Simultaneous calcium phosphate granules and methane recovery from black water

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Black water (Feces + Urine)

Kitchen waste

Grey water

Conventional sewer

<table>
<thead>
<tr>
<th>Volume</th>
<th>COD</th>
<th>P</th>
<th>NH₄+</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>L·m⁻¹·d⁻¹</td>
<td>g L⁻¹</td>
<td>mg L⁻¹</td>
<td>g L⁻¹</td>
<td>g L⁻¹</td>
</tr>
<tr>
<td>6</td>
<td>6.0</td>
<td>0.6</td>
<td>79</td>
<td>300</td>
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<tr>
<td>8</td>
<td>98</td>
<td>0.7</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>330</td>
<td>5</td>
<td>12</td>
<td>0.8</td>
</tr>
</tbody>
</table>

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Resource Recovery - Oriented Sanitation

Current concept for black water treatment

Why does P accumulate in the UASB reactor?

Biomass granulation in UASB reactors

Black water treatment in UASB reactor

Influent soluble Ca

PO₄ Removal

Formation and accumulation of Ca₅(PO₄)₆ seed particles

Calcium phosphate (CaP) granules

UASB reactor

N₂ Removal

P Recovery

Upflow velocities between 100 cm h⁻¹ to 3 m h⁻¹ are generally applied

Constant selection pressure for retention of biomass agglomerates over disperse biomass, triggering formation of granules

Long hydraulic retention time (HRT), resulting in an upflow velocity of less than 1 cm h⁻¹

No selection pressure, allowing retention of fine solids, such as inorganic seed particles
Formation of CaP granules from seeds

Increase of Ca in BW

Microbial colonization

Formation of an outer biofilm

Increase of internal pH (7.4 to 8)

Enhances the crystallization of Hydroxyapatite

Preferable accumulation of CaP in the granules

Higher P accumulation by adding Ca$^{2+}$
Impact on treatment concept

Black Water

CH$_4$

1.9 LCH$_4$ L$^{-1}$ event

UASB reactor

Calcium phosphate (CaP) granules

$\text{N}_2$

$\text{P}$ accumulation

Calcium

300 mg L$^{-1}$

UASB reactor

N Removal

$\text{N}_2$

$\text{P}$ accumulation

Calcium phosphate (CaP) granules

$\text{CH}_4$

1.9 LCH$_4$ L$^{-1}$ event