An energy-efficient membrane bioreactor for on-site treatment and recovery of wastewater

SUPPLEMENTARY INFORMATION

FEED WATER

Simulated wastewater consisted of a mixture of human feces and human urine. In addition, a local soap (Bul Star Wahsing soap from Bidco Uganda Ltd) and/or calf blood was added in Phase C (for concentrations see Table S1). A simplified daily variation of feeding was implemented: 16 h of 50 regular pumping events of 5 min each approximately every 20 min, followed by 8 h without feeding (reflecting the night).

The chemical oxygen demand (COD) concentration without soap, blood and recirculation was in the order of 300–450 $g_{COD}\ m^{-3}$.

During the experimental period of 260 days, the system was fed with a mixture of concentrate (feces, urine, and water; stirred and stored in a fridge at 4 °C) and fresh water to reach the expected concentration of the wastewater. In Phase C, the additional effect of soap, blood and recirculation of the wash and flush water was tested as follows:

C1: 3.9 $g_{COD}\ p^{-1}d^{-1}$ of soap and (only from day 209) 5 $g_{COD}\ p^{-1}d^{-1}$ of calf blood.

C2 and C3: The reactors were run with 80% recirculation of the permeate water. This was achieved by using 80% of the permeate water to dilute concentrate instead of fresh water. Twenty percent of the permeate water was discharged as water loss.

SYSTEM SET-UP

The flux data were corrected for the change of viscosity with the water temperature (T). If not declared otherwise, the data in this publication are adjusted to the viscosity at 20 °C with a viscosity correction factor (VCF) of 10^x with $x = (20\text{-}T)*(T+96)^{-1}*[1.2364–1.37*10^{-3}*(20\text{-}T) + 5.7*10^{-6}*(20\text{-}T)^2]$.

$$\mathrm{Log}_{10}(\mathrm{VCF}) = \frac{20^\circ - T}{96^\circ + T} \cdot [1.2364 - 1.37 \cdot 10^{-3} \cdot (20^\circ - T) + 5.7 \cdot 10^{-6} \cdot (20^\circ - T)^2]$$

TOTAL SUSPENDED SOLIDS

The inlet total suspended solids (TSS) concentration in Phase C was around 0.8 g L^{-1} and the measured TSS concentrations in the modules are shown in Figure S1. The dotted lines refer to the theoretically estimated TSS

Table S1 | Composition of the wastewater used in the experiments. This composition mirrors the expected loading rates for one water recovery system serving ten people. Soap and blood was only added in Phase C

Compound	Loading	Assumptions
Feces	50–100 g d^{-1}	Assuming 2.5–5% of daily produced feces (2.1 kg d^{-1}) in wastewater
Urine	0.1–0.2 L d^{-1}	Assuming 1–2% of daily produced urine (10 L d^{-1}) in wastewater
Water	40–80 L d^{-1}	Assuming 50 toilet visits per day (Schouw *et al.* 2002) with 0.8–1.6 L water consumption per visit
Soap	10–20 g d^{-1}	Assuming 50 toilet visits per day with 0.2–0.4 g soap per toilet visit (own results)
Blood	60–120 mL d^{-1}	Assuming a maximum amount of blood (based on 3–6 women with concurrent menstruation and a blood excretion of 20 mL p^{-1} d^{-1} (Dasharathy *et al.* 2012). Please note that reusable menstrual pads may be washed in the wash basin

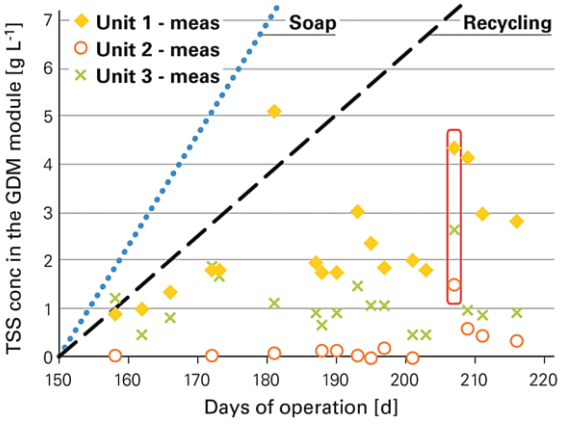

Figure S1 | TSS concentration in the GDM tanks over time (dotted lines refer to theoretical TSS accumulation due to influent concentration and biomass production with the two different inlet concentrations). The box indicates the data when the reactors were fully mixed.

concentration with different inlet COD concentrations and a COD degradation of 95% (cf. Table 2 in the paper) based on the assumptions of a conversion factor of 1.1 $g_{COD}\ g_{TSS}^{-1}$ and a yield of 0.66 g produced $COD_{biomass}$ per g $COD_{degraded}$ (Gujer 2007).

The figure shows that the measured TSS concentrations were below the estimation. Although some of the discrepancy can be explained by a non-complete mixing in the system (see the measurement points in the marked box), it seems that the sludge is to a large degree degraded within the reactors, possibly through predation.

REFERENCES

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