An environmental approach to compare on-site sanitation systems

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INTRODUCTION / MAIN METHIODS

About 700,000 on-site wastewater treatment systems (OWTS) have been installed in Sweden, serving both year-round and summer houses (Olshammar et al., 2015). Their treatment efficiency is often questioned, because they may contribute considerably to eutrophication of natural surface waters. It is estimated that the phosphorus (P) discharge of all the OWTSs accounts for 15% of the total anthropogenic P emissions to Swedish surface waters; the same amount as all municipal wastewater treatment plants combined (Ejhed et al., 2011). About half of the existing facilities are not built according to the guidelines (Ek et al., 2011) and discharge higher levels of nutrients into the receiving waters than suggested by the current recommendations. When new OWTS need to be built, or old ones upgraded because of facility ageing, or population dynamics or the need for legal compliance, it is often difficult for operators (usually house owners) and the supervising authority (the municipalities) to discern among the different available options and their sustainability.

The aim of this study is to benchmark different on-site wastewater treatment solutions using a multi-criteria analysis (MCA) and sustainability indicators. Both, the OWTS options commonly used in Sweden and other less common options, such as source-separation systems, are included. The present paper focuses on the environmental indicators.

Eleven alternatives (general systems types) were analyzed by the MCA, including five soil-based treatment combinations, such as septic tanks, drain fields, sand filters, alkaline filters for P removal, and P removal by precipitation. Furthermore, three source-separation alternatives were chosen, consisting of greywater (sand filter treatment) and blackwater separation (anaerobic digestion treatment and/or urine diversion with different treatments). Finally, three packaged plants closed the list of alternatives, selected mainly on the basis of differences in their technological characteristics and commercial availability in Sweden.

The criteria and indicators used in the MCA were defined on the basis of discussions with experts in the field and the earlier research, and estimated both qualitatively and quantitatively from the available literature data (see Table 1). The scores based on constructed scales (that represent relative preferences for the consequences) were calculated for each indicator to make them mutually comparable. The result of such analysis is a performance matrix that rates the performance of the alternatives against each indicator. Furthermore, a reference group, consisting of researchers, authorities and consultants, will discuss and assign additive weights to each criterion to reflect the relative importance and stakeholders' interests.

Table 1. Criteria and indicators selected for the multi-criteria analysis. The focus of this paper will only cover the environmental indicators. Qual. = quality indicator, quant. = quantity indicator.

Criteria type	**Indicator**	**Units**	**Qual. (L)/ Quant. (T)**	**Aim**
Environmental	Emissions to surface waters	%	T	High reduction
	Potential for nutrients recycling	%	T	High potential
	Emissions to air	Kg CO_2-eq/year	T	Low emissions
	Energy use	MJ/year	T	Low energy use
	Energy recovery	H-M-L (3,2,1)	L	High energy recovery
Economic	Investment costs (capital cost)	SEK/life expectancy	T	Low cost
	Operation & maintenance costs	SEK/year	T	Low cost
Socio-cultural	Social acceptance	H-M-L (3,2,1)	L	High social acceptance
	Complexity of technique	H-M-L (1,2,3)	L	Low technical complexity
Technological	Robustness	H-M-L (3,2,1)	L	High robustness
	Resilience (Upgradability/flexibility)	H-M-L (3,2,1)	L	High resilience

MAIN RESULTS AND CONCLUSIONS

Preliminary results show that the three source-separation options contribute least emissions to surface waters with respect to P and especially N. Soil-based systems that include the septic tank, P precipitation, sand filter and drain field also show high reduction rates for BOD and P, but lower for N as compared to source separation systems.

The calculation of the potential for nutrients recycling was challenging, because various assumptions substantially influenced the results. Two indicators for potential recycling of nutrients were considered; the total recoverable fraction, assuming that nutrients are recovered from most of the materials (sand filters, P filters, and sludge), and the more "realistic" fraction that is potentially recoverable according to the current practice.

The expected results consist in a ranking of the selected alternatives, on the basis of their performance against the environmental criteria, and stakeholders´ preferences that can be used in support of the decision-making processes. Multi-criteria analysis was found to be a useful tool to compare a range of criteria of different nature, support complex decisions and provide informed preferences.

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