A novel sanitation concept: use of seawater for toilet flushing
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Introduction
Limited availability of freshwater is often an issue in both low and high income countries, especially taking place in coastal megacities. Direct use of seawater for toilet flushing can alleviate the stress on freshwater resources. Besides substantial reduction in freshwater usage, the direct use of saline water as a secondary quality water in urban environments has additional benefits, thanks to the innovative saline sanitation concept called Sulphate reduction Autotrophic denitrification and Nitrification Integrated process (SANI-process). The SANI process make use of the sulphate present in seawater which results in reduced energy demand and sludge production, leading to cheaper and more sustainable solutions (Wang et al. 2009, Lau et al. 2006)

Methods
Ameland, an island in the north of the Netherlands, experiences saviour shortage of freshwater and therefore was subject to case study which investigates the premier use of seawater for toilet flushing in the Netherlands. To study the performance of SANI process under temperate climate conditions (sewage temperature between 10 and 20°C) sulphate reduction in a two 3 litre laboratory-scale anaerobic sequencing batch reactors (SBR) was studied. One SBR operated at 10°C and the other at 20°C. Both SBRs operated at controlled pH (7.6±0.2), dissolved oxygen (DO; 0%), solid retention time (SRT; 15 days) and mixing speed (300 rpm). The SBR cycle (6 hours) consisted of gradually feeding and reaction phase (5.33h), settling (0.33h) and an effluent withdrawal phase (0.33h). Main components of the media were acetate and propionate (300 mgCOD/L) and aquarium salt (7.32 g/L=500 mg SO₄²⁻/L, reef crystals). As inoculum the activated sludge from wastewater treatment plant Amsterdam-West (Waternet, The Netherlands) and soil from the ecological garden of KWR were used. Samples collected during operation (over the feed/reaction phase) were analyzed on sulphate, sulphide, CODsubstrate (without sulphide), acetate, propionate and volatile suspend solids (VSS).
Results
The case study revealed that seawater can relatively straightforwardly be used for toilet flushing at camping sites on the Island of Ameland, reducing the freshwater demand by approximately 40%. This results in reduced requirement for water to be obtained by rather expensive desalination technology and/or less need for freshwater transport from the mainland. Theoretically, the concentration of sulphate, present in the resulting saline wastewater, is sufficient to achieve complete COD removal. The resulting production of sulphide is furthermore matching requirements for complete nitrogen removal. Introduction of this concept on the Island of Ameland seems feasible with potential to save large quantities of freshwater. Results show that the COD-removal efficiency at 10°C is by approximately one third lower then that at 20°C (Table 1). It is also interesting that propionate removal was not affected.

Table 1 Results of the anaerobic biological sulphate reduction at 10 and 20°C

<table>
<thead>
<tr>
<th>Parameter</th>
<th>10°C</th>
<th>20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD removal (%)</td>
<td>69</td>
<td>100</td>
</tr>
<tr>
<td>Propionate removal (%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Acetate removal (%)</td>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>COD/(\text{SO}_4^{2-})(g/g)</td>
<td>0.50</td>
<td>0.71</td>
</tr>
<tr>
<td>S-balance</td>
<td>98%</td>
<td>91%</td>
</tr>
<tr>
<td>COD-balance</td>
<td>97%</td>
<td>106%</td>
</tr>
</tbody>
</table>

Discussion and conclusions
The introduction of a saline sanitation concept at the Island of Ameland could lead up to 40% freshwater saving, which is significant on an island which needs supplementary freshwater supply from the mainland. The applicability of the SANI process has been demonstrated already at 30°C (Wang et al. 2009), however at 10 and 20°C, typical temperatures of wastewater in moderate climates, sulphate reduction was not demonstrated yet. Sulphate reduction occurred at 20°C, resulting in complete COD-removal in 4.5 hours. At 10°C, COD-removal was substantially lower and slower. This may be solved by increasing the hydraulic retention time (HRT) at lower temperatures. In the summer, when more tourists are visiting Ameland, the SANI-process can operate sufficiently well. In the winter period, less people visit Ameland, and thus the volume of wastewater decreases. Despite that the HRT must increase to have efficient COD removals in winter it seems not necessary to expand the plants, because of the fact that the wastewater volume decreases significantly.

The nutrient composition and temperature of Amelands wastewater are supporting the applicability of the SANI process, the final conclusion is that direct use of seawater as secondary quality water can reduce freshwater usages at Ameland, as an example of a moderate climate location, significantly.

References


Disclosures
The authors have nothing to disclose.