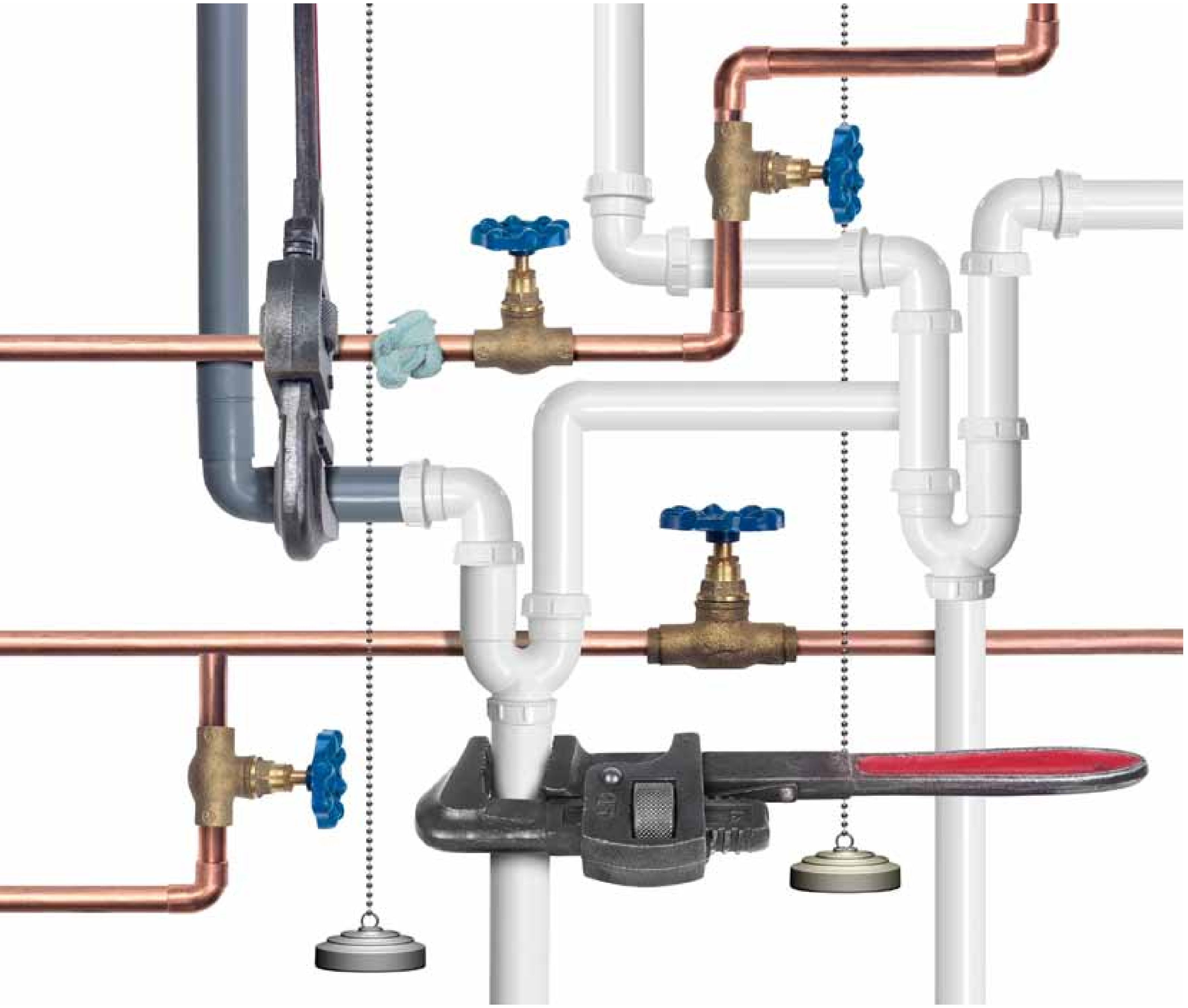
Urban Water Security: LCA and Sanitary Waste Management

Hazem Gouda describes a case study that aimed to reduce sanitary waste disposal via WCs and used life cycle assessment to assess the various reduction strategy options.



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A water-secure world is one where everyone has access to safe, affordable water, protected from floods, droughts and water-borne diseases. Urban water security means that urban water systems should not have negative environmental effects, even over a long time perspective, while providing required services, protecting human health and the environment, and minimising the use of scarce resources.

FLUSHING OF SANITARY WASTE PRODUCTS

The flushing of sanitary waste (SW) items via water closets (WCs) has undermined urban water security in a number of developed countries. The presence of WCs and fully sewered systems has eased the disposal of a range of items, with the WC being used as a 'rubbish bin'. Sanitary waste items disposed of via the WC comprise female sanitary items including sanitary towels, panty liners, tampons and applicators, and general bathroom refuse such as cotton buds, baby wipes and condoms.

An investigation of people's opinion about the disposal of SW items has shown that the practice of flushing is due to convenience and perceived hygiene. In the UK it is estimated that about 700,000 panty liners, 2.5 million tampons and 1.4 million sanitary towels are flushed via the WC every day. The total contribution of SW to total sewer solids load varies and depends on water supply, cultural habits, way of life and level of development.

SW causes technical problems for the sewer network (e.g. deposition and blockage) and aesthetic problems when the waste finds its way through the combined sewer overflows (CSOs) in combined sewer systems. The CSOs normally operate when the sewer system is running under full capacity during heavy rainfall storms; then the wastewater will be released to the aquatic environment. In the UK about 70 per cent by total length of sewerage systems are combined, and these systems typically have CSOs.

CASE STUDY: LIFE CYCLE ASSESSMENT AND SW MANAGEMENT

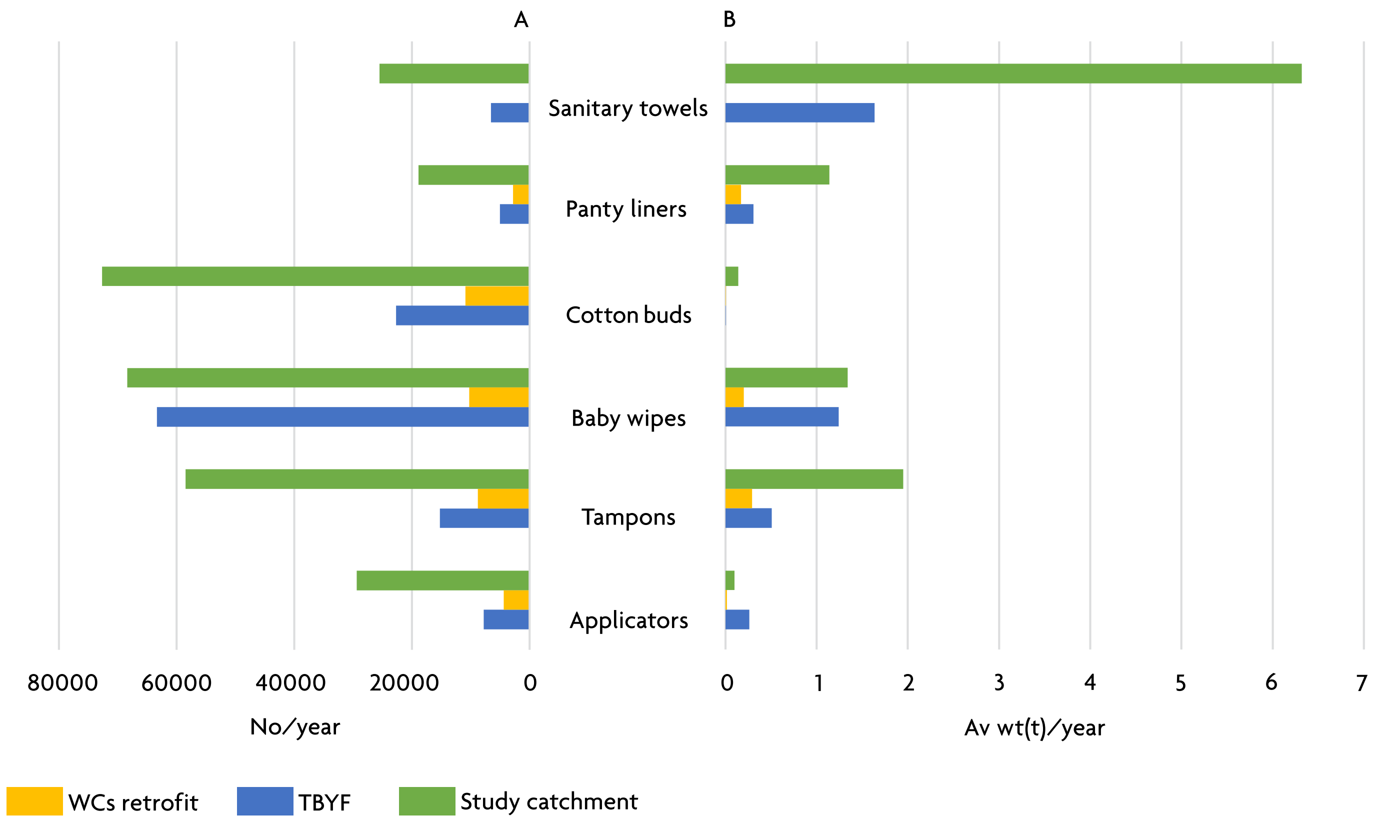
The case study presented in this article addresses SW management and actively presents solutions that address the challenges to urban water security. The case study has been carried out under the SWARD (Sustainable Water industry Asset Resource Decision) project funded by the UK Government and the UK water industry. The case study demonstrates a wide variety of efficient and effective strategies for reducing SW disposal via WCs.

The study has estimated the amount of SW that enters the sewer systems for a catchment in Scotland. A detailed hydraulic model was used to simulate the flow in the sewer system and estimate the annual amount of SW escape to the aquatic environment from CSOs and sewer overflows (SOs) during heavy rainfall storms.

The data from the hydraulic model are needed for the life cycle assessment (LCA) component of the study. LCA is a technique that can be employed to determine energy, mass flows and environmental burdens for a number of sewer-related options for handling SW. LCA can help to direct decision-makers

▼ **Table 1. Options for the management of sanitary solids**

Option	Measure	Primary objective
1	Install 6 mm screens on storm overflow at WTP	To screen storm overflows to constrain solids larger than 6 mm or equivalent to comply with minimum aesthetic pollution requirements for discharges
2	'Think before you flush' campaigns	To encourage a change in domestic disposal habits to dispose of sanitary solids via the bin rather than the WC
3	Install flow storage	To reduce the frequency and volume of overflow spills, thus reducing the number of SW items discharged to the environment
4	Retrofit stormwater source control	To reduce stormwater entry to the sewer system, thus reducing the frequency and volume of overflow spills
5	Sewer rehabilitation	To limit infiltration to the sewer system, thus reducing overflow spill frequency and volume
6	Retrofit outlet chokes on existing WCs and introduce these to new building developments	To force a change in disposal habits from using the WC to using the bin through the increased possibility of WC blockage in the home



▲ **Figure 1. Fushing profiles for study catchment, think before you flush (TBYF) campaign and retrofit campaign showing (A) Number flushed/year (B) Average weight (t)/year of sanitary waste.**

towards the more sustainable/preferred investment solution, and the transparency of the process can help demonstrate to stakeholders that decisions made are as environmentally sound as possible. LCA is one of the tools commonly in use for products and services to assess the environmental impacts on *environmental* systems and/or compare energy use, pollutant emissions and impacts between proposed alternatives.

CATCHMENT DESCRIPTION AND MANAGEMENT OPTIONS

The case study presented here was conducted as part of a EPSRC-funded project that developed a decision support system to assist water service providers to include sustainability in their asset management planning processes. Six proposed options used in the case study for the management of SW are presented in **Table 1**.

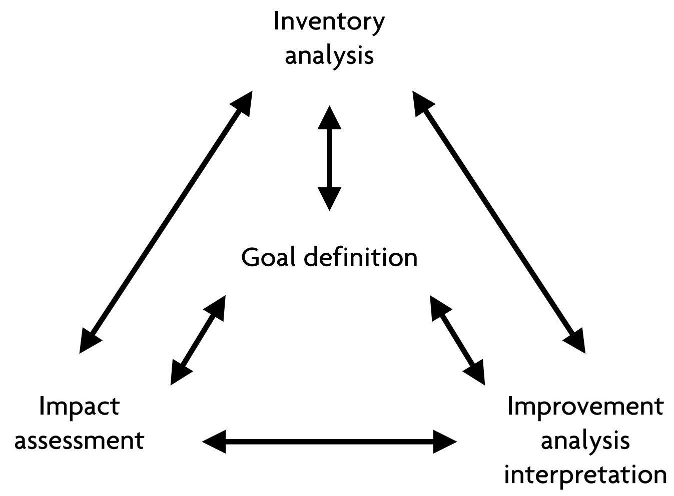
The catchment is located on the coast of Scotland and has 626 domestic properties with a population of about 1,500. The 'system' is formed by the sewerage system from the household WC to the wastewater treatment plant (WTP) and its outfalls. The catchment isserved by 80 per cent combined sewers and 20 per cent surface water sewers. The network has an internal CSO, a storm outfall at the treatment plant and an emergency outfall.

SW ENTERING THE SEWER SYSTEM

The amount of SW that enters the sewer system was estimated based on population, number of women and their age, and number of babies in the town. Data regarding the average number of items used per person per day were available from the surveys conducted prior to the 'think before you flush' (TBYF) campaign.

▼ **Table 2. Population data**

	Women aged 18—59	Women aged 12—17	Children 0—4	Total population
Total No.	426	35	69	1516



▲ **Figure 2. Interactions between LCA stages.**

The population data presented in **Table 2** were obtained from the census that represents the catchment at the time of the study. The profile of the SW entering the system for the study catchment is shown in **Figure 1**.

THINK BEFORE YOU FLUSH CAMPAIGN

The TBYF campaign was run in the catchment along with collection of social survey data. The survey data from running the campaign (option 2) shows a reduction of 65–70 per cent in the total amount of SW entering the system. The SW input data from the TBYF campaign, shown in **Figure 1**, has been used for this option or when it is combined with any other option.

RETROFITTING TO CONSTRICT WC OUTLETS

For the retrofit option (6) it is assumed that, although sanitary towels will not be flushed, 15 per cent of certain other SW items will still be flushed, resulting in 681.435 kg of SW entering the system per year, as shown in **Figure 1**.

The SW profile data for each option was used along with the detailed hydraulic model to estimate the total weight of SW escape from the sewer system to the aquatic environment via CSO/SO.

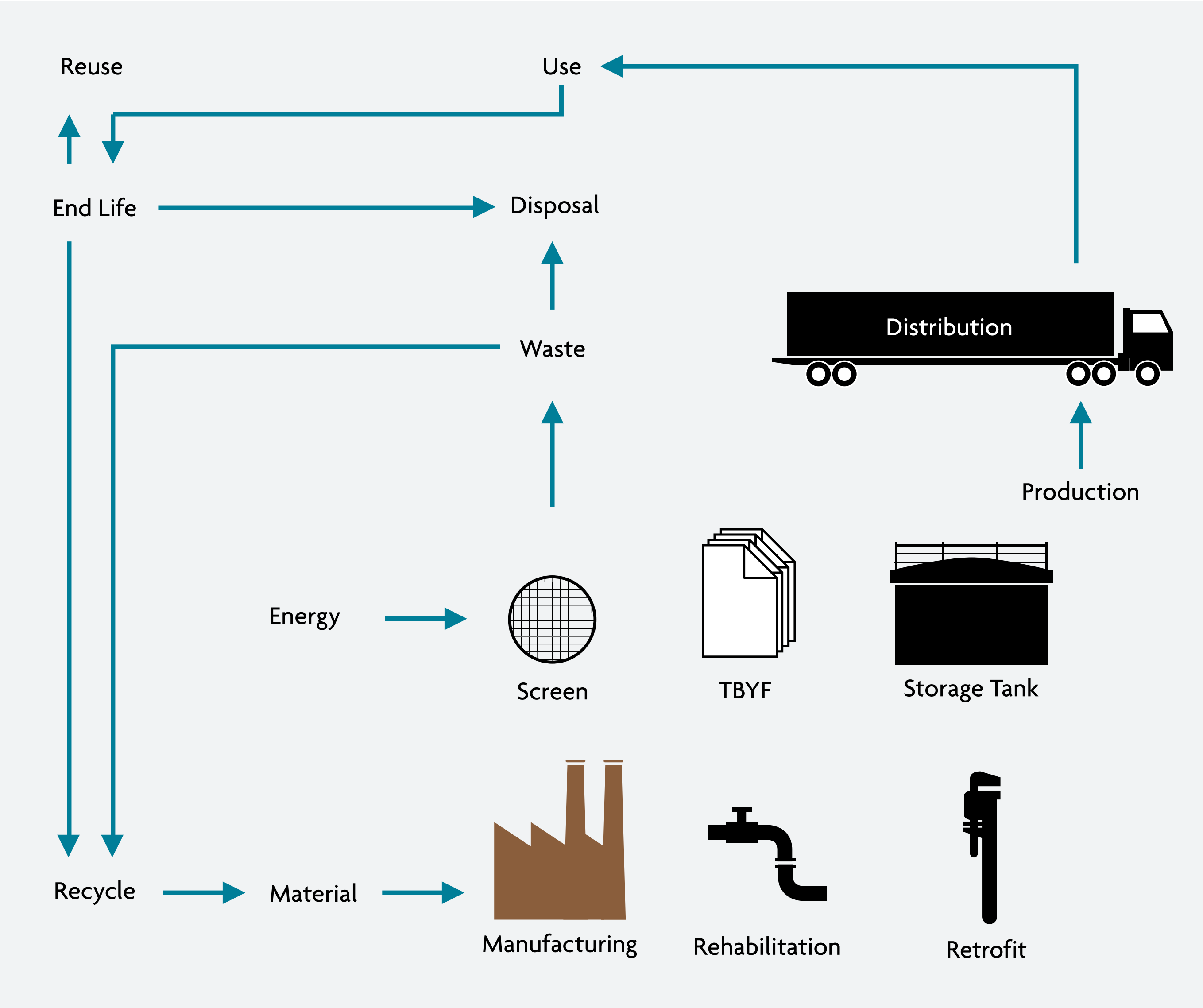
LIFE CYCLE ASSESSMENT

LCA is a technique involving cradle-to-grave analyses of production systems or services and provides comprehensive evaluations of all upstream and downstream energy inputs and multimedia environmental emissions. The International Organization for Standardization outlined the methodological framework for conducting LCA in four phases: goal and scope definition, inventory analysis, impact assessment, and improvement analysis and interpretation. The interactions of the four main LCA phases are represented diagrammatically in **Figure 2**. The study has been carried out in order to evaluate the environmental consequences of six different alternatives for SW management for a particular catchment. The goal of the study was to evaluate the resource consumption, pollutant emissions and the consequential environmental impacts of alternative SW management options and scenarios during their operation period, in a European context. The boundaries that are set for the options must be identical if a comparison is to be considered. In this study the materials, energy, natural resources, transportation, use and disposal were analysed.

Table 3 gives an overview of the material used for the SW management options. Data from specific manufacturers of the products implemented for each option and data from the SimaPro database were utilised where data for the specific process were not available. Waste streams are generated at each phase of the life cycle and waste management, including the mechanisms for treating, handling and transport of waste prior to release into the environment. Sensitivity analysis was carried out for the waste scenario for the different options. The main life cycle stages include three phases and their related boundaries are shown in **Figure 3**.

LCA RESULTS

The environmental indicators selected for this case study included carbon dioxide (CO_2), sulphate (SO_4), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) emissions and energy use. The results are presented in this section according to the functional unit, which is emissions per kilogram of gross solids reduction



▲ **Figure 3. The elements of life cycle inventory analysis for proposed options.**

▼ **Table 3. The material components used for each of the options.**

Option	Component
1. Screen	6 mm rotary drum screen at storm outfall made of stainless steel.
2. TBYF	Paper leaflets, questionnaire and posters.
3. Storage tank	Concrete tank to store 1100m3 of water.
4. Rainwater barrel	Plastic barrels: total of 219 barrels made of polythylene.
5. Rehabilitation	Replace 300 mm, 450 mm and 600 mm concrete pipes. Total pipe length 87m.
6. Constricting toilets (WC)	Replacing toilet outlet connection with smaller plastic pipes (75 mm dia.) and cistern-flushing valve to 3 L/flush.

▼ **Table 4. Emissions values per kg gross solids reduction for proposed options**

	Option	SW Escape reduction	Greenhouse gas kg CO_2 equ.	Acidification kg SO_4 + equ.	NO_x kg	SO_2 kg	Energy MJ
1	Screen	95%	8	0.2067	0.0092	0.1764	127.07
2	TBYF	66%	0.56	0.0026	0	0	11.79
3	Storage tank	51%	136	1.7188	1.7097	0.3155	1282.27
4	Rainwater barrel 35% roof surface control)	17%	16	0.0972	0.0080	0.0136	471.32
5	Rehabilitation (infiltration reduction 42%)	35%	4	0.0200	0.0106	0.00098	53.10
6	Retrofit	94%	2.3	0.0296	0.0153	0.00322	73.16

for the proposed options. **Table 7** illustrates the SW results from the hydraulic model for each option and the relevant environmental emissions per kilogram of SW prevented from escaping to the environment during its life cycle.

The results show that the storage tank has the highest environmental emissions and energy use among all studied options per kilogram of SW prevented from escaping to the environment. The TBYF option gives the lowest energy use and environmental effect as it has the lowest score among all studied options, followed by rehabilitation and retrofit constricting of WC respectively.

CONCLUSION

LCA has been used to suggest improvements to the way in which SW is managed in urban drainage systems and addresses the challenges to our urban water security. The results from the SW case study have indicated that the option of changing user habit can significantly reduce the items flushed down WCs and hence reduce the total amount of SW entering the system.

The LCA results show that the TBYF campaign option, which is related to habit change, has the lowest environmental impact per kilogram of SW prevented from entering the sewerage system. However, one of the critical aspects is the lifecycle of the sanitary product itself. It should be possible to design products which have a strong likelihood of being disposed of via a WC in such a way that they degrade appropriately and can be appropriately dealt with by the sewage undertaker.

This involves the designers of sanitary products liaising closely with sewage undertakers in the design and procurement phase of their products. Hence, the way forward towards a secure urban water system is to manage SW in a sustainable way by encouraging behavioural change to stop the flushing of such items and design degradable products. ES

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