CEST 2023

18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Development of indicators for performance assessment of blue-green infrastructures

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Abstract The application of blue-green infrastructures in urban areas incorporate various benefits and is thus widely accepted today. However, while aspects of planning and construction are well approved, operation and maintenance are still lacking broad attention. To contribute to the progress in the field, this conference contribution provides a framework for developing related performance indicators and service levels based on an international and well-established European standard focusing on drain and sewer systems. While the standard focuses on grey infrastructure our preliminary results show the adaptability towards more innovative blue-green perspectives. Currently, our work is still on a more theoretic and conceptual level, but an ongoing case study application in a city quarter reconstruction site will show its practicability and support the development of suitable performance indictors and service levels for selected blue-green infrastructures. Finally, building on an existing European standard will make our work easily transferable and adaptable to other European countries and beyond.

Keywords: nature-based solutions; operation and maintenance; stormwater management; EN 752

1. Introduction

Climate change related extreme storm weather events and heat waves pose great challenges on urban areas. To relieve pressure from existing drainage systems and to adapt to urban heat island effects, the application of blue-green infrastructures (BGI) represents an appropriate and approved measure (O´Donnel et al., 2020, Almaaitah et al., 2021). Consequently, the framework for planning and design of a broad variety of BGI is well established today (Langergraber et al., 2021). On the contrary, aspects concerning their operation and maintenance are still less considered. This is highly unsatisfactory, because functional failure of BGI can lead to the same negative effects as malfunction of conventional drainage systems (e. g. urban flooding, groundwater pollution).

Today, already a broad variety of indicators addressing the performance of wastewater systems is documented in literature. Santos et al. (2019) provide a related overview in regard to stormwater networks. However, in a follow-up work the authors (Santos et al. 2022) deplore the lack of a performance assessment framework considering conventional as well as innovative stormwater management. Based on the structural concept of ISO 24511 (2007) and an extensive literature review, they introduce a performance assessment framework including 8 objectives, 25 assessment criteria, and 80 performance indicators as a basis for assessing the proper functioning of a broad variety of stormwater systems. The suggested framework is very informative and provides helpful orientation. However, the authors also report, that consolidation with 2 water utilities revealed, that practitioners tend to focus on rather common aspects as structural, hydraulic, and economic performance of a system. Novel perspectives including biodiversity or amenity aspects still seem less recognized, inter alia, due to the lack of data, financial and/or human resources.

To overcome operators concerns, it appears promising to consider and build on already existing and well-established standards. On the European level, the standard EN 752 (2017) provides the basis and framework for all aspects of sewer system management but has a main focus on conventional drain and sewer systems. However, we believe, that this framework can be expended for additional application for BGI. Consequently, to contribute to the development in the field, this work presents a possible approach on how to adapt current European standard EN 752 (2017) to serve as a framework for performance assessment of both, conventional (grey) and innovative BGI for stormwater management.

2. Methods

2.1. Theory framework

ISO 24511 (2007), which was used by Santos et al. (2022) to develop a performance assessment framework, addresses 4 different process steps: (i) identification of components (of a waste-/stormwater system), (ii) definition of objectives (for wastewater utilities), (iii) definition of assessment criteria, and (iv) performance indicators. In regard to objectives, the standard clearly defines 4 of them (protection of public health, the natural environment, the built environment, and promotion of sustainable development). In regard to assessment criteria and performance indicators ISO 24511 (2007) is less specific by only presenting various examples. In comparison, EN 752 (2017) is very similar from a conceptional point of view. It addresses drain and sewer systems (components) and also defines 4 objectives, namely public and operational health and safety, environmental protection, and sustainable development. Subsequently, it presents 13 performance requirements (e. g. protection from flooding, protection of surface receiving waters and groundwaters, structural integrity, sustainable use of materials). Finally, the standard states, that related performance requirements are to be defined on European Union member state level. Concluding, the comparison of the conceptual approaches for performance assessment reveals, that both standards follow a quite similar structure. However, EN 752 (20017), in contrast to ISO 24511 (2007), also defines specific functional requirements (assessment criteria). Consequently, those functional requirements (as well as their superordinate objectives) provide the basis for our further work.

2.2. Methodological approach

The definition of performance indicators for blue-green systems follows a 4-step approach:

First, the relevant BGI are identified focusing, primarily, on their function to prevent stormwater run-off to reach existing sewer systems. 6 main processes provided by one or more BGI are identified, namely infiltration, detention, retention, conveyance, treatment and evapotranspiration (Oral et al., 2021). Basic (technical) components necessary for the proper functioning of these main processes were assigned (e. g. inflow pipe, infiltration matrix). In addition, related follow-up processes (failures) were derived (e. g. blockage of the inflow pipe, clogging of infiltration matrix). This information is later used for the assignment of functional requirements relevant to each of the defined 6 main processes.

Second, the objectives and their existing specifications presented in EN 752 (2017) will be revised in regard to BGI and their related additional benefits (e. g. urban heat island mitigation, biodiversity). This work also aims at addressing possible additional functional requirements not covered in the current version of the European standard.

Third, each of the 6 main processes (incl. the related technical components and follow-up processes) will be compared to the 13 pre-defined functional requirements. This determines those functional requirements relevant for the performance assessment of each of the main processes. In addition, this comparison will directly reveal missing functional requirements. In this context, a differentiation between technical-functional and organizational-economic performance requirements can help to structure the different assessments and their informative value for wastewater operators.

Fourth, performance indicators and related service-levels (thresholds) must be defined. The focus of this works moves from the previous meta-plane of 6 main processes back to a BGI specific level. In this regard, the local context (available national standards and literature) is of crucial importance (compare EN 752 (2017) delegating the definition of performance indicators to member state level).

3. Intermediate Results

3.1. Selected BGI, basic components and processes

The main considered BGI are listed in Table 1. The selection is based on the list for rainwater management units provided by Langergraber et al. (2021).

To ensure a proper functioning of the 6 main processes, each of them requires various (technical) components. These again are prone to specific follow-up processes (failures), which can be of structural, environmental, operational and/or hydraulic concern (based to the integrated management concept presented in EN 752, 2017). Table 2 displays these relationships for the example of the process “infiltration” (the other 5 main process must be neglected in this conference contribution due to space limitations).

3.2. Objectives

As already mentioned before, EN 752 (2017) defines 4 objectives for drain and sewer systems. “Public health and safety” refer to community hygiene, protection of drinking water sources and prevention of urban flooding. “Occupational health and safety” addresses risks related to installation, operation, maintenance, and rehabilitation activities. “Environmental protection” is about minimising the impact of drains and sewers on the environment. This refers to receiving waters as well as to other environmental requirements. Finally, “sustainable development” primarily concerns material and energy usage.

Concluding the above, it is evident, that EN 752 (2017) is still not very explicit in regard to possible benefits incorporated with the application of BGI. However, the current definition of objectives is held in a rather general manner and can thus be easily expended by new concerns (e. g. urban heat island mitigation serves “public health” or biodiversity issues are clearly related to “environmental protection”). Consequently, a combined consideration of conventional and innovative stormwater systems certainly could be covered be the framework of the European standard.

3.3. Functional requirements

The presented definition of components and follow-up processes provide the basis for the related assignment of functional requirements. Table 3 shows the comparison of theses aspects, again, for the example of the process “infiltration”.

It is obvious, that all components must be maintainable and not endangering other structures at any time. In this context, structural integrity is also a major concern. Protection of receiving waters is limited to the emergency spill, if not anyway connected to the sewer system. Protection of groundwater refers to the infiltration layer only, as all other components have to be constructed and

Table 1. Selected BGI, main processes and their relationship (own presentation)

Selected BGI	Infiltration	Detention	Retention	Conveyance	Treatment	Evapotranspiration
Infiltration basin	+++	++	+		+	++
Infiltration trench	+++			+		
Filter strips	+			+++	+	
Green roof		+++				++
(wet) Retention pond			+++		+	+++
(dry) Detention pond		+++				
Bioretention cell	+	+++				+++
Bioswale				+++		
Dry swale				+++		
Tree pits	+++			+		+++
Vegetated grid pavement	+++					+

Relationship: +++ high, + low

Table 2. Overview on main processes, basic components and related follow-up processes on the example of "infiltration" (own presentation)

Main process	Basic components	Follow-up processes
Infiltration	Inflow (pipe)	Structural damage, leaking, sedimentation, blockage, hydraulic overload
	Pre-treatment (sedimentation tank)	Structural damage, leaking, sediment accumulation, sediment digestion, hydraulic overload
	Infiltration layer (substrate)	Structural damage (compression of substrate), surface sedimentation, clogging, hydraulic overload
	Emergency spill (pipe)	Structural damage, leaking, blockage, hydraulic overload
	Maintenance manhole	Structural damage, leaking, step iron corrosion

Table 3. Assignment of EN 752 (2017) functional requirements and basic components on the example of "infiltration" (own presentation)

Functional requirement	Infiltration				
	Inflow	Pre-treatment	Infiltration layer	Emergency spill	Maintenance manhole
Protection from flooding	x	x	x	x	
Maintainability	x	x	x	x	x
Protection of surface receiving waters				x	
Protection of groundwater			x		
Prevention of odors and toxic, explosive and corrosive gases	x	x			
Prevention of noise and vibration					
Sustainable use of products and materials			x		
Sustainable use of energy		x			
Structural integrity and design life	x	x	x	x	x
Maintaining the flow	x	x	x	x	
Watertightness	x	x		x	x
Not endangering adjacent structures and utility services	x	x	x	x	x
Inputs quality	x		x		

maintained in a watertight way. In this regard, the input water quality is an issue for the infiltration layer as well as for the inflow as the entering point to the entire system. Maintaining the water flow is strongly connected to protection of flooding and relevant for all components in contact with water. Prevention of odors and gases concern the inflow (e. g. fuel entering the system after a car accident) and the pre-treatment (digestion of sediments). Sustainable use of material might be an issue for the infiltration matrix (material reuse), those of energy for (automated) pre-treatment. Noise and vibration, in our point of view, play no relevant role in the context of BGI.

Possible side-benefits of BGI cannot be addressed with the existing set of 13 functional requirements. However, the suggested methodological approach can easily be used to expand Table 3 accordingly (e. g. urban heat island adaption, biodiversity improvement). Although, this might be only of minor relevance for the presented example of "infiltration".

3.4. Performance requirements and service levels

For the final step, the previous assignment of functional requirements to the 6 main processes (infiltration, detention, retention, conveyance, treatment, evapotranspiration) provides orientation to define specific performance indicators and related service levels (thresholds) on BGI specific level (compare Table 1), primarily considering requirements from local/national standards, guidelines, and literature. This step, however, is still project work in progress and thus not included in this conference contribution.

3.5. Performance assessment

In the following, the presented approach will provide an appropriate framework for the performance assessment of BGI. Investigations can involve common (integrated) approaches as structural, environmental, operational, and hydraulic investigations but might also include new topics as for instance urban microclimate or biodiversity.

4. Conclusions and outlook

BGI are considered to play an important role in future urban water management as they represent core assets of climate change adaptation in the built environment. While planning and construction of related systems is common practice today, their operation and maintenance have not received sufficient attention yet. This conference contribution suggests a framework for developing related performance indicators to support targeted operation and maintenance of BGI guaranteeing their proper and continuous functioning. Our approach is based on the existing and well-established international standard EN 752 (2017). This makes our findings easily transferable and adaptable to other regions of Europe and beyond. At the moment, our work is still on a more theoretic and conceptual level. However, in a next step, the approach will be applied on a case study site in Austria, where an entire city quarter is being rebuilt also for improving environmental quality. Selected BGI are part of the realization concept. They will serve to practical application of our suggested approach for proving its practicability and deriving appropriate sets of performance indicators and service levels (thresholds), considering the entire life-span of the concerned assets.

Acknowledgement

The presented work has been carried out in the Austrian national research project "ViCorp - Villach - integrated and cooperative measures for stormwater management at local (demonstration) sites" supported by the Austrian Research Promotion Agency (grant no. FO999894919) and the City of Villach.

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