Technological improvements in compact UASB/SBTF systems for decentralized sewage treatment in developing countries


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Federal University of Minas Gerais - Brazil
Acceptance of the anaerobic technology for domestic sewage treatment - updated Brazilian data

- Brazilian urban population (152.6 M inhabitants)
- Sample universe: 1439 STPs (73.7 M inhabitants)

<table>
<thead>
<tr>
<th>State</th>
<th>Treated sewage flow (m³.s⁻¹)</th>
<th>Population served</th>
</tr>
</thead>
<tbody>
<tr>
<td>DF</td>
<td>3.3</td>
<td>1.847.850</td>
</tr>
<tr>
<td>MG</td>
<td>11.8</td>
<td>6.532.306</td>
</tr>
<tr>
<td>SP</td>
<td>6.8</td>
<td>3.284.438</td>
</tr>
<tr>
<td>SC</td>
<td>1.5</td>
<td>780.559</td>
</tr>
<tr>
<td>RJ</td>
<td>1.7</td>
<td>447.327</td>
</tr>
<tr>
<td>ES</td>
<td>0.6</td>
<td>307.343</td>
</tr>
<tr>
<td>PR</td>
<td>12.4</td>
<td>6.894.283</td>
</tr>
<tr>
<td>BA</td>
<td>2.9</td>
<td>1.600.659</td>
</tr>
<tr>
<td>GO</td>
<td>0.6</td>
<td>306.972</td>
</tr>
<tr>
<td>MS</td>
<td>1.4</td>
<td>971.280</td>
</tr>
<tr>
<td>∑</td>
<td>42.8</td>
<td>22.973.017</td>
</tr>
</tbody>
</table>

UASB reactors

Introduction

13th SWWS – Athens – 2016
## UASB and post-treatment in Brazil

- **Sample universe:** 1439 STPs (9 states + Federal District)

<table>
<thead>
<tr>
<th>Process</th>
<th>Number of STPs (inhabitants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UASB</td>
<td>8,961,057</td>
</tr>
<tr>
<td>UASB + AS</td>
<td>4,302,925</td>
</tr>
<tr>
<td>UASB + TF</td>
<td>3,926,198</td>
</tr>
<tr>
<td>UASB + PP</td>
<td>2,966,773</td>
</tr>
<tr>
<td>UASB + Flotation</td>
<td>1,319,640</td>
</tr>
<tr>
<td>UASB + others</td>
<td>1,496,424</td>
</tr>
</tbody>
</table>

- **Q (m³/s):**
  - UASB: 16.3
  - UASB + AS: 8.4
  - UASB + TF: 7.0
  - UASB + PP: 5.4
  - UASB + Flotation: 2.7
  - UASB + others: 2.9

- **Total:** 637 STPs
Developing countries

- Enormous sanitation deficit
- Shortage of financial resources
- Lack of qualified personal for operation
- Need of low cost, sustainable and simplified sewage treatment systems

Combined anaerobic + simple post-treatment systems fit these criteria and can play a major role towards sustainable sewage treatment plants

Some alternatives:
- UASB + Polishing Ponds
- UASB + Wetlands
- UASB + Trickling Filters
The idea behind the proposal

UASB + TF system

Possibility of energy recovery
Lower construction costs
Lower O&M costs
Simple to operate

Central player

Introduction

13th SWWS – Athens – 2016
The idea behind the proposal

UASB + SBTF system

- Reduced sludge management
- Proper effluent quality
- Compactness (< 0.03 m²/inhab.)

### Parameter Effluent (mg.L⁻¹) Removal efficiency (%)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>&lt; 100</th>
<th>80 – 85</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOD</td>
<td>&lt; 40</td>
<td>85 – 90</td>
</tr>
<tr>
<td>TSS</td>
<td>&lt; 40</td>
<td>75 – 80</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>&lt; 15</td>
<td>60 – 90</td>
</tr>
<tr>
<td>E. coli</td>
<td>&lt; 1E05 MPN.100ml⁻¹</td>
<td>&gt; 4.0 log. units</td>
</tr>
</tbody>
</table>
Current Limitations and Constraints

Gas phase
- Waste gas
  - Can be collected and treated (ex. biofilter)

Liquid phase
- Residual carbon, ammonia and pathogens
  - Can be removed in the aerobic post-treatment of the liquid phase

Solid phase
- Scum management
  - Can be controlled inside the TPS (ex. hydrostatic removal system)
Main objective

Present a compact sewage treatment system that incorporates technological improvements matching current constraints

- Effluent quality improvements with the use of high rate settlers in the anaerobic step followed by sponge-bed tricking filters

- Procedures for scum management using a hydrostatic removal device

- The use of a cost-effective biofilter for the treatment of waste-gas
**Material and Methods**

### Waste gas
Collection: dissipation/exhaustion chambers

### Raw sewage
Preliminary treatment

### Anaerobic sludge
(As by-product)

### Final effluent
Operation without secondary settlers

### Post-treatment: Trickling filters
Use of sponge-based packing media

### Biogas
(as by-product)

### Scum
Hydrostatic removal

### High-rate settlers
Parallel inclined plates

### Waste gas
Treatment: Biofilters

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**Table: Characteristics**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unit</th>
<th>UASB reactor</th>
<th>SBTF</th>
<th>Dissipation chamber</th>
<th>Biofilter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average flow</td>
<td>m³.d⁻¹</td>
<td>45.7</td>
<td>13.8</td>
<td>45.7</td>
<td>0.3 - 1.5</td>
</tr>
<tr>
<td>Useful height</td>
<td>m</td>
<td>4.5</td>
<td>3.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Useful volume</td>
<td>m³</td>
<td>16.8</td>
<td>4.4²</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>Organic loading rate</td>
<td>kgCOD.m⁻³.d⁻¹</td>
<td>1.4</td>
<td>0.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hydraulic loading rate</td>
<td>m³.m⁻².d⁻¹</td>
<td>13.0</td>
<td>11.5</td>
<td>1448.3</td>
<td>-</td>
</tr>
<tr>
<td>Retention time</td>
<td>h</td>
<td>8.6</td>
<td>3.0</td>
<td>-</td>
<td>0.12 - 0.71</td>
</tr>
</tbody>
</table>
Material and Methods

• Improvements for the treatment of the liquid phase: UASB and TF effluent quality

Centre for Research and Training in Sanitation (CePTS)
• Improvements for the treatment of the **liquid phase**: UASB and TF effluent quality
Material and Methods

- Improvements for the treatment of the solid phase: scum management

Centre for Research and Training in Sanitation (CePTS)
Material and Methods

- **Gas phase**: waste gas treatment

Material and Methods

Composted leaves

- Blast furnace slag: 60%
- Expanded vermiculite: 40%
- Biobob®
Results

- Technological improvements regarding UASB reactors: **HR settler**

- Effluent TSS concentrations was **30% lower** with the use of high rate settlers.
- **Smaller data variability** with the use of high rate settlers was observed, even operating the system under a typical full-scale STP flow regime.

12% decrease of total COD effluent concentration
Results

- Technological improvements regarding UASB reactors: **scum management**

  - Scum accumulation coefficient varied between 5.0 and 12.3 gTS.kgCOD\(^{-1}\) applied: importance of a **proper sludge management**

  - Best discharge routine:
    - frequency of discharge of 5 days.week\(^{-1}\)
    - level of scum between 2 and 5 cm below the edge of the collection weir

  Scum volume corresponded to only **0.05%** of the sewage volume treated during two consecutive operations of scum discharge.
Results

- Technological improvements regarding UASB reactors: biofilters (waste gas)

Potential use of composted leaves and expanded vermiculite for the treatment of waste gas from UASB reactors treating domestic sewage

- The CH$_4$ conversions decreased gradually (from above 90% to below 10%) with the increase of the CH$_4$ inlet concentration and decrease of the EBRT
Results

- Technological improvements regarding SBTF

- Total coliforms and *Escherichia coli* removals: 4.3 and 3.5 log units, respectively
Final Remarks

- The operation of the UASB reactor with high rate settlers and the use of a sponge-bed trickling filter without final clarifier post-UASB reactor can lead to the production of a final effluent that can consistently comply with the discharge standards adopted in developing countries.

- The use of a hydrostatic scum removal device has shown promising and effective results, requiring a minimal level of operation and expertise.
The use of **desorption chambers** followed by **biofilters** for collection and treatment of **dissolved gases** present in the effluent of UASB reactors seems to be **appropriate** for a decentralized system applied to developing countries, although further research is needed for the **simultaneous treatment** of CH$_4$ and H$_2$S.
Thank you for your kind attention