

Performance of onsite wastewater treatment systems –a case study in rural Finland

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Abstract

We studied the performance of 37 onsite domestic wastewater treatment systems in rural Finland. The evaluated systems included 24 septic tank systems for black waters, 5 black water systems with a sand filter bed in addition to septic tanks and 8 source separation systems where gray waters were treated separately. None of the black water treatment systems fulfilled all the treatment requirements set by the new Finnish legislation: 90 % reduction of BOD₇, 85% reduction of P_{tot}, and 40% reduction of N_{tot}. As expected, septic tank effluents contained a high amount of organic matter and nutrients. Sand filter beds failed to fulfill the requirements of phosphorus reduction with a median effluent concentration of 13 mg/l of P_{tot}. Four out of 8 gray water treatment systems fulfilled all reduction requirements whereas 4 had elevated BOD₇ effluent concentrations. The gray water systems failing to fulfill the requirements had only septic tanks and their performance could be improved by an additional sand filter bed. The results indicate that significant changes are needed in a major part of the existing treatment systems. Dry toilet combined with a suitable gray water treatment system would be an economical and sustainable alternative to fulfill the treatment requirements.

Keywords: Finland, onsite wastewater treatment, performance

Introduction

In sparsely populated Finland approximately one million people live in houses not connected to the municipal sewage network. According to Finnish legislation (Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks 542/2003) onsite domestic wastewater systems must meet the minimum requirements of 90 % reduction of BOD₇ (7-day biochemical oxygen demand), 85% reduction of P_{tot} (total phosphorus), and 40% reduction of N_{tot} (total nitrogen). The Decree applies immediately to all new systems, while older wastewater treatment systems must fulfill the requirements by 2014.

The aim of this study was to evaluate the performance of the existing wastewater systems in a rural municipality in Finland. The study was conducted as a part of a larger well water quality sampling project.

Methods

We evaluated the performance of 37 onsite domestic wastewater treatment systems in Nurmijärvi municipality in Southern Finland in May-June 2007. In 24 systems all wastewaters including toilet waste were treated in septic tanks only, 5 had a sand filter bed in addition to septic tanks and 8 dwellings had source separation systems where black waters were collected in closed tanks and gray waters were treated separately. Out of the total 8 gray water treatment systems 5 had septic tanks only and in 3 systems septic tanks were followed by a sand filter bed.

One grab sample was taken from the effluent of each treatment system. The samples were analyzed for BOD₇, P_{tot}, N_{tot}, COD (chemical oxygen demand), DOC (dissolved organic carbon) and EC (electric conductivity). BOD₇ was determined using OxiTop® measuring system (WTW, Weilheim, Germany) equipped with OxiTop-OC100 controller. P_{tot}, N_{tot} and COD were measured according to standard methods SFS-EN ISO 6878, SFS 5505 and SFS 5504, respectively. DOC concentrations were determined with a Shimadzu TOC-5000 analyzer.

The ability of the systems to reach the BOD₇, phosphorus, and nitrogen removal requirements set by the new Finnish legislation was evaluated by comparing the measured effluent concentrations to calculated highest allowed effluent concentrations. The calculation was based on the house-specific wastewater load (g/person/day) and required removal efficiency specified in the Decree (Table 1). The water consumption was estimated to be 110 L/person/day for black waters and 80 L/person/day for gray waters as in a previous Finnish study (Vilpas et al. 2005).

Table 1. The calculation parameters based on the Finnish Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks (542/2003).

	BOD₇	P_{tot}	N_{tot}
House-specific wastewater load (g/person/day)	50	2.2	14
Required removal efficiency (%)	90	85	40
Calculated highest allowed effluent concentration (mg/l), water consumption 110 L/person/day (black waters)	45	3	76
Calculated highest allowed effluent concentration (mg/l), water consumption 80 L/person/day (only gray waters)	63	4	105

Results and discussion

None of the black water treatment systems fulfilled all the treatment requirements (Figure 1). As expected, septic tank effluents contained a high amount of organic matter and nutrients (Table 2). Septic tanks are not sufficient as the only treatment step but information on their performance is not insignificant if the inhabitants wish to use them as a part of an upgraded treatment system. Sand filter beds removed efficiently nitrogen from black waters but with a median effluent concentration of 13 mg/l of P_{tot} they failed to fulfill the requirements of phosphorus reduction. Two of the oldest filter systems, installed 14-15 years ago, had also elevated BOD₇ effluent concentrations indicating possible clogging of the filters and the need for maintenance (Figure 1).

Table 2. Median concentrations of the effluents.

Treatment system (number of systems studied)	BOD₇ (mg/l)	COD (mg/l)	P_{tot} (mg/l)	N_{tot} (mg/l)	DOC (mg/l)	EC (μS/cm)
Septic tanks for black waters (24)	340	638	18	110	97	1460
Septic tanks + sand filter bed for black waters (5)	60	173	13	50	24	850
Gray water systems (8)	70	234	3	7	17	500

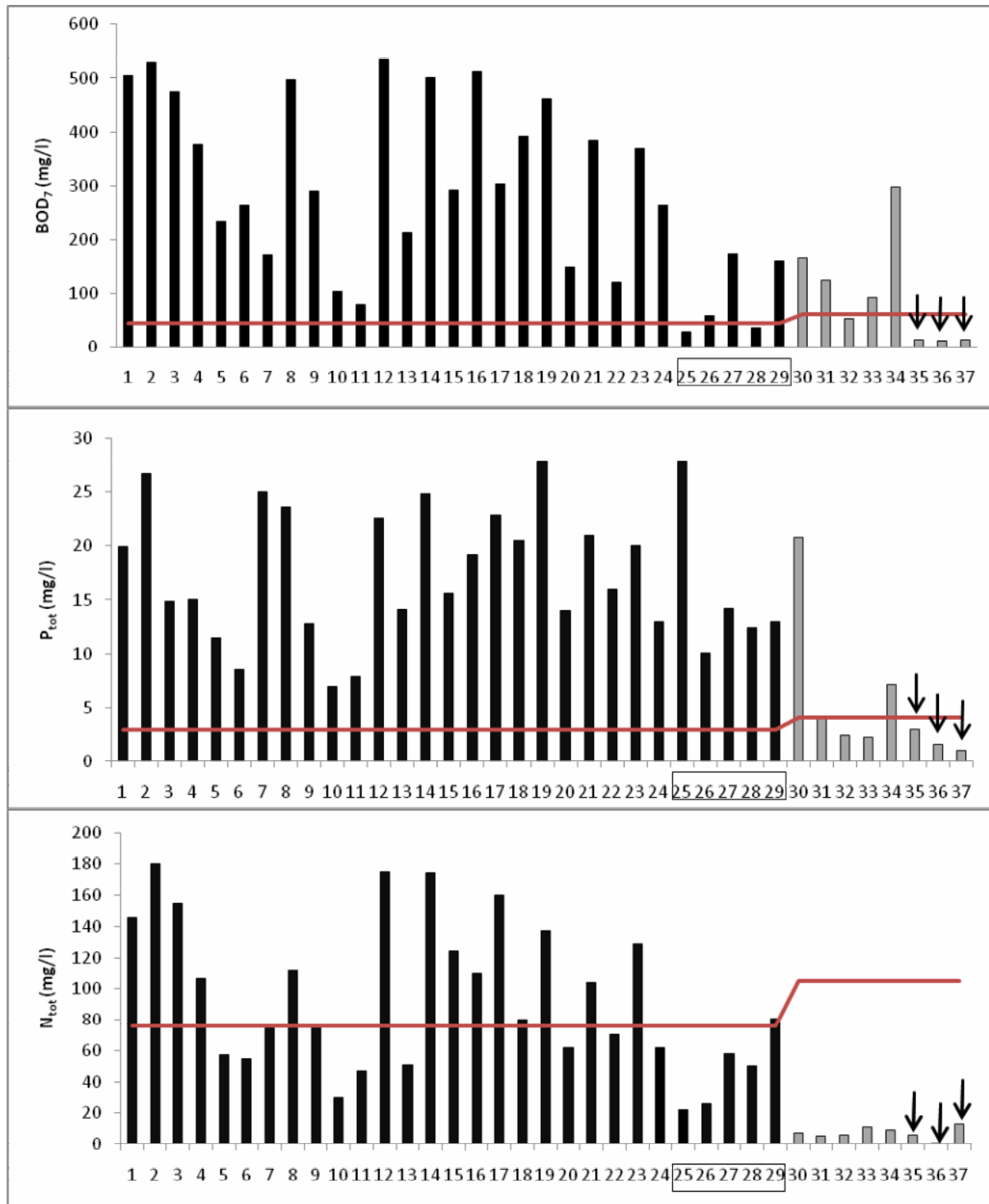


Figure 1. Measured effluent concentrations of BOD₇, P_{tot} and N_{tot} compared to the calculated maximum allowed effluent concentration based on the estimated water consumption. Black columns (1-29) refer to black water treatment systems, out of which the systems 1-24 had only septic tanks and the systems 25-29 had an additional sand filter bed. Gray columns (30-37) refer to gray water systems. The gray water systems marked with an arrow had a sand filter bed.

Four out of 8 gray water treatment systems fulfilled all the reduction requirements whereas 4 had elevated BOD₇ effluent concentrations and 2 exceeded the phosphorus limit values (Figure 1). The gray water systems failing to fulfill the requirements had only septic tanks and their performance could be improved by an additional sand filter bed. In addition, the phosphorus flow to the sand filters could be reduced by using phosphorus free detergents.

To confirm the results of this study, more samples on different time intervals would be needed to reduce the impact of influent quality variation on the results. In addition, the maximum allowed effluent concentrations used in the comparison to legal requirements are based on water consumption estimates. If the real water consumption in a household was significantly higher or lower, the comparison could underestimate or overestimate the environmental load of the system. Nevertheless, the measured median concentrations of the septic tank effluents are similar to those of previous studies. It is also known that the conventional sand filters have a limited phosphorus removal capacity (e.g. Vilpas et al 2005). Thus, it is clear that major changes are needed in many existing systems to fulfill the new treatment requirements. Several types of sequencing batch reactors, biological filters and sand filters with improved P-adsorption have been shown to be able to reach the treatment requirements (Vilpas et al. 2005). However, these black water treatment systems are only efficient if properly maintained and the complexity of the systems makes them vulnerable to system failures. Dry toilet technology combined with a gray water treatment could offer a more simple and sustainable alternative.

Conclusions

The case study indicates that significant changes are needed in a major part of the existing treatment systems before the goals of the new Finnish onsite domestic wastewater treatment decree can be achieved. Dry toilet combined with a suitable gray water treatment system would be an economical and sustainable alternative to fulfill the treatment requirements. Unfortunately, the existing structures are mostly relying on the use of water-based flush toilet. Increasing people's knowledge on different dry sanitation options is especially important now that people search for solutions to fulfill the new treatment requirements in their household.

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