Full scale nanofilter treatment of Urban Source Separated Greywater in Helsingborg, Sweden, and its Potential for Reuse

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Highlights:

- 65 m3/day urban greywater has been treated for 3 years in Helsingborg Sweden.
- Biological treatment and nanofiltration of greywater produce a high enough quality to meet standards established by the EU for non-potable reuse.
- Extended monitoring is needed to ensure drinking water quality standards are met.
- The intended reuse (i.e. drinking water or irrigation) influences what parameters need to be monitored.

Keywords: Source Separation; Water Reuse; Greywater

INTRODUCTION

With water scarcity becoming an all-too-common occurrence across the planet, alternative sources of water are needed to meet demands (Lee & Jepson, 2020). One potential source to reduce water stress is greywater, which consists of all domestically produced wastewater with the exception of what is generated from the toilet. This relatively clean (Shaikh & Ahammed, 2020) greywater fraction allows for more targeted treatment of greywater to meet a higher standard than a traditional municipal wastewater.

In line with these trends, the city of Helsingborg, Sweden has developed a new city district where urban source separated wastewater is collected via three pipes: greywater, blackwater (from the toilet), and ground up food waste. These three wastewaters are treated separately at the resource recovery facility called RecoLab. Greywater is treated with a two-stage anaerobic-aerobic biological treatment system and sedimentation followed by 10 µm drum filtration and 400 Da hollow fiber nanofiltration (NX Filtration, MW200).

This study aims to assess the potential for greywater reuse in a European context based on existing legislation at the EU level and the current effluent greywater quality from RecoLab.

METHODOLOGY

Nanofilter permeate samples from the greywater treatment line were taken weekly and analyzed for total nitrogen (TN), ammonia (NH_4), nitrate (NO_3), nitrite (NO_2), total phosphorous (TP), chemical oxygen demand (COD), and pH between July 7th 2021 and March 27th 2024 (n=70) using Hach Lange cuvettes. Nanofilter permeate samples were also taken monthly and analyzed for E. Coli, coliform bacteria, intestinal enterococci, and heavy metals at an external laboratory between November 13th 2023 and March 21st 2024 (n=5). The resulting analyses were then compared to the proposed EU Urban Wastewater Treatment Directive (2022) , the EU Bathing Water Directive (2006), the EU Water Reuse Directive (2020b), and the EU Drinking Water Directive (2020a), see Table 1. After analysis it was discovered that some nanofilter columns had started leaking and therefore microbial presence was higher than when nanofilters were not leaking, leading to large differences between pathogen sampling events.

RESULTS

Nanofilter permeate from greywater treatment (Table 1) satisfies the requirements of the Urban Wastewater Treatment Directive for environmental release and the requirements for agricultural irrigation as a class C or D water from the water reuse directive as well as the requirements for inland bathing water in regard to parameters that are currently monitored. Permeate from the nanofilters has an average concentration of 3.1 mg/L TN, 0.3 mg/L TP, 14 mg/L COD, pH of 7.8, and no detectable coliform bacteria or enterococci.

When filters are leaking, the presence of pathogens is in the range of 500 cfu/100 mL. When nanofilters were not leaking, the permeate quality met standards for all irrigation uses as well as that of coastal bathing water in addition to the standards listed above. Though the current monitoring at RecoLab does not cover all parameters listed in the Drinking Water Directive, heavy metals are not present in concentrations above those specified in the directive in nanofilter permeate and only ammonium concentrations and pathogens failed to meet the specified guidelines. A more in depth analysis of the treatment stages at RecoLab from the first two years of operation concluded that nanofilters act redundant to biological treatment in regards to nutrient removal and help to maintain a high quality effluent, even if biological treatment is disturbed (Hall et al., 2024).

Table 1. Selected regulation limits for different water reuse cases compared to RecoLab Nanofilter Permeate. Green text means standard is achieved, red means standard is not achieved, and orange means the standard is likely achieved.

Parameter	*RecoLab Nanofilter Permeate*	*Discharge*	*Bathing*	*Irrigation*	*Drinking*
E. Coli	**<10 cfu/100 mL no leaks 510 cfu/100 ml when leaking**	-	500-1000 cfu/100 mL Inland 100-200 cfu/100 mL Coastal	≤10 class A ≤100 class B ≤1000 class C ≤10000 class D	Detectable
Intestinal Enterococci	**<10 cfu/100 mL**	-	-	-	Detectable
Coliform Bacteria	**<10 cfu/100 mL no leaks 655 dfu/100 mL with leaks**	-	-	-	Detectable
TN	**3.1 mg/L**	6 mg/L	-	-	-
NH4-N	**1.1 mg/L**	-	-	-	0.5 mg/L
NO3-N	**1.7 mg/L**	-	-	-	50 mg/L
NO2-N	**0.02 mg/L**	-	-	-	0.1 mg/L at production plant 0.5 mg/L at user
TP	**0.3 mg/L**	0.5 mg/L	-	-	-
Organic Carbon	**14 mg/L COD**	125 mg/L COD 25 mg/L BOD_5 37 mg/L TOC	-	≤10 mg/L BOD_5 class A 25 mg/L BOD_5 classes B, C, and D	No abnormal changes
pH	**7.8**	-	-	-	<10,5 at production plant 6.5-9.5 at user
Mercury	**<5 ng/L**	-	-	-	1 µg/L
Arsenic	**0.49 µg/L**	-	-	-	5 µg/L
Lead	**<0.2 µg/L**	-	-	-	5 µg/L
Manganese	**<0.03 µg/L**	-	-	-	50 µg/L
Organic Micropollutants	**80% Removal***	80% removal	-	-	See Legislaton for detail

*(Rutten, 2024)

CONCLUSIONS

It can be concluded that nanofilter permeate from greywater treatment at RecoLab shows promise in its ability to be reused from a technical perspective. The scalability of this technology as well as the high effluent quality makes it possibly to adapt this style of treatment so that it can be implemented in large urban settings around the world so that water can be reused and stress on drinking water networks can be reduced. Increased monitoring and the repairing of the nanofilter units at RecoLab will allow for a more certain assessment of the ability to reuse nanofilter permeate in a potable setting.

REFERENCES

Directive 2006/7/EC concerning the management of bathing water quality, 37 (2006). https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02006L0007-20140101

Directive (EU) 2020/2184 on the Quality of Water Intended for Human Consumption, 1 (2020). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020L2184

Hall, A., Widén, A., Edefell, E., Davidsson, Å., & Kjerstadius, H. (2024). Treatment of greywater with nanofiltration for nutrient removal – Two years experience from Helsingborg. *Water Practice and Technology*.

Lee, K., & Jepson, W. (2020). Drivers and barriers to urban water reuse: A systematic review. *Water Security*, *11*, 100073. https://doi.org/https://doi.org/10.1016/j.wasec.2020.100073

Proposal for a Directive of the European Parliament and of the Council concerning Urban Wastewater Treatment (recast), (2022/0345(COD)). https://environment.ec.europa.eu/publications/proposal-revised-urban-wastewater-treatment-directive_en

Regulation (EU) 2020/741 on Minimum Requirements for Water Reuse, 32 (2020). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0741&from=EN

Rutten, S. (2024). Nanofiltration of greywater for micropollutant removal University of Twente].

Shaikh, I. N., & Ahammed, M. M. (2020). Quantity and quality characteristics of greywater: A review. *Journal of Environmental Management*, *261*, 110266. https://doi.org/https://doi.org/10.1016/j.jenvman.2020.110266