Modeling waste stabilization ponds with an extend version of ASM 3

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<td>Investigate principle processes in waste stabilization ponds and extend IWA-ASM 3 model by the following processes:</td>
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<td>– Algae growth on NH$_4$ and NO$_3^-$; considering light intensity</td>
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<td>– Algae decay</td>
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<td>– Light attenuation through WSP depth considering the Beer’s Law</td>
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<td>– Exchange of O$_2$, NH$_3$, CO$_2$ on the liquid-atmosphere interface considering the wind influence</td>
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<td>– Dissociation processes for NH$_4^+$/NH$_3$ and CO$_2$/HCO$_3^-$</td>
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<td>– pH calculation</td>
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<td>Validation of the extended model with a data set from pilot scale WSP treating municipal landfill leachate.</td>
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Experimental pilot ponds
UFSC Campus – Florianópolis (Brazil) – 27°38’S, 48°30’O

**Objective**
- Experimental pilot ponds

**Materials**
- Anaerobic pond
- Facultative pond
- Maturation pond

**Methods**
- Superficial area: 1.2 m²
- Leachate inflow: 60 L/d
- Hydraulic retention time: 18 days

*Just facultative and maturation ponds are investigated here for modeling.*
Mean measured output parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>AN</th>
<th>FAC</th>
<th>MAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>g/m³</td>
<td>1456</td>
<td>1233</td>
<td>743</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>g/m³</td>
<td>301</td>
<td>239</td>
<td>146</td>
</tr>
<tr>
<td>Total Ammonia Nitrogen</td>
<td>g/m³</td>
<td>505</td>
<td>208</td>
<td>53</td>
</tr>
<tr>
<td>Nitrate Nitrogen</td>
<td>g/m³</td>
<td>7.5</td>
<td>6.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>µg/L</td>
<td>-</td>
<td>65.3</td>
<td>93.4</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>g/m³</td>
<td>-</td>
<td>3.7</td>
<td>3.9</td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
<td>8.7</td>
<td>8.8</td>
<td>8.9</td>
</tr>
<tr>
<td>Temperature</td>
<td>ºC</td>
<td>25.9</td>
<td>25.6</td>
<td>25.2</td>
</tr>
</tbody>
</table>
Extended version of ASM3

- Sun*
- Wind*

Inflow → Heterotrophs → Algae → Nitrifiers → Outflow

NH4+ + HCO3- → O2 + NH3 → CO2 → NH4+ + HCO3-

*measured data was used for wind (hydrological station) and sun (Labsolar, UFSC)

Light attenuation through depth

ASM 3 + Algae Biomass + Ionic Equilibrium + Gas Exchange
Hydraulic conception

Each pond modeled as set of three CSTR`s (Completely Stirred Tank Reactors) with exchange fluxes:
Ponds implemented in the software SIMBA 4.2
Algae Processes

- Algae endogenous respiration and growth based on NH$_4^+$ and NO$_3^-$ (see also Reichert et al., 2001)
- Light inhibition → Beer`s Law:

\[
I_{av} = 0.47 \times I \times e^{-K_d \times H}
\]

- Light available to photosynthesis [W/m$^2$]
- Measured light radiation [W/m$^2$]
- Water depth [m]
- Light attenuation parameter
- Light attenuation from suspended solids [m$^{-1}$]

\[
K_d = \alpha_1 + \alpha_2 \times X_{TSS}
\]

- Light attenuation constant form water colour and turbidity [m$^{-1}$]
Ionic equilibrium and gas transfer

- Equilibrium equations: \( \text{NH}_3 \leftrightarrow \text{NH}_4^+ \)
  \( \text{HCO}_3^- \leftrightarrow \text{CO}_2 \)
- \( \text{pH} = f (\text{NH}_4^+, \text{NO}_3^-, \text{HCO}_3^-, \text{H}^+, \text{OH}^-) \)
- Gas transfer rate between pond top layer and atmosphere:

\[
J_{\text{gas}_i} = k\alpha_{\text{gas}_i} \times \frac{A}{V} \times (S_{\text{gas}_i} - S_i)
\]

- Surperficial area \([\text{m}^2]\)
- Critical concentration between gas and liquid phases \([\text{g/m}^3]\)
- Mass transfer coefficient \([\text{m/d}]\)
- Layer volume \([\text{m}^3]\)
- Concentration in the liquid phase \([\text{g/m}^3]\)
• Oxygen transfer coefficient (see also Ro and Hunt, 2006):

\[
k_{la_{O2}} = 0.24 \times 170.6 \times Sc^{-\frac{1}{2}} \times U^{1.81} \times \left(\frac{\rho_a}{\rho_w}\right)^{\frac{1}{2}}
\]

- Measured wind velocity [m/s]
- Schmidt number [-]
- Atmosphere and water densities [kg/m³]

• Normalization of carbon dioxide and ammonia transfer coefficients:

\[
\frac{K_{la_{-1}}}{K_{la_{-2}}} = \left(\frac{Sc_1}{Sc_2}\right)^{-\frac{1}{2}}
\]
Maximal heterotrophic growth rate $0.52 \text{ d}^{-1}$ caused by ammonia inhibition. Rate four times smaller than compared with uninhibited activated sludge processes.
Objective

Materials

Methods

Results

Conclusion

Algae

Maturation Pond

- Light attenuation coefficients $\alpha_1$ and $\alpha_2$ as Juspin et al. (2003)
- Light saturation constant, $K_I$, calibrated as 1200 W/m²
Facultative Pond

Ammonia dissociation constant was one fifth of the pure water. Which is in the same range related to animal manure (Ni, 1999)
Ammonia Nitrogen

Mean ammonia stripping rates were 18.2 and 4.5 g_N/(m^2*d) in the facultative and maturation pond respectively.
Conclusions

- Algae, TSS, COD and ammonia concentrations, as well the pH in WSP’s can be modeled well with the extended version of ASM3.
- Gas exchange with pond and atmosphere could be described in the model.
- Light attenuation can be modeled by the Beer-Lambert Equation. However better determination of related parameters is recommended.
- Free ammonia concentrations seem to inhibit nitrification completely and heterotrophic biomass partly, algae growth could also be affected.
- Model results suggest that oxygen contribution from wind aeration was very important, with mean inputs of 14.4 and 11.1 g\text{OXYGEN}/(m^2*d) to the facultative and maturation pond respectively.
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