Assessment of classical surface organic loading design equations based on the actual performance of primary and secondary facultative ponds

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A series of mechanisms contribute to the purification of the wastewater treated in a facultative pond, as a result of the complex mutualistic relationship of bacteria and algae.

The biological process consists of retaining the wastewater for periods long enough for natural organic matter stabilisation.
Introduction

Oxidation of organic matter accomplished by bacteria

presence of dissolved oxygen

which is mainly supplied by algal photosynthesis
Facultative ponds are designed for BOD removal on the basis of a specified surface organic loading.

Various empirical approaches have been proposed: McGarry and Pescod (1970); Mara (1976); Mara (1987); Arthur (1983); Ellis and Rodrigues (1995).
Operational records from 110 full-scale pond systems in Brazil

- 73 primary facultative ponds (FAC.1ary)
- 37 secondary facultative ponds (FAC.2ary)

Used to check the applicability of some of these design equations
Three empirical equations used for establishing the design surface organic loading were:

- Mean air temperature of the coldest month:
  - Mara (1987): \[ Ls = 350 \times (1.107 - 0.002T)^{(T - 25)} \]
  - McGarry and Pescod (1970): \[ Ls = 60 \times (1.099)^T \]

- Based on the mean air temperature:
  - Mara (1976): \[ Ls = 20T - 120 \]
Descriptive statistics of BOD influent and effluent concentration and BOD removal efficiencies of the pond systems

<table>
<thead>
<tr>
<th>System</th>
<th>Primary facultative ponds</th>
<th>Secondary facultative ponds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Influent (raw)</td>
<td>Effluent</td>
</tr>
<tr>
<td><strong>Unit</strong></td>
<td>mgL(^{-1})</td>
<td>mgL(^{-1})</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>516</strong></td>
<td><strong>120</strong></td>
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<tr>
<td>Stand. dev.</td>
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<td>97</td>
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<tr>
<td>10%ile</td>
<td>150</td>
<td>29</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td><strong>466</strong></td>
<td><strong>95</strong></td>
</tr>
<tr>
<td>90%ile</td>
<td>905</td>
<td>230</td>
</tr>
</tbody>
</table>
Variation of surface BOD loading (Ls) with temperature on primary facultative ponds, and comparison with classical design equations.

**Equation 1 (Mara, 1987):**

\[ L_s = 350 \times (1.107 - 0.002T)(T - 25) \]

**Equation 2 (McGarry and Pescod, 1970):**

\[ L_s = 60 \times (1.099)^T \]

Effluent BOD concentration \( \leq 80 \text{ mgL}^{-1} \)

80% and 93% of the data presented Ls values below the maximum recommended by equations 1 and 2.

Equation 2 (McGarry and Pescod) is considered an envelope of failure, that is, it sets the limits above which failure is expected to occur.

1006 operational data analysed.
Variation of surface BOD loading (Ls) with temperature on primary facultative ponds, and comparison with classical design equations.

Effluent BOD concentration ≤ 80 mgL⁻¹

88% of Ls applied were below the maximum recommended by equation 3.
Variation of surface BOD loading (Ls) with temperature on **primary facultative ponds**, and comparison with classical design equations

**Effluent BOD concentration > 80 mgL⁻¹**

Lower percentage of surface BOD loading values under the curves generated by equations 1 and 2 (48% and 75%)
Variation of surface BOD loading ($L_s$) with temperature on primary facultative ponds, and comparison with classical design equations.

Effluent BOD concentration $> 80 \text{ mgL}^{-1}$

62% of $L_s$ values $<$ recommended by equation 3.
Variation of surface BOD loading (Ls) with temperature on *secondary facultative ponds*, and comparison with classical design equations

**Effluent BOD ≤ 80 mgL⁻¹**

388 operational data analysed

79%, 91% and 75% of Ls values < recommended by equations 1, 2 and 3
Variation of surface BOD loading (Ls) with temperature on secondary facultative ponds, and comparison with classical design equations

Effluent BOD > 80 mgL⁻¹

No expressive differences between the loadings applied by FAC.2ary that showed good and poor performances

Percentage of Ls values under the curves 1, 2 and 3 was 61%, 82% and 67%
Results and discussion

- Validity of the design equations 1 and 3 can be better assessed when the pond is receiving its designed load.

- The designed load data of the ponds were not available, but based on typical design and operational parameters recommended by the technical literature (150 to 350 kg BOD.ha\(^{-1}.d^{-1}\)), F次要的 ponds:
  - 35% underloaded
  - 32% with BOD loads within the range
  - 34% overloaded
The literature design equations are more applicable for FAC.ary ponds.

They represent good indicators of the limit value of loading rates to be applied on ponds, above which a good performance cannot be guaranteed.

The maximum loading rates recommended by the equation proposed by McGarry and Pescod (1970) are very high because they represent limits for failure.
Conclusions

- FAC.2ary ponds showed good and poor performances for all loading rates and the best ponds are not those which follow the design equations recommendation.

- The influence of the loading conditions on the ponds performance was very small and scattered in all units.
Acknowledgments

And municipal service providers
Thank you for your attention

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