Implementing source-separating wastewater systems when the existing sewer network lacks capacity – Considerations and consequences

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Highlights:

- **Source-separating wastewater systems with local greywater management are an alternative for new urban developments where existing network lacks capacity.**
- **Vacuum systems are the most viable option, but struvite precipitation issues need to be addressed by appropriate management.**
- **The formation of H_2S in low-pressure sewer systems is potentially higher for blackwater compared to conventional wastewater.**

Keywords: blackwater; greywater; LCA

INTRODUCTION

Source-separating wastewater systems (SSWS) are a promising alternative for new urban developments as they have multiple benefits. Blackwater systems have been shown to achieve a 70% increase in biogas production, along with approximately 20 times greater phosphorus and nitrogen recovery potential compared to conventional wastewater treatment systems (CWTS) (Kjerstadius et al., 2015). Given that greywater represents up to 75% of the wastewater volume generated by households (Oteng-Peprah et al., 2018), separate collection and local treatment of greywater is a potential option in those areas where there is limited possibility of using and/or replacing the existing sewer network. SSWS offer the possibility of avoiding expansions of sewer networks that new urban developments might require. This would not only be reflected in reducing investment costs but also carbon dioxide (CO_2) emissions, as the expansions of existing sewers implies the use of mostly gasoline-powered vehicles for the excavation and filling processes. Although the environmental benefits of SSWS have been highlighted, their potential as an alternative to replacing sewer networks has not yet been discussed.

The objective of this study is to develop a conceptual framework for the implementation of SSWS by analyzing different configurations and identifying the considerations and consequences for their implementation. For the evaluation, three main categories were considered comprising a total of eight topics shown in Figure 1. In addition, this study aims to propose viable alternatives of SSWS considering that the existing sewer network cannot receive discharges from new households.

METHODOLOGY

This study is a conceptual research including literature review, interviews and a critical analysis. In this study concepts, previous studies and practical experience are used to analyze and find a correlation between facts and consequences. The content of the literature review is presented in Figure 1. The results will provide a comprehensive understanding of the challenges and consequences involved in implementing SSWS based on the premise that the existing sewer network cannot receive any additional discharges.

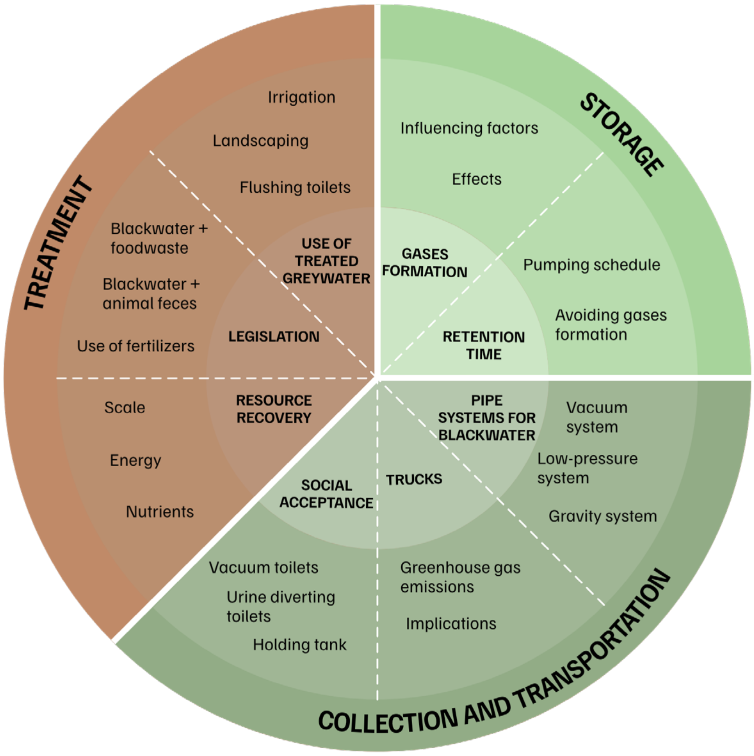

Figure 1. Structure of this conceptual study presenting the topics addressed.

RESULTS AND CONCLUSIONS

SSWS imply, at least, two main networks: black and greywater sewers. Blackwater systems are applied to reduce the sewage flow and/or generate a concentrated stream for resource recovery which makes vacuum pipe systems the most viable option to evaluate (Kjerstadius et al., 2015). But also, low-pressure sewers (LPS) have been suggested for blackwater transport. In the case of small and rural areas, trucks as blackwater transport system is one of the most viable options (Jönsson et al., 2013). In addition, considering the lack of hydraulic capacity of the sewage system, retaining blackwater for a period and then discharging it into the existing sewer network could be one of the options.

As vacuum toilets use around 1 liter of water per toilet flush, the solids concentration in vacuum blackwater systems is higher than in gravity systems. Further, there is a risk of precipitation of struvite in vacuum pipes reducing their internal pipe diameter and removing nitrogen and phosphorous from blackwater before it reaches the recovery facility. Precipitations are promoted by leaks that allow air to enter the system increasing the air-water ratio (Rohde, 2016). In addition, if the temperature gradient between the blackwater and the environment is, there is a risk of precipitation (Rohde, 2016). In a full-scale blackwater system in Sweden, struvite precipitation was observed in vacuum pipes inside buildings, where the temperature is higher than outside (H. Kjerstadius, 2024, personal communication).

LPS systems have been widely implemented in Sweden in recent years and can potentially be used for transport of blackwater. However, some challenges presented in the operation phase may increase if implemented for blackwater transportation due to a higher concentration of biodegradable material compared to conventional wastewater. Odor and corrosion on concrete pipes due to H_2S have been reported in wastewater systems, especially those with long residence times (Wärnö, 2004). They can be reduced by the use of smaller pipe diameters which in turn would limit the expandability of the system. LPS systems can be installed shallowly which saves on construction costs but could lead to warmer wastewater in the summer. A temperature rise from 10 to 20°C increases the H_2S production rate by 35% in pressure mains (Nielsen et al., 1998).

The amount of CO_2 equivalent emissions due to truck transportation is significant in sparsely populated areas with long distances. Excluding the contribution to environmental impacts of sanitation equipment and sewer network, transporting dried feces to a composting plant located 20 km away has the same impacts on climate change and resources as CWTS (Benetto et al. 2009). However, in scenarios with urine separation due to smaller volume to be transported and the reuse of urine as fertilizer, the impact on energy demand and global warming potential could be reduced (Remy, 2010).

In the presence of high concentrations of organic compounds, as in blackwater systems, sulfate (SO_4^{2-}) reduction occurs in anaerobic areas of sewer biofilm. Therefore, hydraulic retention time (HRT) in pressure systems (including rising mains and wet wells) should be limited to restrain anaerobic conditions. However, recommendations vary by country. A period between two and eight hours is the one suggested by European Committee for Standardization (2018) and U.S. Environmental Protection Agency (1985) recommends for wet wells a maximum retention time of 30 minutes.

Our preliminary findings indicate challenges associated with blackwater conveyance systems that need to be addressed in both design phase and practical implementations. The results will serve as inputs to formulate alternatives for the implementation of SSWS to be further evaluated by life cycle and life cost analyses.

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