UASB-polishing ponds design parameters. Contributions from a pilot scale study in southeast Brazil

Rafael K.X. Bastos
E.N. Rios
P.D. Bevilacqua
R.C. Andrade

Universidade Federal de Viçosa
Departamento de Engenharia Civil
- UASB reactors: BOD, COD, TSS, N, P, pathogens
- WSP: simplicity, low cost, low maintenance, robustness, and sustainability vs large land areas requirements
- UASB + WSP (post-treatment)
- WSP: BOD, COD, TSS, N, P, pathogens
The removal of BOD, nitrogen and coliforms within WSP in warm climates is well documented.

Polishing ponds (UASB+ponds) can absorb the UASB effluent's organic (nitrogen) load, so that they can be designed as maturation-like ponds, i.e. shallow ponds, aiming at pathogens (nitrogen) removal.

Polishing ponds: specific design criteria, design input parameters (??)

There will always be room for modeling under specific conditions (local/regional design criteria).
FC removal (von Sperling)

\[ K_b (\text{dispersed flow}) = 0.542 \, H^{-1.259} \]

\[ K_b (\text{dispersed flow}) = 0.917 \, (H)^{-0.877} \cdot (\text{HRT})^{-0.329} \]

\( K_b \) = first-order rate constant for \( E. \, coli \) removal \((20^\circ C) \, (d^{-1})\)

- polishing ponds: similar/higher than assumed for facultative or maturation ponds (??)
- Local design criteria
Nitrogen removal (Pano & Middlebrooks)

\[
C_e = \frac{C_0}{1 + \left[ 5,035 \times 10^{-3} \cdot (A/Q) \cdot e^{(1,540 \times (pH-6.6))} \right]} \quad T < 20^\circ C
\]

\[
C_e = \frac{C_0}{1 + \left[ (A/Q) \cdot (0.0038 + 0.000134 \cdot T) \cdot e^{(1.041+0.044 \cdot T) \cdot (pH-6.6)} \right]} \quad T \geq 20^\circ C
\]

facultative ponds in the USA, < 40 kg BOD ha\(^{-1}\) d\(^{-1}\)

- polishing ponds (??)
- pH (??)
Introduction / Methods

UASB

Polishing ponds

Viçosa, Minas Gerais
Composite sampling (hourly 6:00 am – 6:00 pm) RW, UASB, BF

Column sampling (morning) Ponds

BOD, COD, solids, nitrogen, phosphorus, *E. coli*, helminths

Weekly + Biweekly - monthly

Hourly (ponds profile, 20cm) pH, DO, temperature

October 2001 - February 2007
## Ponds characteristics

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td>P4</td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td>P4</td>
<td>P1</td>
</tr>
<tr>
<td>Q (m$^3$d$^{-1}$)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>-</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>HRT (d)</td>
<td>9.4</td>
<td>9.4</td>
<td>9.4</td>
<td>-</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>-</td>
<td>7.0</td>
</tr>
<tr>
<td>h (m)</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>-</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>-</td>
<td>0.9</td>
</tr>
<tr>
<td>Q (m$^3$d$^{-1}$)</td>
<td>4.2</td>
<td>4.2</td>
<td>2.1</td>
<td>2.1</td>
<td>3.0</td>
<td>3.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>HRT (d)</td>
<td>3.4</td>
<td>3.4</td>
<td>5.1</td>
<td>5.1</td>
<td>4.7</td>
<td>4.7</td>
<td>7.2</td>
<td>7.2</td>
<td>5.1</td>
</tr>
<tr>
<td>h (m)</td>
<td>0.9</td>
<td>0.9</td>
<td>0.7</td>
<td>0.7</td>
<td>0.9</td>
<td>0.9</td>
<td>0.7</td>
<td>0.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Results – water temperature

Mid-depth

local input design parameter, for instance in Pano and Middlebrooks equations or in the dispersed flow model for coliforms removal

Tw = 8.7 + 0.73 Ta

R² = 0.79
Results – BOD surface loading rates and BOD removal

- UASB + BF: 70% - 80%, total BOD5 removal (mainly in the UASB) ► low SOLR onto P1
- BOD removal took place basically in P1 (30%) ► 20-80 mg BOD/L
- No clear further BOD removal after P1
Results – DO

Daily variations of DO, mean values, along pond depth

P1: 2 -3 mg/L, at the deepest measuring points, usually at dawn.
✓ pH >7.5 at mid-depth and never below 7 at any depth
✓ mean values, surface level (0.15 m) 7.7 -8.1-8.7 -8.7
✓ mid depth : 7.6-7.8-8.2-8.4

✓ Input design parameters: P1 pH = 7.5 ► 3-5% pH rise in P2 ► 5-7% in P3.
✓ No marked further increase is to be expected in a fourth pond.
Results – Nitrogen removal

Ammoniacal nitrogen concentration in pond effluents: estimated values - Pano and Middlebrooks model (NH₃ est), and measured values (NH₃ obs).

UASB: N-NH₃ 60% increase  Pond series: TKN (70%) N-NH₃ (90%) removal
Results - *E. coli* removal

- *E. coli* removal efficiency:
  - ≈ 0.7 log unit reduction in the UASB+BF
  - ≈ 4 log units reduction up to P3
  - The fourth pond did no add further removal.
  - Pond 3 consistently produced effluent qualities complying with the WHO Guidelines for unrestricted irrigation (10³ *E. coli* per 100 mL);
  - Pond 3 (systematically) and Pond 2 (most of the time) achieved the WHO guidelines for restricted irrigation and aquaculture (10⁴ *E. coli* per 100 mL)
Results – *E. coli* removal

Observed and estimated values of effluent *E. coli* concentrations using von Sperling models

- von Sperling models: underestimated Kb values
- wider values of pond depths and HRT
(i) it seems that Pano and Middlebrooks model can be confidently used to predict ammonia removal in polishing ponds

(ii) von Sperling equations tend to underestimate $E. coli$ Kb values, hence $E. coli$ removal;

(iii) therefore, designing polishing ponds based on them incorporates a factor of safety;

(iv) a series of three ponds showed to achieve high quality ammonia and $E. coli$ effluent standards, whereas adding a fourth pond seems to be worthless.

(v) a pH value of 7.0 can be confidently assumed in the first pond and, subsequently, a pH rise of 3-5% in the second pond and 5-7% in the third pond;

(vi) an $E. coli$ Kb value of 1.0 could be assumed in the first pond and, subsequently, an increase of 10% in the second pond and 20% in the third pond.

Conclusions

A series of four pilot scale ponds
pond depth = 0.4-0.9 m, L/B=2, HRT = 4.1-9.4 d