WASTEWATER QUALITY AFTER GREY WATER FILTRATION SYSTEM

FINAL REPORT

Aino Pelto-Huikko and Martti Latva

December 16th, 2021
Confidential

Table of contents

1 Introduction

The goal of sewage treatment is to reduce substances harmful to humans and the environment of ending up in the environment. In areas outside sewer networks this effect can be reduced with property-specific wastewater system. Wastewater system is a combination of grey and black water treatments. Grey water is all wastewater generated inside the premises without faecal contamination i.e., wastewater from toilets (black water). Treatment of grey water reduces the nutrient and organic matter flow into the environment. One way to treat the wastewater according to the Finnish legislation is to use a dry closet and a grey water treatment system. Alternatively, black waters can be also directed to separate tank for later transportation.

In Finland, to protect the environment there is Environmental Protection Act (527/2014) and Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks (157/2017) (Table 1). Requirements are based on the type of wastewater system and area where the treatment is located. Areas are divided into basic requirement areas and areas, which are easily contaminated. Sensitive areas are usually areas where the nature would be more easily affected by the nutrient flow. Different treatment requirements apply depending on the chosen treatment method. When black waters are separated from grey waters there are lower requirements for phosphorus removal and no requirements for nitrogen removal in grey waters, as most of phosphorus and nitrogen is from black waters. This study examines the untreated domestic sewage average occupancy on daily load on a property where black water is separated from gray waters. The subject of the study is grey water filter combined with a dry closet. Results in this study will be compared to the values and limits in the Finnish legislation.

Table 1. Parameters according to Environmental Protection Act (527/2014) and Government Decree (157/2017) for total phosphorus, total nitrogen and organic material in grey waters.

Parameter	Total phosphorus	Total nitrogen	BOD_7
Treatment requirement in 527/2014 §154b (%)	0	0	67
Treatment requirement for sensitive areas in 157/2017 §4 (%)	18	0	83
Incoming load (g/p/d)	0,4	1,0	30

2 General information

2.1 Biolan Greywater Filter

Wastewater from the properties is cleaned both mechanically and biologically by the grey water filter. Organic material inside the filter catches suspended solids and nutrients in the wastewater and micro-organisms living in the filter break them up. The same filter material can be used up to 100 days. After 100 days of use, it should be replaced to maintain the required cleaning capacity.

Biolan Greywater Filter 70 (HVS 70) is a filter for all grey waters. The filter is designed to be used mainly in the premises not constantly inhabited. Filtering system is installed on the ground and can be used during winter. *Greywater Filter 70* consists of two modules. Wastewater is led into the modules using branched tubing. Inside both modules there are five filtration boxes. First, wastewater is led to the upper box, where it drains down by the gravity. The capacity of Biolan Greywater Filter 70 is 500 liters per 24 hours.

Biolan Greywater Filter Light (HVS Light) is non-isolated filter for all grey waters. Because it is non-isolated, it cannot be used during the winter. Filter can be installed partly buried or on the ground. Inside the filter, there are five filtration boxes placed on top of each other. First, the wastewater is led to the upper box where it drains down by the gravity. Capacity of the Biolan Greywater Filter Light is 300 liters per 24 hours.

Biolan Greywater Filter 125 (HVS 125) is a filter designed to be used mainly on premises not constantly inhabited. It is installed on the ground and can be used during winter. Inside the filter, there are ten filtration boxes placed on top of each other. First, wastewater is led to the upper box where it drains down by gravity. The capacity of Biolan Greywater Filter 125 is 500 liters per 24 hours.

The manufacturer of the filter provided the filtration material. It was a combination of wood fibre (aspen, *Populus tremola*). The test period started after installing the new filter material to the greywater filter.

2.2 Location

This study was done in premises location in the municipalities of Rauma and Eura year 2021. The requirements of Finnish legislation are presented in Table 1.

2.3 Estimated water consuption

The premises have own well as a water source. Number of residents is three persons in the premise A, four persons in B and two persons in C. The water consumption of each premise was evaluated as there are no water flow meters installed to indicate the specific water consumption.

To estimate the water usage in the premise all sources of water use within household must be evaluated. In the premise A, there are shower and hot water tank (15 l). Hot water tank is used only in the kitchen and the shower has own hot water system. The water consumption was estimated to be 50 liters/person/day. This estimate is based on a study made by Finnish Environment Institute on reducing the nutrient loads in rural areas (Vilpas et al. 2005) together with the evaluation of sources of water use within the household.

In the premise B, there are washing machine and hot water tank (15 l). There is a dry toilet, so black wastewater is not involved. Wastewater generated in the kitchen was discharged in the greywater system under study. Other greywater i.e., shower, was treated in another greywater system. The water consumption in the kitchen was estimated to be 25 liters/person/day. This estimate is based on a study made by Finnish Environment Institute on reducing the nutrient loads in rural areas (Vilpas et al. 2005) together with the evaluation of sources of water use within the household. The distribution of the wastewater load in the kitchen and wash water varies according to the destination. According to the summary of Ghaitidak and Yadav (2013), the organic matter load in the kitchen wastewater can be estimated to be higher than that of washing waters. For this study, 60 % of organic matter and 50 % of phosphorus and nitrogen load were estimated coming from kitchen waters.

In the premise C, there are dishwasher, washing machine, hot water tank, and shower. Black wastewater is collected to a holding tank. The water consumption was estimated to be 70 liters/person/day. This estimate is based on a study made by Finnish Environment Institute on reducing the nutrient loads in rural areas (Vilpas et al. 2005) together with the evaluation of sources of water use within the household.

3 Test

3.1 Test arrangements and sampling

All the filters studied were in normal use during this test. They were maintained according to the instructions given by the manufacturer. The study was started with a change of filter material. Week count identifies the time elapsed since changing the filter material. In all the locations, normal maintenance and repair actions were allowed during the test period.

All the samples were taken by researcher (MSc, Tech.) Aino Pelto-Huikko from Satakunta University of Applied Sciences, Nordic Water and Materials Institute WANDER. The sampling was started in June 2021 and the last sampling time was in October 2021 for all the filters.

Samples were taken from sampling wells, the installation of which was arranged by Biolan Oy. The samples were taken into plastic bottles supplied by laboratory.

The sampling well was cleaned one day before the sampling day to minimize the biological growth in the sampling wells. All the sampling equipment were cleaned properly with ultra-pure water.

3.2 Analyses

The samples were analyzed by KVVY laboratory which is a FINAS accredited laboratory.

Suspended solids refer to the small particles in the wastewater. High wastewater loads increase the concentration of suspended solids in the water. It should be taken into consideration, that some material can release from the new filter material right after the change and increase the concentration.

pH refers to the acidity of the wastewater. pH for neutral water is 7,0. Optimal pH for filtered grey water is 6–7. Since new filtration material is naturally relatively acidic, it can affect the pH values in the beginning of the use.

Total phosphorus refers to all organic and inorganic phosphorus compounds in the wastewater. Phosphorus can be found in two forms: organic phosphorus and phosphate (inorganic phosphorus). Food deposits in grey waters contain organic phosphorus and various detergents contain phosphates. Phosphorus causes eutrophication.

Total nitrogen refers to all organic and inorganic nitrogen compounds in the wastewater. Mostly nitrogen exists in organic compounds. Kitchen wastewater contains food deposits which contain nitrogen. Part of the organic compounds break up in the wastewater and nitrogen is released to inorganic ammoniacal nitrogen, nitrate and nitrite. Ammoniacal nitrogen is poisonous to fishes. Nitrate and nitrite cause eutrophication.

BOD_7 (Biological Oxygen Demand in 7 days) is the amount of oxygen needed by organisms to break down the organic material present in the sample at certain temperature over seven days' time. BOD_7 indicates how much organic material is in the sample.

Uncertainties are defined by the analyzing laboratory and are specific for each analyte. The methods and corresponding uncertainties are presented in Table 2.

Table 2. The methods and uncertainties of the analyses. The sample has the year of sampling (2021), the sampling time (1-5) and the sampling location and greywater filter: A: HVS 70, B: HVS Light ja C: HVS 125.

Analyse	**Method**	**Sample**	**Uncertainty**
Suspended solids	SFS-EN 872:2005	2021_1–5 except 2C, 4C, 5C,	± 15 % ± 20 %
pH	SFS 3021:1979	2021_1–5	± 0,2 units
Total phosphorus	SFS-EN ISO 11885, 2009, SFS-EN ISO 15587-2, 2002	2021_1–5 except 5C	± 15 % ± 20 %
Total nitrogen	SFS-EN 12260:2005	2021_1–5 except 2B, 2C, 4C, 5C	± 10 % 0,25 mg/l
BOD_7	SFS-EN ISO 5815-1:2019	2021_1–5	± 16 %

4 Results

4.1 Analyses results

The following analyses were made from the samples: suspended solids, pH, total phosphorus, total nitrogen and BOD_7. The results are presented in for the filter HVS Light (A) in the Table 3, for the filter HVS 70 (B) in the Table 4 and for the filter HVS 125 (C) in the Table 5.

Table 3. Analyses results for the filter HVS Light.

Week	**Suspended solids**	**pH**	**Total phosphorus**	**Total nitrogen**	**BOD_7**
	mg/l		mg/l	mg/l	mg/l
3	48	6,8	1,5	6,4	140
9	18	7,2	0,35	1,6	14
12	31	7,1	1,50	13	41
14	51	7,1	1,4	6,2	59
16	67	7,0	1,7	12	75
Average	43	7,0	1,3	7,8	66

Table 4. Analyses results for the filter HVS 70.

Week	**Suspended solids**	**pH**	**Total phosphorus**	**Total nitrogen**	**BOD_7**
	mg/l		mg/l	mg/l	mg/l
3	32	7,3	0,6	3,3	27
9	34	6,8	0,7	6,2	36
12	41	6,3	0,64	2,5	12
14	28	7,4	0,61	4,2	32
16	34	7,0	0,88	6,2	46
Average	34	7,0	0,69	4,5	31

Table 5. Analyses results for the filter HVS 125.

Week	Suspended solids	pH	Total phosphorus	Total nitrogen	BOD_7
	mg/l		mg/l	mg/l	mg/l
2	42	7,5	0,51	4,7	36
7	5,6	7,4	0,11	2	5,6
10	15	7,5	0,29	3,1	24
12	6	7,6	0,23	2,2	18
14	4	7,6	0,097	1,8	3,8
Average	14,5	7,5	0,25	2,8	17,5

4.2 Reductions

Incoming loads of total phosphorus, total nitrogen and BOD_7 were calculated using an estimation of the incoming load (g/p/d) according to the Finnish legislation (Table 1), as well as estimated water consumption and number of inhabitants with Formula 1.

$$Incoming\ load\ in\ specific\ location = \frac{incoming\ load\ \ (g/(p * d))\ x\ number\ of\ inhabitants\ (p)}{water\ consumption\ (\frac{l}{d})} \qquad (1)$$

Incoming loads for each analyte was calculated with the estimated water consumption mentioned in the clause 2.3. The incoming organic matter and nutrient load estimation is based on the Finnish legislation cause the sample of incoming wastewater was not possible to take. Reductions of incoming load (%) were calculated using calculated incoming loads for each analyte and analysis results with Formula 2.

$$Reduction\ of\ incoming\ load\ (\%) = \frac{calculated\ incoming\ load - analysis\ result}{calculated\ incoming\ load} x\ 100\% \qquad (2)$$

The load reductions calculated using the formula 2 are shown in the Figures 1 to 3 together with the requirements of Finnish legislation.

There are not requirements for total phosphorus in grey water as the using points are not located in a sensitive area. The filter met the requirements for sensitive areas for phosphorus removal. There are no requirements in the Finnish legislation for nitrogen reduction in grey waters. BOD_7 reduction fulfilled the treatment requirements.

The reduction of organic matter (Figure 1), aspen fiber as a filter mass for all devices meets the basic requirements of the legislation, and for devices HVS 70 and 125 also the guide value for sensitive areas. Most of the HVS Light samples (4/5 samples) meet the requirement for sensitive areas. The first sample is slightly below the cut-off value. Overall, the organic matter removal efficiency of all filters appears to remain at a good level throughout the experiment.

All filter types met the requirements in the sensitive area for total phosphorus reduction (Figure 2). There are no requirements for total phosphorus in grey wastewaters if the site is not located in sensitive areas. Total phosphorus removal efficiency remained at a good level throughout the experiment.

The Finnish legislation have no requirements for total nitrogen in grey waters. With the grey wastewater filter 70 and 125 devices (Figure 3), the reduction of nitrogen was constant throughout the experiment. With the HVS Light, the reduction of nitrogen (Figure 3) varied towards the end of the experiment.

With the exception of one sample (HVS 125 12 weeks), the pH of the samples was constant between about 6,5 and 8. The significance of an individual anomalous result is difficult to interpret. The amount of suspended solids (Fig. 5) varied across samples and did not appear to form a clear trend in the 2021 sampling results.

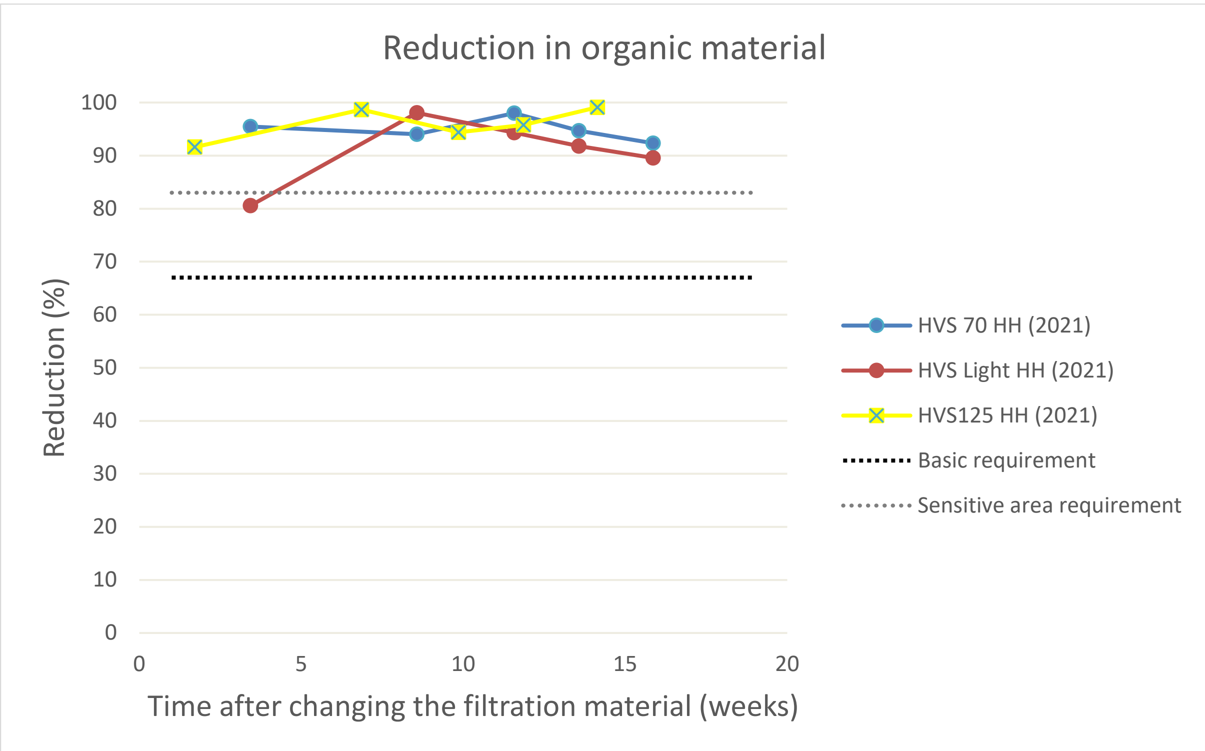

Figure 1. Reduction (%) in organic material based on BOD_7 samples. The results are compared to the basic and sensitive area requirements mentioned in the Finnish Environment Protection Act.

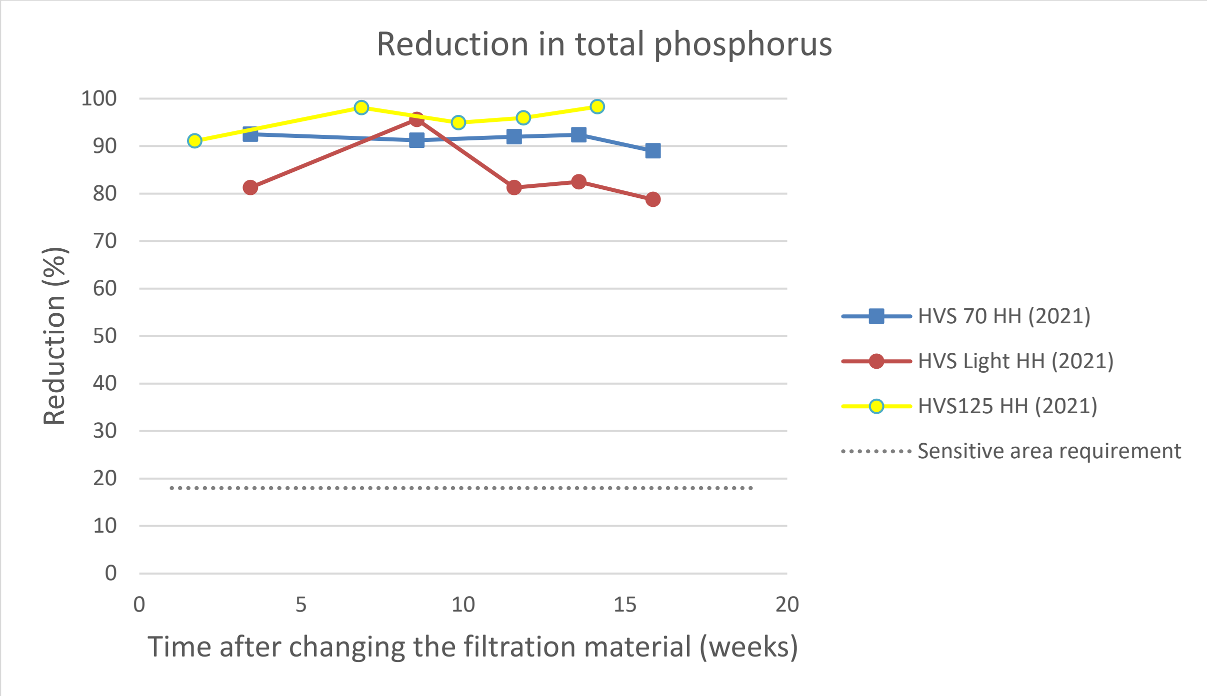

Figure 2. Reduction (%) in total phosphorus. The results are compared to the sensitive area requirement mentioned in the Finnish Environment Protection Act.

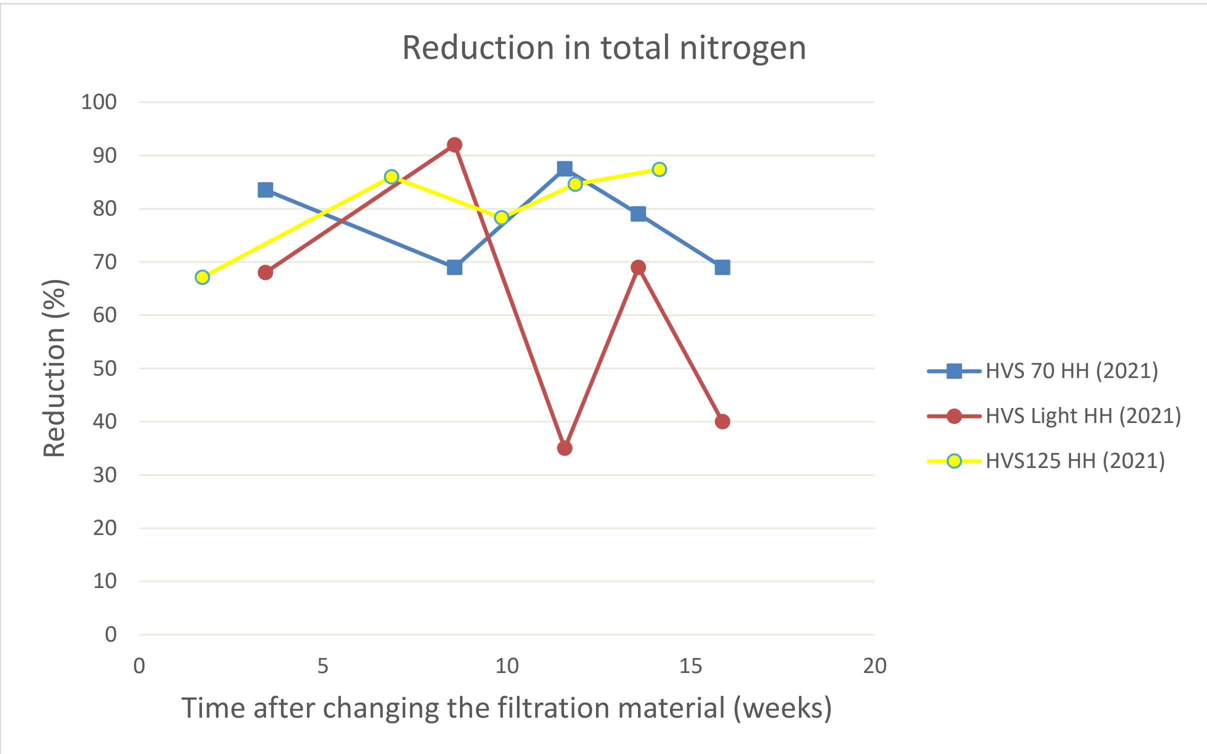

Figure 3. Reduction (%) in total nitrogen.

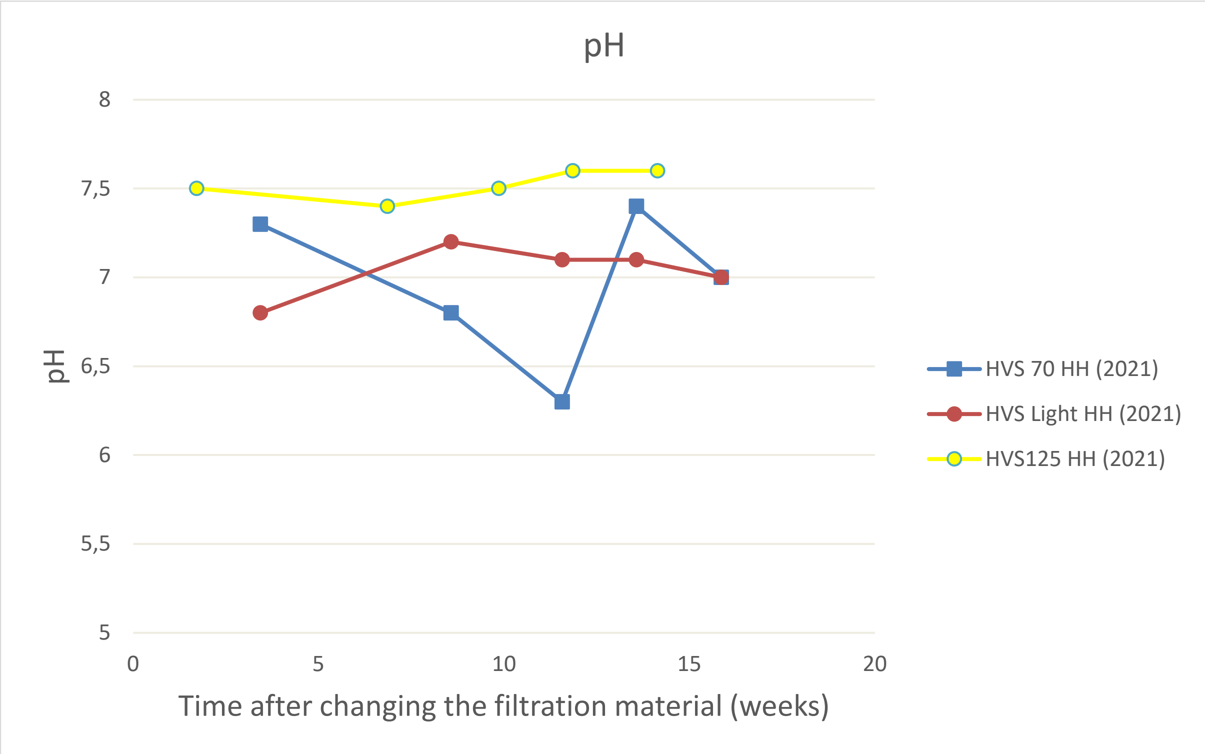

Figure 4. Measured pH-values in different greywater filters.

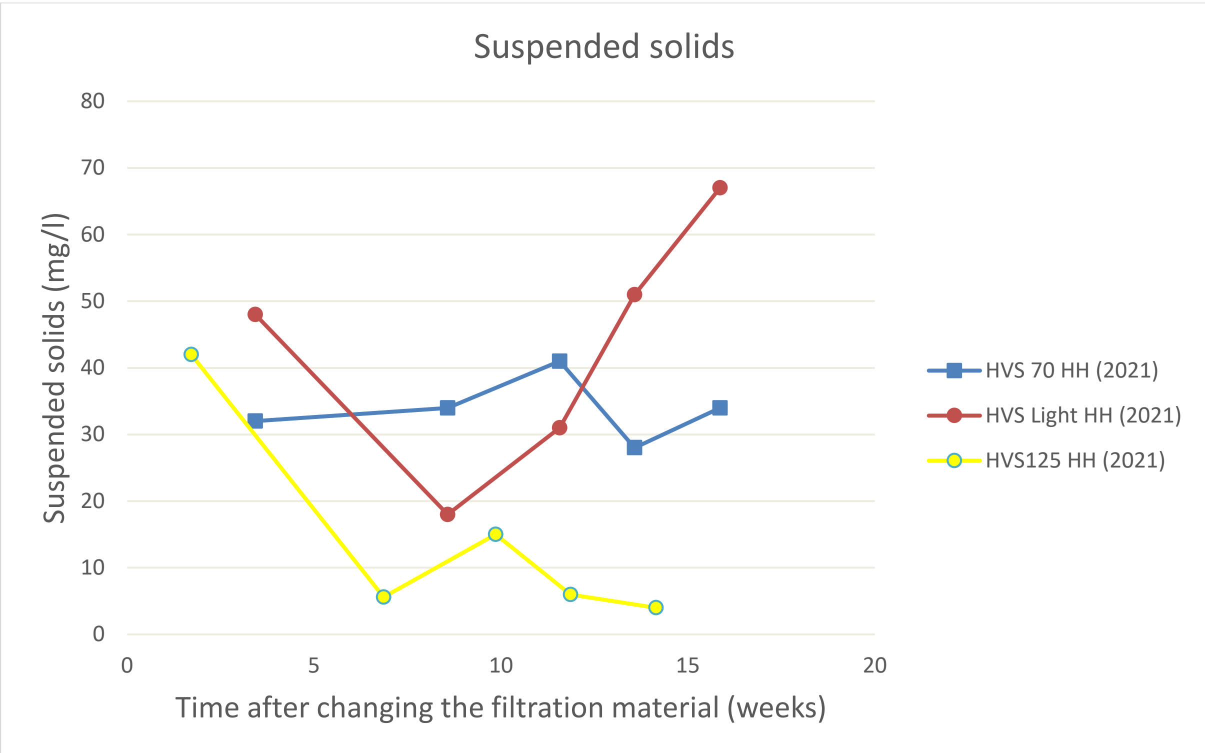

Figure 5. The amount of suspended solids after greywater filtering.

5 Conclusions

The cleaning capacity of the new filtration material increases with time as new biofilm and chemical sediment forms in the filter material surfaces. Microbes in the sediment break up nitrogen and organic material which affects the cleaning results positively. Occasional point-loads, such as unusually high concentrations of food deposits or wash water containing infant faeces, can momentarily increase the concentration of nutrients in the waste waters. This consequently has impact on the reduction values.

The sampling method used affects the analyzed results and it has been developed during the studies. Over the time biological growth starts on the bottom and inner walls of the sampling well. To reduce this effect the sampling well was cleaned before each sampling.

The reductions (%) are calculated using an estimation of the incoming load mentioned in the legislation, as no samples were taken from the incoming wastewater. Because the estimated incoming load is an average, occasional point loads can cause the measured reduction to be lower than it really is.

Filter material is calculated to maintain its cleaning capacity for 100 days of use. The property was irregularly inhabited during the test period and hence, the number of actual days of use might differ from that. Sampling period lasted for a total 99 to 111 days which was longer than the recommended time of use.

In the Finnish legislation there are requirements for normal areas (basic requirement) and higher requirements for sensitive areas. In addition, there is a requirement for phosphorus removal in areas that are particularly sensitive to pollution. Results are compared to the values presented in the Finnish legislation. The all the filter types met the basic requirements for organic material. When compared to the requirement for sensitive areas one sample was slightly below the cut-off value. For total phosphorus the treatment requirement for sensitive areas were met.

There is not exact measured information about the actual loads during this study so the reduction efficiencies might differ from calculated. The loads are evaluated based on the averaged use and wastewater quality values given in the Finnish legislation. The selection of right type of filter depends also on the water use inside the property.

6 List of references

157/2017. Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks (In Finnish)

527/2014. Environmental Protection Act (In Finnish)

Ghaitidak, D.M., Yadav, K.D. Characteristics and treatment of greywater—a review. Environmental Science and Pollutation Research 20, 2795–2809 (2013). https://doi.org/10.1007/s11356-013-1533-0

Vilpas, R., Kujala-Räty, K., Laaksonen, T., Santala, E. 2005. Reducing the nutrient loads in rural areas. Finnish Environmental Institute 762 (In Finnish)