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Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

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Quantifier la durabilité environnementale des systèmes de gestion des eaux pluviales

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RÉSUMÉ

Comparées aux réseaux traditionnels, les techniques alternatives sont généralement considérées comme bénéfiques pour l'environnement. Ce projet présente le test de cette hypothèse via 1) le développement d'une méthode d'analyse du cycle de vie afin de quantifier l'impact environnemental des différents types de système de manière holistique et systématique, 2) l'application de cette méthode dans le cadre d'un cas d'étude où plusieurs systèmes ont pu être comparés pour un même bassin versant. Il a été démontré que chaque type de système peut présenter un risque d'impact environnemental négatif lié aux différents aspects de leur construction, mise en œuvre puis dépose, ainsi qu'aux rejets d'eaux pluviales polluées. Les résultats ont également souligné le nécessaire compromis entre réduction des dommages sur l'écosystème au travers de traitements avancés et réduction de l'impact sur les ressources disponibles via l'utilisation de solutions techniques simples et « vertes ». La méthode d'évaluation développée pour ce projet a servi de base pour la création d'un outil simplifié permettant d'insérer l'analyse de la durabilité environnementale dans la planification des systèmes de gestion des eaux pluviales.

ABSTRACT

Green infrastructure is often assumed to be environmentally beneficial compared to traditional subsurface systems. We tested this assumption by 1) developing a life cycle assessment based method to systematically and holistically quantify the environmental damage and benefit of stormwater management systems, 2) applying it to a case study where we compared two subsurface, and two green infrastructure based systems for the same urban catchment. We showed that both processes associated with the implementation, operation and decommissioning of infrastructure, and discharges of polluted stormwater cause significant environmental damage. The results of the case study highlighted a trade-off between reduced ecosystem damage through advanced treatment, and less damage to resource availability through low-tech, green solutions. The method provided the basis for a simplified tool which allows including environmental sustainability assessment into the planning of stormwater management systems.

KEYWORDS

ecosystems, environmental damage, life cycle assessment, stormwater pollutants, resource availability

1 INTRODUCTION

Green infrastructure is increasingly used as an alternative to underground stormwater systems. It is often economically preferable, while at the same time providing additional functions such as adding recreational and aesthetic benefits (Qiao et al., 2018). It is often assumed that it is also environmentally preferable, but this is rarely substantiated or quantified. We developed a life cycle assessment (LCA) based method to systematically quantify the environmental sustainability of stormwater management systems.

LCA is an internationally standardized method to assess the environmental impacts of products, systems or services across their whole life cycle (ISO, 2006). It's application in urban water systems has seen a sharp increase in the last years, with a focus mainly on wastewater treatment and drinking water supply (Loubet et al., 2014). Studies assessing stormwater management systems are often limited to impacts caused by the implementation, operation and decommissioning of the infrastructure (Brudler et al., 2016). Emissions of polluted stormwater and resulting ecotoxicity and eutrophication impacts are rarely assessed in existing studies. We included both infrastructure processes and point source emission in our method, and tested it using an urban Danish catchment as a case study.

2 METHODS

2.1 Life cycle assessment based method

Using existing and planned stormwater management systems, we developed a generic inventory of required processes throughout the life cycle of a number of infrastructure elements such as pipes, basins, trenches and soakaways. We then quantified the inputs and emissions from these processes using the ecoinvent database (Weidema et al., 2013). Additionally, we identified pollutants contributing significantly to environmental impacts from stormwater discharges and calculated mean concentrations to assess long-term point source emissions (Brudler et al., 2019b). Using characterisation factors from Recipe 2016 (Huijbregts et al., 2016) and USEtox (Rosenbaum et al., 2011), these inputs and emissions were then translated into annual environmental damage to two areas of protection (ecosystems and resource availability) (Figure 1).

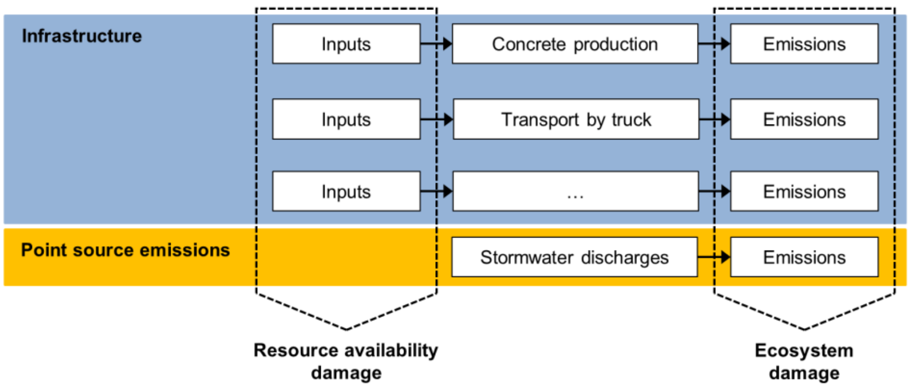

Figure 1. Sources of resource availability and ecosystem damage from infrastructure processes and point source emissions associated with stormwater management systems

2.2 Case study

We used the developed method to assess four different stormwater management systems for a low-density urban catchment in Odense, Denmark of 260ha. All systems were developed to comply with Danish flood safety and pollution management standards (IDA Spildevandskomiteen, 2005), and are based on full hydrodynamic modelling (MIKE URBAN, DHI) or simplified modelling (WEST, DHI). Two systems were designed as underground systems (S1: combined with underground basin and central wastewater treatment, S2: separate with surface basin), and two use only green infrastructure (S3: soakaways, S4: swales). Stormwater is treated through a number of processes in the different systems, e.g. sedimentation and absorption, before discharge to freshwater (Brudler et al., 2019a).

To assess the uncertainty associated with the calculated damage, we varied different parameters characterising the infrastructure processes (e.g. alternative disposal scenarios) and the point source emissions (e.g. removal efficiencies of different elements).

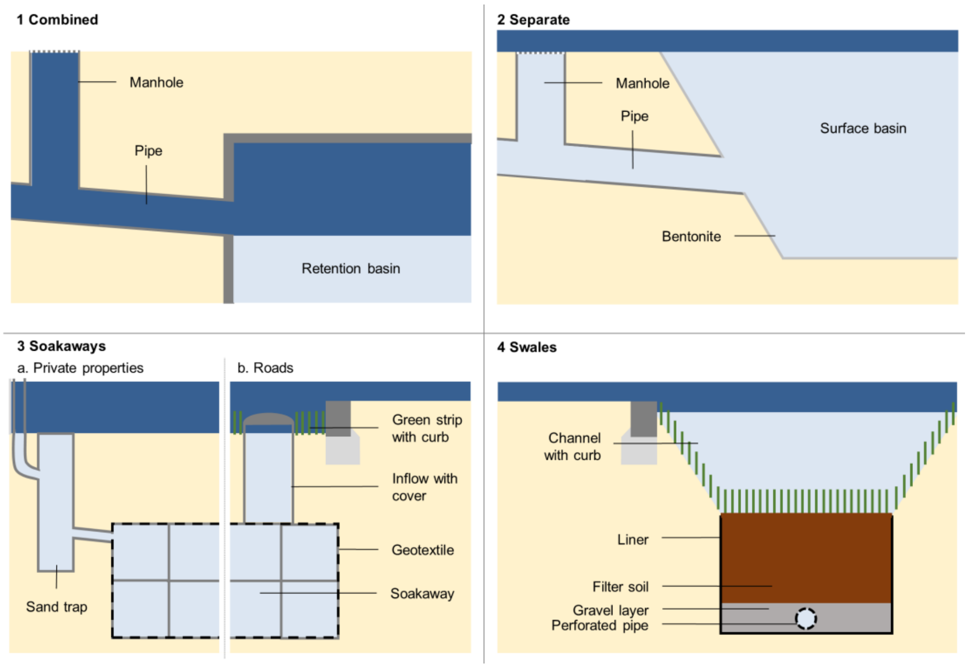

Figure 3. Schematic sketches of the elements in the four different stormwater management systems. The water level during an event with a return period of 5 (10) years is illustrated in light (dark) blue. The water level rises above surface level for events with a return period of 10 years in the systems 2-4 (Brudler et al., 2019a)

3 RESULTS AND DISCUSSION

The subsurface systems cause damage to resource availability between 4.1E+03 (S2) and 8.8E+03 USD/yr (S1), while the green infrastructure systems save costs (S3: -3.7E+03, S4: -5.2E+03 USD/yr) (Figure 2). Negative damage stems from transforming existing roads to green areas, i.e. avoiding road renewal and associated material production and construction processes, and recycling of plastic at the end of life. Ecosystem damage ranges between 1.0E-03 (S3) and 1.4E-03 species.yr/yr (S1) (Figure 2). They are by up to 88% caused by point source emissions. The relative contribution of point source emissions is smaller in the combined system (38%), leading to overall lower ecosystem damage than in the separate systems.

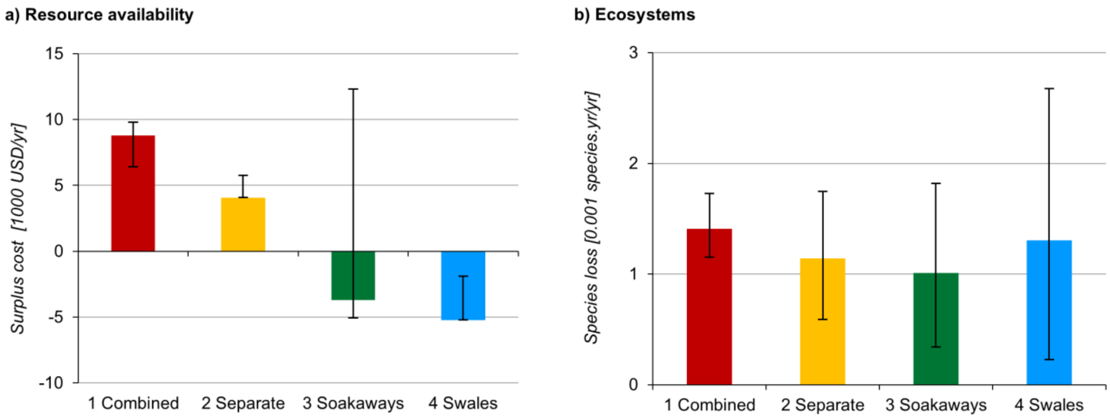

Figure 2. Damage to a) resource availability, b) ecosystems, caused by four different systems managing stormwater according to Danish flood safety and pollution management standards in a catchment area of 260ha. Negative values indicate prevented damages. Error bars illustrate the damages for a worst and best case for each system, varying both infrastructure processes and point source emissions (Brudler et al., 2019a)

Damage to resource availability mainly stems from material production and disposal processes. Incineration instead of recycling of plastic, the size of green areas and the associated avoided road materials, and the lifetime of elements determining the renewal intervals consequently are the main sources of uncertainty. Ecosystem damage is mainly caused by point source emissions, which is determined by the removal of pollutants in the different elements. A wide range of efficiencies is reported in literature and using minimum or maximum removal efficiencies instead of median values affects resulting damage significantly. Both uncertainties associated with resource availability and ecosystem damage potentially change the conclusion regarding the most and least sustainable system, which highlights the need for further research especially regarding the characteristics of green infrastructure systems. At the same time, this also implies an opportunity to optimize the environmental sustainability of said systems, e.g. through design targeted at maximizing pollutant removal and regular maintenance to prolong the lifetime.

These results highlight a trade-off between advanced treatment, leading to low ecosystem damage, and low-tech, green solutions with limited resource consumption. While this dependency in itself is not novel, our method for the first time allows quantifying this trade-off holistically. It allows decision-makers to quantify the environmental costs and benefits of stormwater management systems, and to systematically incorporate these into the decision-making process.

4 CONCLUSIONS

The main conclusions of our study are:

- To assess the sustainability of stormwater management systems, both processes associated with the implementation, operation and decommissioning of the infrastructure and point source emissions from stormwater discharges have to be included.
- Subsurface systems cause higher resource availability damage and ecosystem damage. Green infrastructure based systems can prevent damage to resource availability, but remove less pollutants from stormwater before discharge to the environment.
- A systematic and holistic quantification of this damage can provide valuable information in the planning process of stormwater management systems and consequently allows to.
- Uncertainties associated with the life time and removal efficiency of green infrastructure are high. While affecting the results significantly, this also highlights the potential for optimizing the environmental sustainability through targeted design and maintenance.

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