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WASTE WATER QUALITY AFTER GREY WATER FILTRATION SYSTEM

FINAL REPORT

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Confidential

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1 Background

Waste water systems are a combination of grey and black water treatment. Grey water is all waste water generated inside the premises without faecal contamination i.e. waste water from toilets (black water). Treatment of grey water is done to reduce the nutrient and organic matter flow into the environment. One way to treat the waste water according to the Finnish legislation is to use a dry toilet and a grey water treatment system. Alternativelly, black waters can be also directed to separate tank for later transportation. Different treatment requirements apply depending on the chosen treatment methods. 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 comes from black waters. (Table 1).

In this test the following three different Biolan Oy manufactured grey water filters were tested: Biolan grey water filter 70, Biolan grey water filter Light and Biolan grey water filter 125. In all the locations black waters are treated separately, which means that only grey waters go through the filter.

To protect the environment there is Finnish legal regulation (209/2011) concerning waste water treatment outside the sewerage system (Table 1). Requirements are based on the type of waste water system and area. Areas are divided into basic requirement areas and sensitive areas. Sensitive areas are usually areas where the nature would be more easily affected by the nutrient flow. Final results will be compared to the values and limits stipulated in this regulation.

Table 1. Parameters according to Finnish regulation 209/2011 for total phosphorus, total nitrogen and organic material in grey waters.

Parameter	**Total phosphorus**	**Total nitrogen**	**BOD_7**
Treatment requirement in §3 (%)	0	0	67
Treatment requirement for sensitive areas in §4 (%)	18	0	83
Incoming load (g/p/d)	0,4	1,0	30

All the samples in this study have been taken from the water after the grey water filtration system. Incoming loads are estimates stipulated in Finnish legal regulation 209/2011.

2 General information

2.1 Grey water filter types

Waste water from the premises is cleaned both mechanically and biologically by the grey water filter. Organic material inside the filter catches suspended solids and nutrients in the waste water 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 grey water filter 70 is a filter for all grey waters. The filter is designed to be used mainly in premises not constantly inhabited. Filtering system is installed on the ground and can be used during winter. The filter consists of two modules. Waste water is led in to the modules using branch tubing. Inside both modules there are five filtration boxes. First, waste water is led to the upper box, where it drains down by gravity. The capacity of Biolan grey water filter 70 is 500 liters per 24 hours.

Biolan grey water filter Light is non-isolated filter for all grey waters. Because it is non-isolated, it cannot be used during 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 waste water is led to the upper box where is drains down by gravity. Capacity of Biolan grey water filter Light is 300 liters per 24 hours.

Biolan grey water filter 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, waste water is led to the upper box where it drains down by gravity. The capacity of Biolan grey water filter 125 is 500 liters per 24 hours.

2.2 Locations

Sampling for this study has been done in three (3) locations (Table 2). Filters are identified by alphabetical lettering system. Filters A (Biolan 70) and filter B (Biolan light) are located in city of Rauma. Filter C (Biolan 125) is located in the city of Eura as shown in Table 2.

Table 2. Information on the locations.

Filter	Location	Type of the filter	Material changed	Number of sampling rounds
A	Rauma	Biolan 70	26.5.2017	5
B	Rauma	Biolan Light	16.7.2017	4
C	Eura	Biolan 125	22.6.2017	5

In Rauma normal treatment requirements according to Finnish legal regulations (209/2011) 3§ apply. In Eura, sensitive area treatment requirements according to Finnish legal regulations (209/2011) 4§ apply (City of Eura 2014). The requirements of Finnish legislation are presented in Table 1.

2.2.1 Estimated water consumption

The water consumption of the premise was evaluated as there are no water flow meters installed to indicate the specific water consumption. The premises have own well as a water source.

To estimate the water usage in each sampling location the functions using water must be evaluated (Table 3). The premises with the filter A and B, the water consumption was estimated to be 50 liters/person/day. The premise with the filter C, the water consumption was estimated to be 70 liters/person/day. These estimates are 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 water using functions in each premise.

Table 3. Estimated water consumptions in locations A, B and C.

Filter	Persons	Functions using water	Water consumption (l/p/d)
A	3	Shower, boiler (15 l)*	50
B	4	Washing machine, boiler (15 l)	50
C	2	Dish washer, washing machine, shower, boiler	70

*Boiler (15 l) is used only in kitchen. The shower has its own hot water system.

3 Test

3.1 Test arrangements

In the testing of filters A and C the sampling was started in June 2017 and in the testing filter B the sampling was started in July 2017. The last sampling time was in October 2017 for all the filters.

The numbers added after the filter letter identify the order number of sampling round. For example, sample A1 is the first sample taken from filter A.

All the filters studied were in normal use during this test. They were maintained according to the instructions given by the manufacturer. For the filter A the filtration material was changed on 26th of May, for the filter B on 16th of July and for the filter C on 22nd of June. However, in the case of the filter C, the filtration materials were not changed into two of the lowest filtration boxes. Week count identifies the time elapsed since changing the filter material. For example, first sample in the case of filter A was taken four weeks after the material was changed. In all the locations, normal maintenance and repair actions were allowed during the test period.

All the samples in this report were taken by Aino Pelto-Huikko and Sanna Kopra-Virtanen from Satakunta University of Applied Sciences, Nordic Water and Materials Institute WANDER. Samples were analyzed by KVVY laboratory which is FINAS accredited laboratory.

3.2 Analyses

Suspended solids refer to small particles in the waste water. High waste water loads increase the concentration of suspended solids in the water. It should be taken in to 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 waste water. 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 waste water. 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 waste water. Mostly nitrogen is in its organic form. Kitchen waste water contains food deposits which contain nitrogen. Part of the organic nitrogen breaks up in the waste water to its inorganic form: 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.

All the analyses were performed in KVVY laboratory in Finland. All uncertainties are defined by the analyzing laboratory and are specific for each analyte. The methods and uncertainties are presented in Table 4.

Table 4. The methods and uncertainties of the analyses.

Analyse	Method	Sample	Uncertainty
Suspended solids	SFS-EN 872:2005	All	± 15 %
pH	SFS 3021:1979	All	± 0,2 unit
Total phosphorus	SFS-EN ISO 6878:2004	All	± 15 %
Total nitrogen	SFS 5505:1988	A1-4, C2-5	± 15 %
		B1-5, C1	± 10 %
		A5	± 500 µg/l
		$C5_{non.stirred}$	± 500 µg/l
BOD_7	SFS 3019,1979	All	± 20 %

3.3 Sampling

Samples were taken from sampling wells, the installation of which was arranged by Biolan Oy. Water in sampling wells was stirred before sampling to get the suspended solids mixed into the water evenly. Samples were also taken from non-stirred water in samplings B3 and C4 (for BOD_7 analysis only), B4 and C5. The samples were taken into three plastic bottles (volume 1 liter per bottle) supplied by KVVY laboratory. Non-stirred BOD_7 samples were taken into one plastic bottle (volume 1 liter per bottle).

All the sampling equipment were cleaned properly before, during and after the sampling with ultra-pure water.

3.4 Sampling schedule

The test consisted of five (5) sampling rounds (Table 5). In the first sampling, the samples were collected from the filters A and C. In samplings 3, 4, and 5 samples were collected from all filters.

Table 5. Sampling schedule.

1. Sampling	June	A1, C1
2. Sampling	July	A2, B1, C2
3. Sampling	August	A3, B2, C3
4. Sampling	August	A4, B3, C4
5. Sampling	October	A5, B4, C5

4 Results

4.1 Analysis 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 A in Table 6, for the filter B in Table 7 and for the filter C in the Table 8.

Table 6. The analysis results of all samplings for filter A. Week means the time from the material change to the sampling.

Week	Sample	Suspended solids	pH	Total phosphorus	Total nitrogen	BOD_7
		mg/l		mg/l	mg/l	mg/l
4	**A1**	34	6,9	0,46	5,6	43
5	**A2**	170	7,6	0,61	3,4	41
10	**A3**	32	7,3	0,83	3,4	27
13	**A4**	150	7,0	0,82	6,1	79
18	**A5**	34	7,3	0,37	2,4	22

Table 7. The analysis results of all samplings for filter B.

Week	Sample	Suspended solids	pH	Total phosphorus	Total nitrogen	BOD_7
		mg/l		mg/l	mg/l	mg/l
1	**B1**	130	7,1	1,6	13	87
2	**B2**	120	6,0	3,7	16	340
6	**B3**	330	7,0	3,2	22	260
6	**B3**$_{\text{non-stirred}}$					150
11	**B4**	150	6,9	3,4	18	150
11	**B4**$_{\text{non-stirred}}$	35	7,0	1,8	12	99

Table 8. The analysis results of all samplings for filter C.

Week	Sample	Suspended solids	pH	Total phosphorus	Total nitrogen	BOD_7
		mg/l		mg/l	mg/l	mg/l
1	**C1**	270	5,2	2,7	15	97
2	**C2**	250	7,4	0,44	3,8	10
6	**C3**	110	7,3	0,79	5,5	77
10	**C4**	150	7,5	0,74	6,2	60
10	**C4**$_{\text{non-stirred}}$					21
15	**C5**	130	7,3	0,97	3,9	25
15	**C5**$_{\text{non-stirred}}$	10	7,4	0,19	<1	3,1

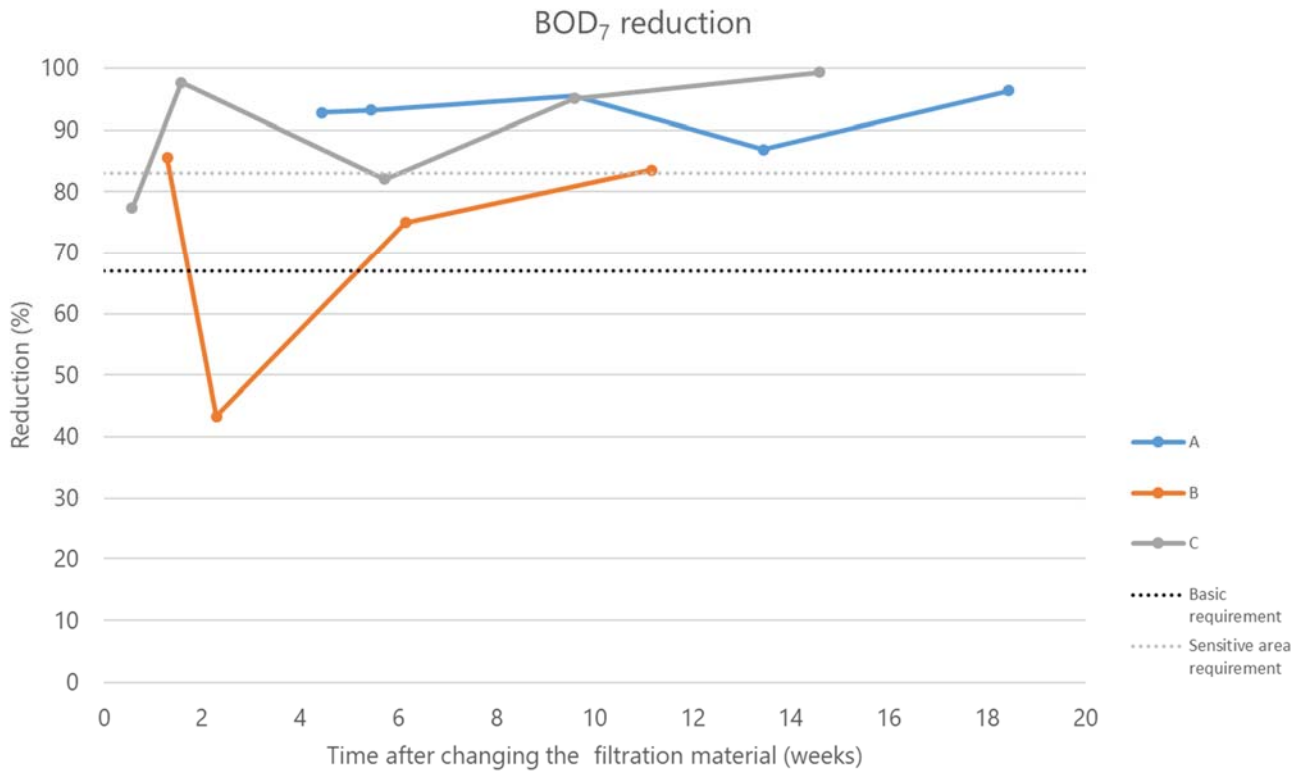
4.2 Reductions

Reductions (%) in total phosphorus, total nitrogen and BOD_7 were calculated using an estimation of the incoming load (g/p/d) according to the regulation (Table 1), as well as estimated water consumption and number of inhabitants in each location (Table 3). Where possible, also analysis results from unstirred samples were used in calculation of the reductions, due to the possible biological growth in sampling wells.

4.2.1 BOD_7 reduction

For the filters A and B in Rauma basic requirements apply. For filter C in Eura sensitive area requirements apply. BOD_7 reductions are presented in Figure 1.

Figure 1. Reductions (%) in BOD_7 based on sampling results.

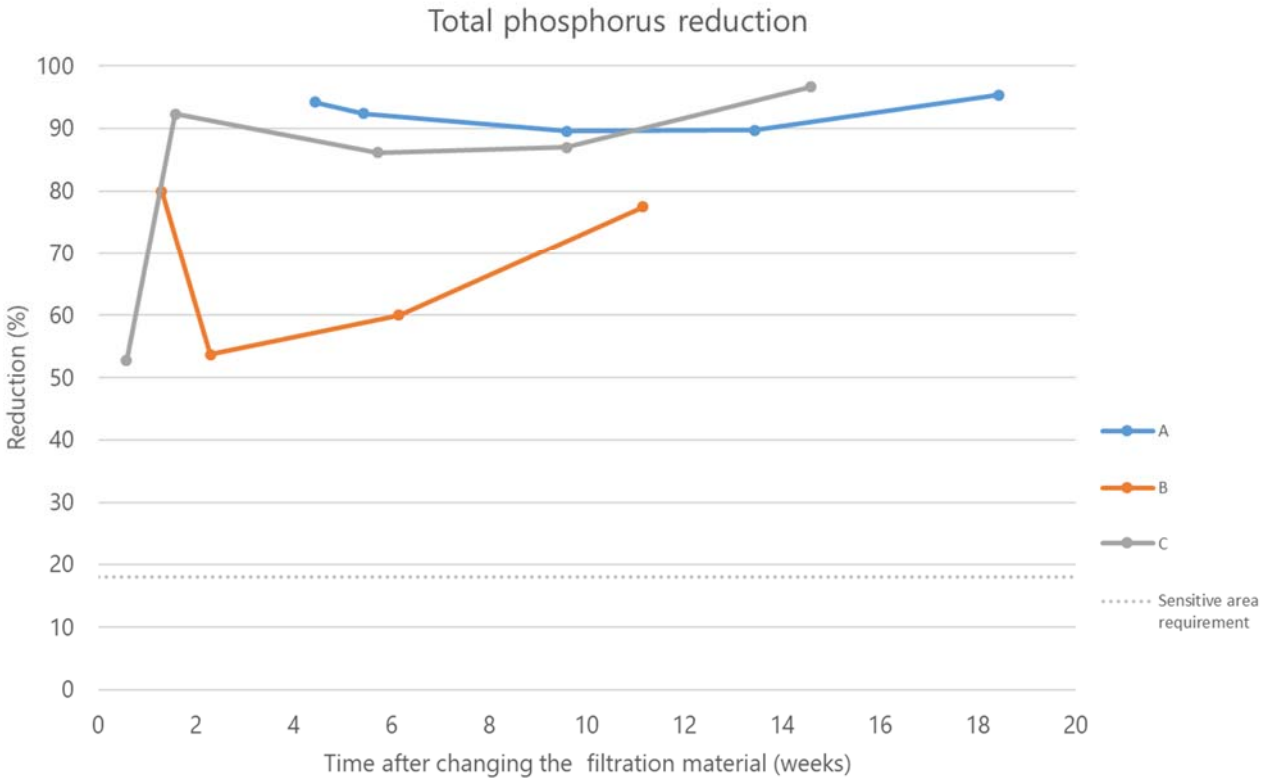


In all the samples for filter A required reductions were met. In addition, all the reductions were also over the sensitive area requirements. For filter B, excluding the second sample, the required reductions were met. For filter C, excluding the first and third sample, the requirements were met. However, all the samples from filter C met the basic area requirements.

4.2.2 Total phosphorus reduction

In Rauma there are no reduction requirements for phosphorus in grey water. In Eura sensitive are requirements apply. Total phosphorus reductions are presented in Figure 2. Reductions (%) in total phosphorus based on sampling results. Reduction requirements were met in all the samples.

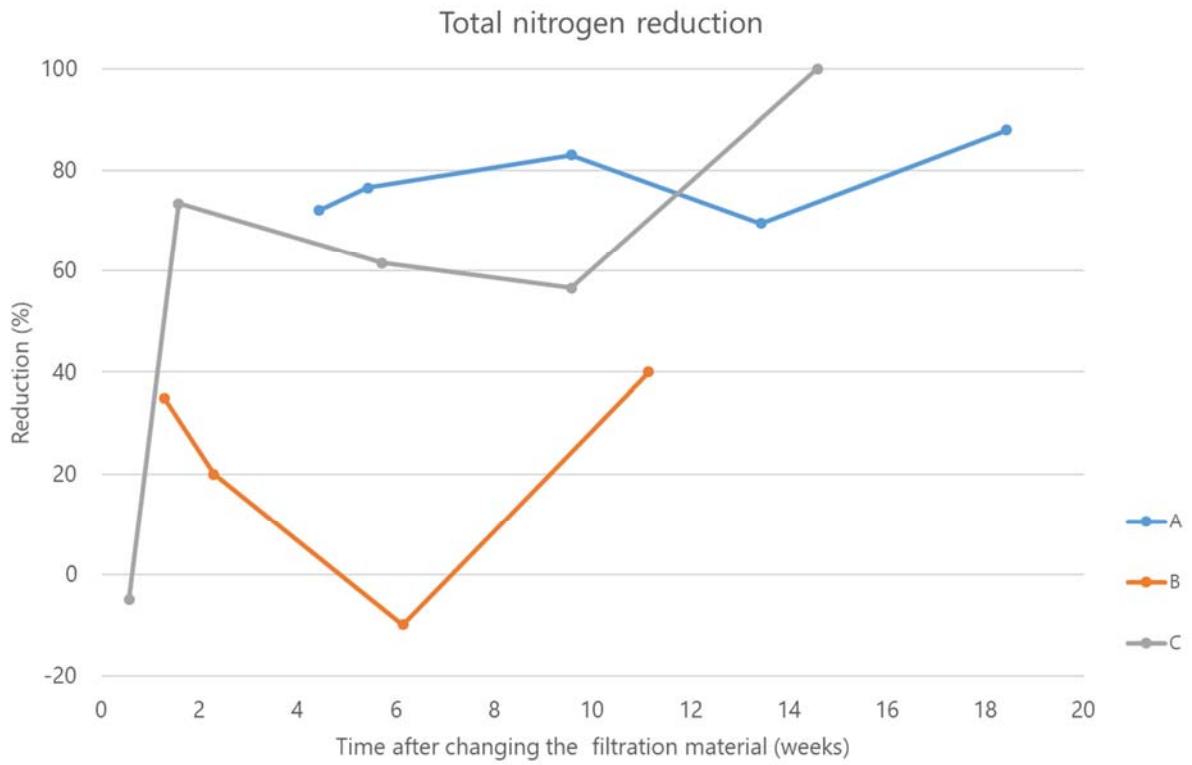
Figure 2. Reductions (%) in total phosphorus based on sampling results.



4.2.3 Total nitrogen reduction

There are no reduction requirements for nitrogen in grey water. Total nitrogen reductions are presented in Figure 3.

Figure 3. Reductions (% in) total nitrogen based on sampling results. There are no basic nor sensitive area requirements.



The negative values for nitrogen reduction are caused by occasional point loads. Because the estimated incoming load used for calculation is lower than the exceptionally high concentration of nitrogen in the outgoing water, the reduction is negative.

4.3 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 analysis results. Over the time biological growth started on the bottom and inner-walls of the sampling wells. The biological growth in the filter A was lesser than for the filters B and C, because of the structure of the sampling well. Because of the growth, also unstirred samples were taken from locations B and C. BOD_7, total nitrogen, total phosphorus and suspended solids are higher in

samples taken from stirred water. Stirring releases and lifts organic material from the bottom and sides of the sampling wells to the water phase affecting the results. Neither stirred or unstirred samples give precise results of the actual waste water quality. Instead true value is somewhere between those and most likely closed to non-stirred sample.

The reductions are calculated using an estimation of the incoming load, as no samples were taken from the incoming water. Because the estimated incoming load is an average, occasional point loads can make the reduction seem lower than it is. Estimation was used instead of incoming samples, because it wasn't possible to take samples from the incoming waste water.

Filter material is calculated to maintain its cleaning capacity for 100 days of use. All premises are irregularly inhabited so that within 100 days period the amount of actual days of use might differ. Sampling period of the locations vary from 129 days (location A) to 78 days (location C). However, the exact amount of actual days of use in these periods is not known.

In the Finnish legislation there are requirements for basic and sensitive areas. There results are compared to these values. Biolan grey water filter 70 met all the required reductions were met in both categories.

For Biolan grey water filter Light, BOD_7 reduction in the sample taken 2 weeks after the filtration material was changed did not met the criteria. This is most probably caused by an occasional point load, because the required reductions in other samples taken from filter B were met.

For Biolan grey water filter 125, BOD_7 the reductions were good and met the basic treatment requirements for BOD_7. However, the samples taken after 2 and 5 weeks of use did not meet the required for sensitive areas. All samples in all locations met the required reductions for total phosphorus and total nitrogen.

The grey waste water composition was different in different testing sites. These results cannot be used to compare filters to each other but how they manage in specific use. Unfortunately, the knowledge of different waste water qualities is only estimation as the water quality and use was not monitored in this study.

Biolan grey water filter Light can be used in basic requirement areas, but is not neccessarily in sensitive areas. Biolan grey water filter 70 and 125 can be used to basic and sensitive areas. The selection of right filter type depends also on the water use inside the premise.

5 List of references

209/2011. Finnish legal regulation on domestic waste water treatment outside the sewerage system (In Finnish)

City of Eura. 2014. Regulations concerning environmental protection in Eura, Köyliö and Säkylä 2014 (In Finnish)

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