Comparative LCSA (Life Cycle Sustainability Assessment) of Decentralization of Wastewater Treatment for Non-Potable Urban Reuse

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Abstract

A sustainability assessment comparing the existing approach to urban wastewater management (i.e. centralized treatment, effluent discharge to stream), with three alternative applications of treatment and non-potable urban water reuse was carried out, using LCA, LCC and S-LCA. Results of the three assessments were aggregated using AHP, a multi criteria decision analysis tool. Results demonstrate that under the conditions tested, distributed urban domestic treatment and reuse is more sustainable than the common centralized approach.

Introduction

Many agree that in face of a continually growing urban population and increasing water scarcity, a shift towards decentralization and source separation of domestic wastewater (WW) should be considered. Interest in decentralized systems is also driven by their financial efficiency, short installation timeframes, issues of water security, environmental degradation and local community empowerment (Wilderer 2004, Makropoulos and Butler 2010, Domènech 2011, Larsen and Gujer 2013, Ng et al. 2014, Lam et al. 2015). Source separation enhances resource recovery from wastewater and is also necessary for reducing the complexity of the treatment processes, thus making available treatment technologies which are simple enough to maintain locally. Furthermore, the shorter life cycle of decentralized source separated solutions, means that new technological developments may be implemented more rapidly.

In this study we refer to a hypothetical (futuristic) Israeli city in which domestic WW is separated into two streams: light greywater (LGW or GW), collected from bath, shower, wash-basin and washing machine, which is treated locally, and black water (BW), collected from kitchen and toilets. GW is characterized by a relatively low organic load and may be treated to a quality level acceptable for non-potable reuse by extensive biological treatment systems (Eriksson et al. 2002, Friedler et al. 2005, Yu et al. 2013).

Methods

A Life Cycle Sustainability Assessment (LCSA) was performed to compare between four alternatives for a hypothetical Israeli city's water-wastewater service system. The baseline scenario is the common centralized approach for WW treatment, in which all domestic streams are conveyed, through a single sewer network, to a large wastewater treatment plant (WWTP) and the effluent is then discharged to a stream. The other three alternatives represent different scales of distribution of the WW treatment phase, along with non-potable urban reuse (garden and park irrigation and toilet flushing). The first alternative includes centralized treatment at a WWTP, with part of the reclaimed WW supplied back to the urban consumers. The second and third alternatives implement decentralized greywater (GW) treatment with local reuse, one at cluster level (320 households) and one at building level (40 households).

The assessment is comprised of the following methodologies, which are integrated using AHP (Analytical Hierarchical Process), a tool for multi-criteria decision analysis:

- ELCA (Environmental Life Cycle Assessment), including an inventory of actual local data for the foreground system, collected from relevant institutions and local professionals.
- LCC (Life Cycle Costing), based on government-published price lists, local tenders and local practitioners.
- S-LCA (Social LCA), assessing the relative impacts of the systems, for three major stakeholders: society, local community and individual consumers.

Results and discussion

Results show a consistent environmental disadvantage of the prevailing centralized approach under local conditions. Electricity is a major driver of the impacts in most categories, pertaining mostly to potable water production and supply. Alternative 1, consisting of centralized treatment with urban reuse is disadvantageous to decentralized treatment of GW because the supply of reclaimed WW back to consumers is very costly in materials and energy. Infrastructure has a notable environmental effect on metal depletion, human and aquatic ecotoxicity. Results of the comparative LCA, LCC and S-LCA and their integration into an overall measure of sustainability will be discussed and presented in detail.

Conclusions

Under the conditions tested, a decentralized approach to urban wastewater management (treatment and reuse) is preferable to the common centralized system. It is worth exploring such options under different conditions as well, especially where new urban infrastructure is planned or replacement of old infrastructure is required.

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