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Grey water treatment by using membrane filtration

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Abstract

This paper evaluated the performance and suitability of resources and nutrients oriented decentralized grey water treatment system which uses a submerged spiral wound module. This grey water treatment system is aimed at treating and recovering the resources present in the wastewater. The study revealed that the UF membrane filtration system was able to maintain a permeate flux between 6 and 10 L/m²/h. TOC can be reduced from the influent value of 161 to 28.6 mg/L in the permeate, meaning an average elimination rate of 83.4%. In addition, soluble nutrients such as ammonia and phosphorus can pass through the UF membrane and remain in the permeate. The total nitrogen and total phosphorus in the permeate were 16.7 and 6.7 mg/L respectively. The permeate was low in turbidity (below 1 NTU) and free of suspended solids and E. coli and had an excellent physical appearance. The permeate can be used in gardening and agriculture for irrigation and soil fertilization or alternatively for toilet flushing after disinfection. The retentate generated in this system can be treated with black water and kitchen waste in an anaerobic digester at a later stage for producing biogas or compost.

Keywords: Direct membrane filtration, grey water, open channel spiral module, water reuse

1. Introduction

As water is becoming a rare resource, the onsite reuse and recycling of grey water is practiced in many countries as a sustainable solution to reduce the overall urban water demand (Eriksson *et al.* 2002; Li *et al.* 2003, Friedler & Hadari 2006). Grey water is defined as the urban wastewater that includes water from baths, showers, hand wash basins, washing machines, dishwashers and kitchen sinks, but excludes input from toilets (Jefferson *et al.* 1999; Otterpohl *et al.* 1999; Eriksson *et al.* 2002; Ottoson & Stenstro" m 2003). Grey water constitutes 50–80% of the total household wastewater (Eriksson *et al.* 2003; Friedler & Hadari 2006). In terms of organic contents, grey water shows similar characteristics to that of the entire municipal wastewater (Eriksson *et al.* 2002; Nghiem *et al.* 2006). As urine is not included in grey water, it has a limited amount of nitrogen, mainly those derived from organic nitrogen in particulate form (Elmitwalli & Otterpohl 2007). A number of technologies have been applied for grey water treatment worldwide, varying in both complexity and performance. However, most of the grey water treatment plants include a biological step and the performance of biological treatment can be affected, especially at small scale, by the variability in strength and flow of the grey water (Pidou *et al.* 2008). The high COD:BOD ratio of the grey water and the deficiency of both nitrogen and trace nutrients in the grey water can further limit the treat efficiency of the biological processes (Jefferson *et al.* 2001). Furthermore, a disadvantage of the biological treatments is that nutrients, which are beneficial for plant growth, are partially lost due to biochemical transformation. Organic materials, which can be applied for biogas production, are also eliminated by biochemical transformation.

2. Materials and Methods

Experimental set up

The grey water used in this study was collected from the ecological settlement in Lubeck, Flintenbreite. It includes wastewater from baths, showers, hand wash basins, washing machines, dishwashers and kitchen sinks. A two-step septic tank was applied for pre-treatment to remove larger particles, hair, oil and grease. The effluent from the septic tanks was then fed into the submerged spiral wound membrane filtration system. A schematic diagram of the grey water treatment system is shown in **Figure 1**. The submerged membrane grey water treatment unit consists of three compartments, each with a volume of 0.5m³. The first, second and third compartment act as the balance tank, the membrane filtration tank and

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the permeate collection tank. Air was introduced intermittently through a fine bubble membrane diffuser installed directly

below the membrane module in order to provide an uplifting flow of bubbles which scour the membrane surface to prevent the membrane from fouling. A vacuum pump was applied to pump the permeate through the permeate collection channel to the permeate collection tank. A submerged pump placed in the permeate collection tank was used for backwashing the membrane. A Rochem open-channel spiral-wound membrane module with a total

membrane surface of 8.2m² and a normalized pore size of 0.0062 mm is submerged into the membrane filtration tank. Once the concentration of suspended solids in the membrane filtration tank reached 3,000 mg/L, the filtration cycle was terminated and the retentate can be discharged and treated together with black water and kitchen waste in an anaerobic digestion system. This membrane filtration system was run at a constant trans-membrane pressure (TMP) of 0.12 bars. Details on the membrane module, membrane material and the membrane operation mode are listed in **Table 1**.

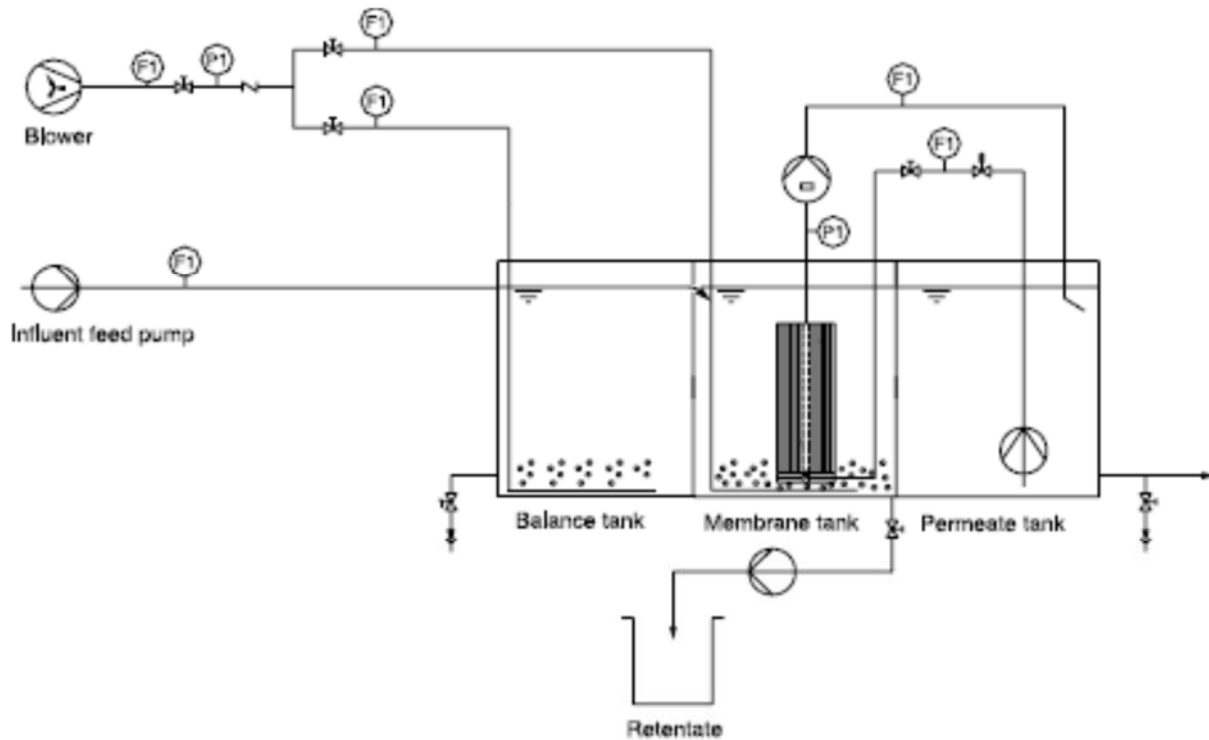


Figure 1 | A schematic diagram of the grey water treatment system.

Table 1 | Characteristic of membrane module and operation conditions

Characteristics

| | |
|--|--|
| Membrane module configuration | Open channel spiral wound module |
| Membrane material | Polyacrylonitrile membrane |
| Membrane pore size | 0.0062 μm |
| Initial flux (deionised water at 25°C and 0.1 bar) | 200 L/m ² h |
| Membrane hydrophobicity | Hydrophilic |
| Membrane surface per module | 8.2 m ² |
| Feed side spacer thickness | 3 mm |
| Module diameter | 0.2 m |
| Module length | 1.0 m |
| Number of modules | 1 |
| Filtration flux | 10 L/m ² h |
| Filtration duration | 10 minutes |
| Backwashing duration | 30 seconds |
| Membrane aeration | 3 Nm ³ /h (40 seconds on/ 20 seconds off) |

Analytical Methods

The total organic carbon (TOC) and total nitrogen (TN) levels were analyzed with a TOC/TN analyzer (multi N/C3000, Analytic/Jena Company). For the analysis of TOC fractions, the effluent of the septic tanks was centrifuged for 10 minutes at 3,000 rpm to separate suspended solids and supernatant. The supernatant was filtered through a 0.45 mm membrane filter to separate colloids from dissolved TOC. The suspended TOC and colloid TOC were calculated from the difference between the total TOC and supernatant TOC, and between the supernatant TOC and dissolved TOC. $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$ were measured using a reflectometer. The total phosphorus (TP) and orthophosphate levels were measured with Dr. Lange cuvette tests. Electrical conductivity, temperature and pH level were measured using probes. The turbidity was measured with a Hach 2100P portable turbidity meter. The suspended solids were analyzed following the German Standard Method DIN38414. Chromocult Coliform Agar developed by Merck was used to determine the amount of *E. coli* in this experiment. Colonies of *E. coli* were characterized by dark-blue to purple spots after the sample had been incubated for 24 hours at a temperature of 36°C. The dissolved organic carbon in permeate was characterized according to a liquid chromatography organic carbon detection method (DOCLABOR Dr. Huber). HW50S column was used in the study due to its good resolution for organic substances with low molecular weight.

3. Results and Discussions

As the experimental results showed similar trends in each filtration cycle, only the results obtained from two consecutive filtration cycles (14 days per cycle) are presented in this paper. The analysis of the major parameters, including temperature, pH, turbidity, electrical conductivity, TOC, TN, $\text{NH}_4\text{-N}$, organic N, $\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$, TP, ortho $\text{PO}_4\text{-P}$ and particulate

$\text{PO}_4\text{-P}$ in feed and permeate, was performed between March and May 2007. The characteristics of the influent and effluent are summarised in **Table 2**.

TOC fractions and TOC Removal

Our results showed that the suspended TOC, colloid TOC and soluble TOC constitute 30, 34 and 36% of the total TOC respectively (date not shown). Compared with the results of Elmitwalli & Otterpohl (2007), the particulate TOC (suspended + colloid) was reduced by 16% in this study. This difference was mainly a result of the suspended solids settling in the septic tanks whereas Elmitwalli & Otterpohl (2007) have used raw grey water. The total TOC was reduced from the influent value of 161 to 28.6 mg/L in the permeate, meaning a reduction rate of 83.4% (**Table 2**). As the median membrane pore size selected in this study was 0.0062 mm, all suspended TOC, most of the colloid TOC and part of the soluble TOC were rejected by the membrane. Ramon *et al.* (2004) reported a low-strength grey water treatment system with direct nanofiltration membrane. In Ramon *et al.*'s study (2004), the membrane with a molecular weight cut off of 0.2 kDa was able to achieve an organic removal rate of 93%, showing that the pore sizes of the membranes have an important impact on the organic removal efficiency. After two weeks of filtration, the retentate TOC in the membrane tank increased continuously to around 890 mg/L at the end of each filtration cycle (Figure 2). Similarly, in the membrane filtration tank, an

increasing trend was found with the TOC of the supernatant (Figure 2). Despite the rise in the levels of the TOC of both the retentate and the supernatant, the level of TOC in the permeate remained relatively constant, as shown in **Figure 2**. A satisfactory removal of organics was achieved by direct UF membrane filtration, confirming that the suspended TOC and colloid TOC constitute the majority of total TOC in grey water. Our results were similar to the findings by Shin *et al.* (1998), who also confirmed that grey water was low in soluble organic carbon. However, they were contradictory to the findings of Jefferson *et al.* (1999), who claimed that grey water is relatively low in suspended solids and it has a greater proportion of soluble organic carbon. At the end of each filtration cycle, the concentration of suspended solids in the membrane filtration tank increased to around 3,000 mg/L. The concentrations of TOC and suspended solids in the retentate were lower than the theoretical values calculated by mass balance, indicating that a partial biodegradation of the organic substances occurred as a result of introducing aeration

Table 2 | Compositions of the influent (effluent of the 2-step septic tanks) grey water and the permeate

| Parameter | Influent | Effluent |
|---|-------------|-------------|
| Temperature (°C) | 20 ± 0.3 | 21 ± 0.3 |
| pH (-) | 7.5 ± 0.5 | 7.2 ± 0.2 |
| Turbidity (NTU) | 140 ± 12 | 0.5 ± 0.3 |
| Electrical conductivity (µS/cm) | 1,115 ± 110 | 1,200 ± 120 |
| TOC (mg/L) | 161 ± 20 | 28.6 ± 4 |
| TN (mg/L) | 16.5 ± 2.3 | 16.7 ± 1.6 |
| $\text{NH}_4\text{-N}$ (mg/L) | 10.1 ± 2.5 | 11.8 ± 1.8 |
| Organic N (mg/L) | 6.4 ± 1.8 | 4.5 ± 1.5 |
| $\text{NO}_3\text{-N}$ (mg/L) | <0.01 | <0.1 |
| $\text{NO}_2\text{-N}$ (mg/L) | <0.01 | <0.1 |
| TP (mg/L) | 9.7 ± 0.9 | 6.7 ± 1.0 |
| Ortho $\text{PO}_4\text{-P}$ (mg/L) | 7.5 ± 0.6 | 5.9 ± 0.8 |
| Particulate $\text{PO}_4\text{-P}$ (mg/L) | 2.2 ± 1.2 | 0.6 ± 1.0 |

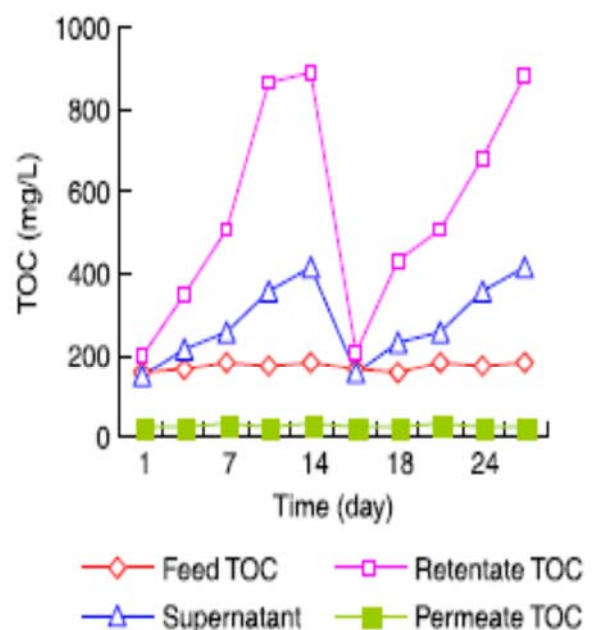


Figure 2 | Reduction of TOC by the submerged UF membrane filtration system.

LC-OCD chromatography

As shown in **Figure 3**, humic substance (HS) (21.8%), building blocks (BB) (19.6%), low molecular neutrals (LMN) (19.4%) and lowmolecular acids (LMA) (12.4%) are the major organic substances in the permeate. Polysaccharide (PS) represents only 2.3% of the total chromatographable organic carbon. Other organic substances accounting for the remaining 24.5% cannot be detected by the LC-OCD method. Many fatty acids and fatty acid esters are used in the manufacturing of detergents, personal care products and food oils. Eriksson *et al.* (2003) found that long-chain fatty acids represent the predominant portion of gas-chromatographically detectable organics in the untreated grey water. Being relatively hydrophobic, these compounds cannot be detected by the LC-OCD method and can be significant in the remaining 24.5%.

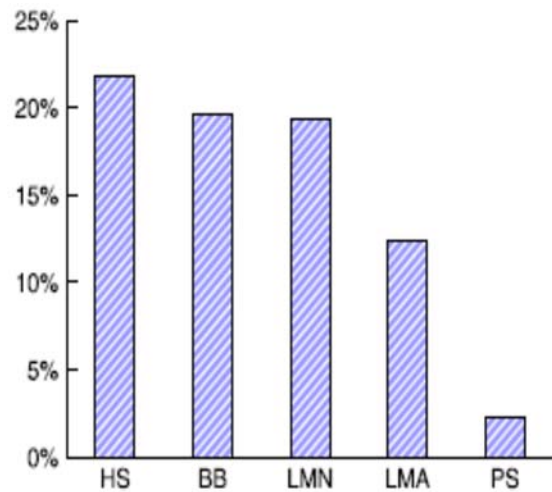


Figure 3 | LC-OCD chromatography of the permeate from the submerged UF membrane filtration system.

Nitrogen Removal

The TN concentration in our study varied from 14.2 to 18.8mg/L with an average value of 16.5mg/L, whereby ammonia nitrogen constituted 61% of the total nitrogen (Table 2). The study led by Elmitwalli and Otterpohl (2007) revealed that the average TN concentration in grey water was 27.2mg/L and the NH₄-N concentration was 4.2mg/L. The concentration of the nitrogen is lower in grey water compared to the household wastewater since no urine is present (Henze *et al.* 2000). The nitrogen in grey water mainly originates from protein contained in food residues, household cleaning products, and personal care products (Del Porto & Steinfeld 2000). In comparison with Elmitwalli & Otterpohl's study (2007), the TN was reduced by 39% owing to the sedimentation of particulate organic nitrogen in the septic tanks. The increased ammonia concentration can be explained by the fact that part of the particulate organic nitrogen was reduced to ammonia nitrogen under the anoxic condition in the septic tanks. As for this membrane filtration system, there was very little effect for the removal of nitrogen. The average TN in permeate was 16.7mg/L. As seen in **Figure 4**, the particulate organic nitrogen was rejected by the membrane, letting the TN concentration in the retentate rise continuously. As the dissolved oxygen (DO) concentration in the membrane tank was maintained at a low level (DO, 1mg/L), the particulate organic nitrogen might be reduced to ammonia nitrogen, causing a slightly higher ammonia concentration in the permeate compared to the influent ammonia concentration.

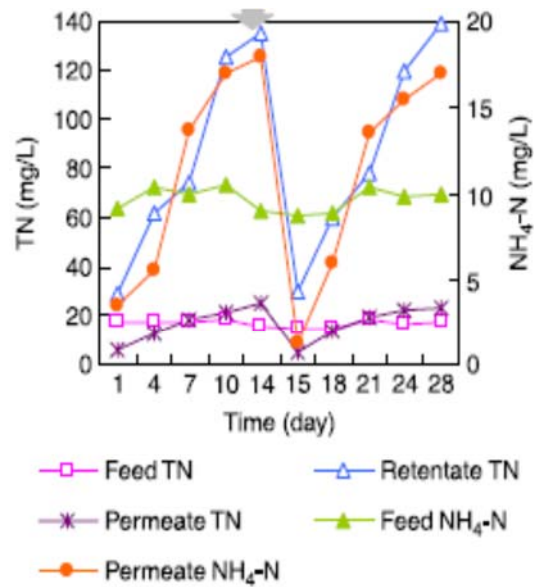


Figure 4 | Reduction of nitrogen by the submerged UF membrane filtration system.

Phosphorus Removal

The mean total phosphorus (TP) and orthophosphate concentrations found in the feed water were 9.65 and 7.49mg/L, respectively (Table 2). The average TP concentration in Elmitwalli & Otterpohl's study (2007) was 9.8mg/L, of which the orthophosphate concentration and particulate phosphorus concentration constituted 8.0 and 1.8mg/L, respectively. Compared with the study of Elmitwalli & Otterpohl (2007), the septic tanks had no influence on the removal of phosphorus. This can be explained by the fact that particulate phosphorus in grey water constitutes less than 30% of the TP, and is largely in colloid form resulting in ineffective removal by sedimentation in the septic tanks. Due to the uses of phosphorus containing detergents, the phosphorus concentration in grey water is present at similar levels compared to the entire municipal wastewater. The average TP in permeate was 6.7 mg/L with an average orthophosphate concentration of 5.9 mg/L. At the end of each filtration cycle, the retentate TP increased continuously from the initial value of 9.65 mg/L to around 40 mg/L (**Figure 5**).

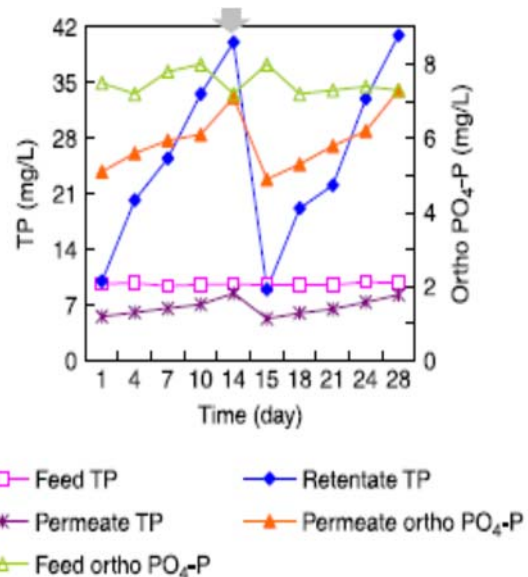


Figure 5 | Reduction of phosphorus by the submerged UF membrane filtration system.

Membrane flux

As shown in **Figure 6**, the submerged membrane filtration system was able to maintain an initial permeate flux of 10 L/m²/h, which decreased to around 6 L/m²/h after two weeks operation. Instead of suspended solids, dissolved organic matter was found to be a major cause of membrane fouling. Soluble and colloid matter are assumed to be responsible for membrane pore blockage, whilst suspended solids account mainly for cake layer resistance, which can be removed by the cross flow effect introduced by the intermittent aeration. It was observed that the DOC in the membrane filtration tank increased from the initial value of 55 mg/L to nearly 200 mg/L at the end of each filtration cycle (data not shown). This study showed that the decrease in the membrane flux correlated very well to the rise in the DOC concentration in the membrane filtration tank. A backwashing was carried out to remove the reversible membrane fouling caused by the gross solids attached to the membrane surface and by the colloids in the membrane pores. At the end of each filtration cycle, the membrane was maintained through alkaline chemical cleaning in order to remove any irreversible membrane fouling. After the maintenance procedure, the membrane flux was found to recover to the initial value. In the study from Lesjean & Gnirss (2006), a submerged plate and frame membrane bioreactor (MBR) grey water treatment unit was operated under low SRT and low HRT condition and was able to achieve a stable permeate flux of 7 L/m²/h. The membrane flux achieved in this study was comparable to that from Lesjean & Gnirss (2006). However, the duration of each filtration cycle was relatively short. This study was in agreement with the results from Ahn *et al.* (2001), who demonstrated that the MBR system performed better than the direct membrane filtration system in terms of filtration characteristics.

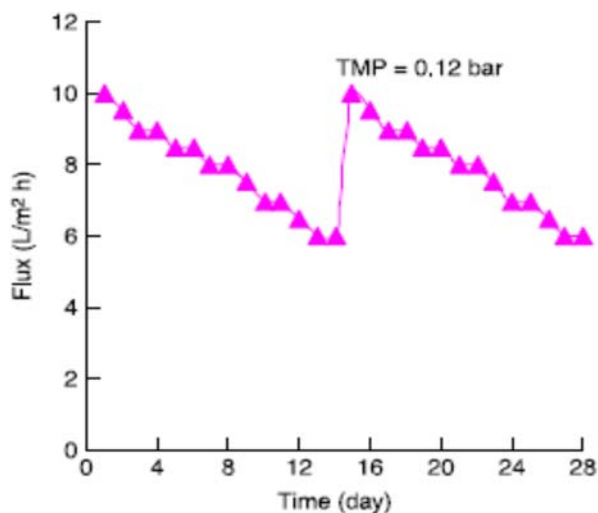


Figure 6 | Variation of the membrane flux in two consecutive filtration cycles.

Removal of conductivity, turbidity, colour and Pathogens

Many soluble salts derived from the drinking water supply, human diet and household chemicals have been found in grey water. Most of the soluble salts are sodium compounds such as sodium chloride used in the human diet, sodium nitrate used as meat preservatives and in food preparation, and sodium sulfate, sodium tri-polyphosphates and sodium carbonates used in laundry products (Patterson 2006; Carden *et al.* 2007). The concentrations of soluble salts stand in

close correlation with both electrical conductivity and sodium adsorption ratio (SAR). The conductivity of the feed water, retentate and the permeate in our study showed insignificant variation, ranging from 1,100 to 1,200 μ S/cm (Table 2). Application of irrigation water with excessive sodium in relation to calcium and magnesium concentrations can destroy the soil structure and maybe toxic to some crops. The metal elements in the feed and the permeate were not analysed in our study. However, based on the study conducted by Palmquist & Hanæus (2005), the SAR of the separately collected raw grey water from ordinary Swedish households is 3.37, which poses no risks for use in irrigation. Turbidity was reduced from 140 NTU in the feed water to less than 1 NTU in the permeate (Table 2). The removal of turbidity of up to 100% by means of membrane has been observed (Ahn *et al.* 1998; Ramon *et al.* 2004). Due to the exclusion of urine in grey water, the permeate was colourless. Chiemchaisri *et al.* (1992) reported that an MBR installed with two types of membranes (pore size 0.1 and 0.03 μ m) was able to achieve the same 4 to 6 log removal of the seeded Qb coliphage at a stable stage although the membrane pore sizes are larger than the size of viruses (25 nm). Due to the smaller membrane pore size (0.0062 μ m) used in this study, it is therefore not surprising that the permeate was free of SS, and that the existence of *E. coli* could not be determined.

Comparison of the system performance with membrane bioreactor and constructed wetland

The direct UF membrane filtration system was able to reduce the TOC by 83.4% and this value is comparable to the organic reduction rates of the MBR grey water treatment system (Lesjean & Gnirss 2006) and the constructed wetland grey water treatment system (Li *et al.* 2003). The soluble nutrients such as ammonia and phosphorus can pass through the UF membrane and remain in the permeate. The total nitrogen and total phosphorus in the permeate were 16.7 and 6.7 mg/L, respectively. With regard to the MBR grey water treatment system, the total nitrogen was reduced from 21 mg/L in the feed to 10 mg/L in the permeate and the total phosphorus was reduced from 7.4 mg/L in the feed to 3.5 mg/L in the permeate (Lesjean & Gnirss 2006). As for the constructed wetland, the TN concentration was lowered from a range of 9.7–16.6 mg/L in the feed to a range of 1.2–5 mg/L in the effluent and the TP concentration was reduced from 5.2–9.6 mg/L in the feed to 5.6–6.8 mg/L in the effluent (Li *et al.* 2003). In contrast to the MBR and the constructed wetland, nutrients (especially nitrogen) were well preserved in the permeate of the direct UF membrane filtration system.

4. Conclusions

The study shows that the total TOC was reduced by 83.4%. And the soluble nutrients can pass through the UF membrane and remain in the permeate. The permeate was low in turbidity and free of suspended solids and *E. coli* and had an excellent physical appearance. The membrane flux achieved in this study was between 6 and 10 L/m²/h. However, the duration of each filtration cycle was relative short. The permeate can be used in gardening and agriculture for irrigation and soil fertilisation. Unless the water quality requirements regarding the concentration of organic material is obligatory, the reclaimed grey water in this study can also be used for toilet flushing after disinfection. The retentate generated from this system can

later be treated together with blackwater and kitchen waste in an anaerobic treatment system to produce biogas and soil conditioner. This concept, however, is still to be tested on a pilot scale.

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6. References

- Ahn, K. H., Song, J. H. & Cha, H. Y. 1998 Application of tubular ceramic membranes for reuse of wastewater from buildings. *Water Sci. Technol.* 38(4–5), 373–382.
- Ahn, K. H., Song, K. G., Yeom, I. T. & Park, K. Y. 2001 Performance comparison of direct membrane separation and membrane bioreactor for domestic wastewater treatment and water reuse. *Water Sci. Technol.: Water Supply* 1(5–6), 315–323.
- Carden, K., Armitage, N., Winter, K., Sichone, O., Rivett, U. & Kahonde, J. 2007 The use and disposal of greywater in the nonsewered areas of South Africa: part 1—quantifying the greywater generated and assessing its quality. *Water SA* 33(4), 425–432.
- Chiemchaisri, C., Wong, Y. K., Uruse, T. & Yamamoto, K. 1992 Organic stabilization and nitrogen removal in membrane separation bioreactor for domestic wastewater treatment. *Water Sci. Technol.* 25(10), 231–240.
- Del Porto, D. & Steinfeld, C. 2000 What About Graywater, *The Composting Toilet System Book*. The Center for Ecological Pollution Prevention (CEPP), Concord, Massachusetts, pp. 167–193.
- Elmitwalli, T. A. & Otterpohl, R. 2007 Anaerobic biodegradability and treatment of greywater in upflow anaerobic sludge blanket (UASB) reactor. *Water Res.* 41(6), 1379–1387.
- Eriksson, E., Auffarth, K., Henze, M. & Ledin, A. 2002 Characteristics of grey wastewater. *Urban Water* 4(1), 85–104.
- Eriksson, E., Auffarth, K., Eilersen, A-M., Henze, M. & Ledin, A. 2003 Household chemicals and personal care products as sources for xenobiotic organic compounds in grey wastewater.
- Water SA* 29(2), 135–146.
- Friedler, E. & Hadari, M. 2006 Economic feasibility of on-site greywater reuse in multi-storey buildings. *Desalination* 190(1–3), 221–234.
- Henze, M., Harremoes, P., la Cour Jansen, J. & Arvin, E. 2000 *Wastewater Treatment, Biological and Chemical Processes*, 3rd edition. Springer Verlag, Berlin.
- Jefferson, B., Laine, A., Parsons, S., Stephenson, T. & Judd, S. 1999 Technologies for domestic wastewater recycling. *Urban Water* 1(4), 285–292.
- Jefferson, B., Burgess, J. E., Pichon, A., Harkness, J. & Judd, S. 2001 Nutrient addition to enhance biological treatment of greywater. *Water Res.* 35(11), 2702–2710.
- Lesjean, B. & Gnirss, R. 2006 Greywater treatment with a membrane bioreactor operated at low SRT and low HRT. *Desalination* 199(1–3), 432–434.
- Li, Z., Gulyas, H., Jahn, M., Gajurel, D. R. & Otterpohl, R. 2003 Greywater treatment by constructed wetland in combination with TiO₂-based photocatalytic oxidation for suburban and rural areas without sewer system. *Water Sci. Technol.* 48(11), 101–106.
- Nghiem, L. D., Oschmann, N. & Schafer, A. I. 2006 Fouling in greywater recycling by direct ultrafiltration. *Desalination* 187(1–3), 283–290.
- Otterpohl, R., Albold, A. & Oldenburg, M. 1999 Source control in urban sanitation and waste management: ten systems with reuse of resources. *Water Sci. Technol.* 39(5), 153–160.
- Ottoson, J. & Stenstrom, T.A. 2003 Faecal contamination of greywater and associated microbial risks. *Water Res.* 37(3), 645–655.
- Palmquist, H. & Hanæus, J. 2005 Hazardous substances in separately collected grey- and blackwater from ordinary Swedish households. *Sci. Tot. Environ.* 348(1–3), 151–163.
- Patterson, R. A. 2006 Consideration of soil salinity when assessing land application of effluent or greywater. Accessed in 2008 at <http://www.lanfaxlabs.com.au>
- Pidou, M., Avery, L., Stephenson, T., Jeffrey, P., Parsons, S. A., Liu, S., Memon, F. A. & Bruce Jefferson, B. 2008 Chemical solutions for greywater recycling. *Chemosphere* 71(1), 147–155.
- Ramon, G., Green, M., Semiat, R. & Dosoretz, C. 2004 Low strength greywater characterization and treatment by direct membrane filtration. *Desalination* 170(3), 241–250.
- Shin, H. S., Lee, S. M., Seo, I. S., Kim, G. O., Lim, K. H. & Song, J. S. 1998 Pilot-scale SBR and MF operation for the removal of organic and nitrogen compounds from greywater. *Water Sci. Technol.* 38(6), 79