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Lifecycle assessment of a system for food waste disposers to tank – A full-scale system evaluation

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ABSTRACT

An increased interest for separate collection of household food waste in Sweden has led to development of a number of different collection-systems – each with their particular benefits and drawbacks. In the present study, two systems for collection of food waste in households were compared; (a) use of food waste disposers (FWD) in kitchen sinks and (b) collection of food waste in paper bags for further treatment. The comparison was made in relation to greenhouse gas emissions as well as primary energy utilization. In both cases, collected food waste was treated through anaerobic digestion and digestate was used as fertilizer on farmland. Systems emissions of greenhouse gases from collection and treatment of 1 ton of food waste (dry matter), are according to the performed assessment lower from the FWD-system compared to the reference system (−990 and −770 kg CO_2-eq./ton food waste dry matter respectively). The main reasons are a higher substitution of mineral nitrogen fertilizer followed by a higher substitution of diesel. Performed uncertainty analyses state that results are robust, but that decreasing losses of organic matter in pre-treatment of food waste collected in paper bags, as well as increased losses of organic matter and nutrients from the FWD-system could change the hierarchy in relation to greenhouse gas emissions. Owing to a higher use of electricity in the FWD-system, the paper bag collection system was preferable in relation to primary energy utilization. Due to the many questions still remaining regarding the impacts of an increased amount of nutrients and organic matter to the sewage system through an increased use of FWD, the later treatment of effluent from the FWD-system, as well as treatment of wastewater from kitchen sinks in the reference system, was not included in the assessment. In future work, these aspects would be of relevance to monitor.

1. Introduction

Collection of food waste from households for subsequent biogas production is becoming increasingly common in Sweden. The most utilized scheme for collection is use of paper bags for collection of food waste in households and later disposal in single or multi-compartment waste bins (Waste Management Sweden, 2014). However, in several other countries, use of food waste disposers (FWD) is a common method for separate collection of food waste from households.

Previous studies have suggested that FWDs can present a practical alternative for source-separation of food waste, without increasing transports, and through avoidance of problems related to odor and increased need for waste bins (Marashlian and El-Fadel, 2005). However, several questions can be raised regarding the effects of FWDs connected to conventional sewer systems. Several potential adverse effects have previously been described. Bolzonella et al. (2003) stated that FWD could cause an increased organic load in the biological step at the wastewater treatment plant (WWTP) and thereby increase energy demand for wastewater treatment. Nilsson et al. (1990) raised problems with increased oil and grease load at WWTPs as well as risks of increased production of H_2S in sewerage systems, potentially resulting in corrosion of cement pipes.

On the other hand, Evans (2012) and Galil and Yaacov (2001) presented measurements of significant increases in biogas production in WWTP-sludge digestion when 50% of connected households introduced FWD. At the same time, Raunkjaer et al. (1995) showed that the removal of dissolved organic matter and proteins in

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wastewater during sewage transport to WWTP could be considerable, which implies that effects on subsequent WWTP-processes will be of lesser significance.

In addition, the effects on WWTP processes due to FWDs will to a large extent depend on the WWTP design. Bolzonella et al. (2003) state that an increased carbon concentration in incoming wastewater gained through use of FWDs can improve the C/N and C/P-ratio in WWTPs and, depending on the process design, result in an improved nutrient removal and reduced requirement for external carbon sources. In summary, our knowledge of the quantity and quality of food waste disposed of in FWDs that actually reaches the WWTP as well as net-effects on sewerage systems and WWTP-processes from FWD installation is still limited, and probably influenced by several different factors. Thus, this is certainly an area for further investigations.

With the potential problems stated above as a background, and yet a constant search for methods which can facilitate household food waste collection both for users as well as for solid waste and wastewater management organizations, a novel FWD-system was developed in Sweden in 2001. With the aim of combining the benefits from use of FWD for users, without increasing risks for problems in later transport and treatment of household wastewater, a system with tank-connected FWDs was implemented and tested. The system is graphically illustrated in Fig. 1. The system included around 60 households in low-rise buildings in Malmö, a city with around 320,000 habitants in southern Sweden. A similar system was installed in 2007, linked to more than 140 apartments in a high rise building in the same area. The evaluation showed that the design of these systems has not been optimal, with the consequence that the fraction of organic matter in collected material is low, and that a significant amount of organic material is lost from the tank between each emptying (Davidsson et al., 2011). However, the evaluations of these earlier systems were partly based on estimations, due to an absence of flow measurements at the outlet from the tank. As the system can provide large benefits from various perspectives (working environment for waste collectors, maximizing use of high value urban land, reduction of potential risks for clogging of sewage pipes, etc.), a system similar to the ones described above was installed in a newly constructed quarter in the same city in 2010. However, some changes were made with the intention to optimize the system.

1.1. Aim and scope

The purpose of the present study is to evaluate this new system from an environmental perspective, using lifecycle assessment (LCA) methodology, and compare this system to a reference collection system for household food waste. In addition, the aim is also to identify processes with a large impact to overall results, as this constitutes an important basis for further improvements and optimizations. The aim is thus to make a statement about which of the compared systems is more advantageous from an environmental perspective, and the conditions under which this is true.

The functional unit in the study is defined as: "Management and treatment of 1 ton TS source separated food waste from households." The proposal means that we in the functional unit takes no account of the recycling rate may be different in the different systems. This is because we, in the context of this study, not will be able to establish any general differences between use of food waste disposers and the reference system with regard to separation behavior. In the case of the food waste disposer system, production of biogas and nutrient content in digestate is assessed based on experimental data, while literature data is used for these parameters in the assessment of the reference system.

Collection of food waste in paper bags is selected as the reference system, as this system currently is the most common system for food waste collection in Sweden (Waste Management Sweden, 2013).

Produced biogas is assumed to substitute diesel as fuel in busses, as upgrading of biogas for use as vehicle fuel was the most common application of biogas in Sweden in 2014 (Swedish Energy Authority, 2015).

1.2. System boundaries

Choices of system boundaries should be based on the following principles (ILCD, 2010):

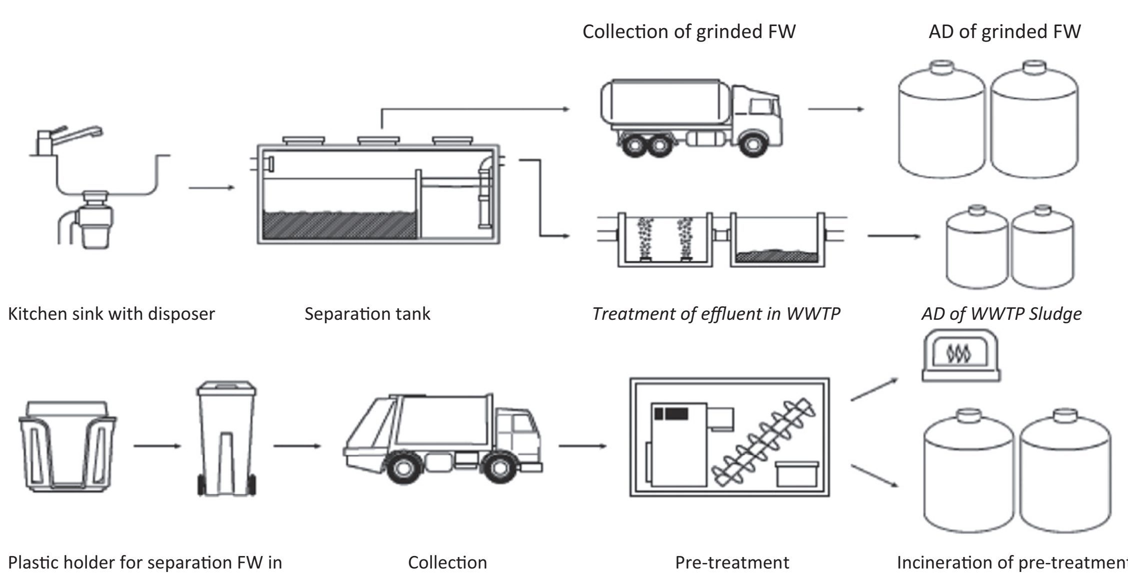

Fig. 1. Graphical representation of the character of the tank-connected food waste disposer system (top) and the reference system (bottom) investigated in the study. FW = Food waste, AD = Anaerobic digestion. Processes with labels in italics are not included in the assessment.