urban stormwater management into practice.

Keywords: smart stormwater systems; water quality monitoring; urban stormwater management

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1. Introduction

The year 2023 was a watershed year, with many worldwide high-level discussions about water quality and quantity, climate change mitigation, and the need for early warning systems [1,2]. Countries in the European Union (EU) were preparing to implement new water and wastewater directives, and the EU was nudging the lagging water sector to become digitalized and announced the call for an EU Blue Deal [3–6]. It was also the year that the new HOLAS report on the Baltic Sea's environmental status was published, revealing that the Baltic Sea's water quality still remained poor [7]. Concurrently in Estonia, Tallinn's largest water company began to plan for a future with stricter urban stormwater management legislation, adherence to which may also necessitate a more data-driven approach.

The purpose of this paper was to present a framework for assessing the need and possibility of implementing stormwater quality and quantity e-monitoring in the Tallinn stormwater catchment. The approach was generalized to capture the needs of stormwater managers around the Baltic Sea and beyond.

2. Materials and Methods

An extensive literature review was conducted, based on scientific literature, various technical reports, gray literature, and manufacturers' documentations. This review included 103 references, specifically selected for their relevance to the preidentified research questions, as presented below:

- What is the state-of-the-art for monitoring stormwater quality and quantity?
- What are the main stormwater pollutants and their pathways, effects, and real-time monitoring options?

- What is the status of existing best practices in Estonia's largest water company, compared to the state-of-the-art, and which benefits could the company reap from the digitalization of stormwater management?
- What are the requirements for setting up systems for stormwater quality monitoring?

The findings from the review were generalized to evaluate the need and the capacity of stormwater managers to move towards continuous stormwater monitoring. The capacity to integrate stormwater quality and quantity monitoring into their workflow was evaluated according to criteria such as organization's size, environmental considerations, servicing area and income base, number of personnel, existing infrastructures, number of employed personnel, and their technological savviness. The strategy took inspiration from the RTC guidelines developed by the German Water Association (DWA M180) [8]. The paper concludes with a proposed step-by-step strategy for enhancing stormwater management through implementing continuous water quality and quantity monitoring.

3. Results and Discussion

Continuous stormwater quality and quantity monitoring requires significant investment and long-term commitment from stormwater managers. The purpose of such monitoring is to inform decision-making; thus, the entire process, from data collection to interpretation, should be reviewed on a regular basis. Trustworthy and representative data serve as the foundation for planning and carrying out activities, such as stormwater infrastructure maintenance and reconstruction, nature-based solutions (NBS) implementation, hybrid green-gray infrastructure deployment, and augmenting the stormwater systems with controls. An approach for transitioning from static to dynamic stormwater sewer systems was proposed in [9]. However, prior to implementing controls, monitoring is required. Table 1 proposes a self-assessment tool for stormwater managers to determine the need and the capacity for continuous stormwater monitoring. According to the table, stormwater managers should assign points based on their experience and proprietary data to establish the baseline extent of the need for continuous monitoring. Weights are added and adjusted to highlight the importance of specific aspects, such as environmental degradation. These weights can be used on multiple scales to normalize results within sections, prioritize specific items or sections, and account for the differences between groups.

Table 1. Scoring table for the assessment of water quality and quantity continuous monitoring potential of stormwater sewer systems. (A total of 36 points is the maximum; the classification for the implementation of continuous monitoring according to the points is: >24, very suitable for stormwater monitoring; 12–24, probably suitable for stormwater monitoring; and 0–12, probably not suitable for stormwater monitoring. The results are adjusted by weights.)

Catchment Scale Impacts	Description	Points	Weights
Public health and safety issues	Frequency and severity of public health incidents linked to water quality per year.	None—0 Some—1 Multiple—2	0.4
Poor environmental status of the receiving waterbodies	Environmental quality status according to the European Water Framework Directive	High—0 Moderate—1 Bad—2	0.2
Exceedance of regulatory limits	Number of times that the regulatory limits have been exceeded in the past 5 years	None—0 Some—1 Multiple—2	0.2
Areas with increased pollution	Number of identified high-risk areas prone to runoff pollution.	None—0 Some—1 Multiple—2	0.1
Catchment imperviousness	Determined according to land use data (e.g., Estonian Land Board)	Low (<33%)—0 Avg. (33–66%)—1 High (>66%)—2	0.1

Table 1. *Cont.*

Technical considerations	**Description**	**Points**	
Suitable monitoring station locations	Based on a review of technical requirements (placement of sensors, automatic samplers, rain gauges, etc.) and site accessibility and vicinity of pollution hotspots.	None—0 Some—1 Multiple—2	0.16
Integration of GIS into day-to-day workflows	Organizational assessment on the integration of GIS tools into their workflows.	None—0 Some—1 Multiple—2	0.16
Availability of IT infrastructure and hydro-informatics specialists	Organizational assessment on the level of digitalization and IT-related skills in the organization.	None—0 Some—1 Extensive—2	0.16
Experience with automatic samplers and water quality sensors	How much experience does the organization have with automatic samplers and/or water quality sensors?	None—0 Some—1 Extensive—2	0.16
Monitoring system architecture	Does the organization use open-access IoT solutions that allow the adjustment of data collection, storage, handling, and visualization?	None—0 Some—1 Extensive—2	0.16
Pre-existing network of monitoring nodes on the stormwater network	Does the organization have a pre-existing network of rain gauges, water quality sensors, flow meters, or other devices in the stormwater catchment?	None—0 Some—1 Extensive—2	0.16
Financial and HR	**Description**	**Points**	
Efficient service area	Servicing area to number of consumers ratio. The higher the value, the more feasible it is.	Small—0 Medium—1 Large—2	0.14
Maintenance personnel availability	Servicing personnel ratio = (avg. nr. of visits per month x avg. time on site)/total time per month	Avg. (0.25–0.5)—1 Little (0–0.25)—0 Sufficient (0.5–1)—2	0.14
Total CAPEX ratio	What is the relationship between the new investment costs and the total value of existing investments? The lower the value, the more likely that the investment is feasible.	High (10%)—0 Avg. (5–10%)—1 Low (0–5%)—2	0.14
Operation cost ratio	What is the relationship between the new operational costs to the existing operational costs? The lower the value, the more likely it is that the investment is feasible.	High (10%)—0 Avg. (5–10%)—1 Low (0–5%)—2	0.14
Effect of investment on the asset to debt ratio	Investment impacts on the company's asset-to-debt ratio; the lower the ratio, the more sustainable it is. Investment size is site-dependent.	High (10%)—0 Avg. (5–10%)—1 Low (0–5%)—2	0.14
Funding dependencies	How often is the organization dependent on external funding?	Never—0 Sometimes—1 Mostly—2	0.14
Infrastructure age	The higher the average age of the stormwater infrastructure, the more important it is to monitor it.	<20 years—0 20–35 years—1 >35years—2	0.14

4. Conclusions

The introduction of new regulations by the European Urban Wastewater Directive 91/271/EEC is prompting a significant shift in stormwater management in cities across Europe, including Tallinn, Estonia. The city's water utility is estimating the potential of continuous stormwater quality and quantity monitoring. This initiative positions them at the forefront of Estonia's stormwater management practices. However, it also raises concerns about the potential for a widening gap between larger utilities with ample resources and smaller ones, along with municipalities that might struggle to meet these new environmental standards due to limited resources. To address this issue and ensure a unified approach towards compliance, it is essential to conduct an audit of the needs and capabilities of these organizations and to provide a standardized approach that is easy to follow. The suggested strategy represents the first step towards establishing a framework tailored for Estonian stormwater managers and marks the beginning of a transition towards a more data-driven management of stormwater.

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