

# **Baffled primary facultative ponds with inlets and outlets set at different levels treating domestic wastewater in northeast Brazil**

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# Introduction

- The process design procedure for primary and secondary facultative waste stabilization ponds receiving raw sewage and secondary facultative ponds is identical and well established.
- It is usually based simply on permissible surface organic loading for given mean ambient temperatures during the coldest period of the year (Gloyna, 1976; Mara, 1975; Mara and Pearson, 1998; Mara et al., 1992).

Attempts have been made to refine this process, for example:

- By including a factor for pond dispersion into the design equations (Nameche and Vassel, 1998), but the problem has always been how to accurately predict the dispersion number for a yet to be built pond.
- An approach based on uncertainty analysis has been suggested by von Sperling (1996), for facultative ponds adopting a range of values for parameters such as flow, BOD and thermotolerant coliforms to achieve the required effluent quality via a multi-trial Monte Carlo simulation programme.

- Whist pond geometry has been shown to effect pond performance (Pearson, et al., 1995).
- it would seem that aspects of physical design in terms of pond hydraulics and the positioning and design of the inlet and outlet structures are less secure and have been recently reviewed by Shilton and Sweeney (2005).

It is known that:

- Hydraulic short circuiting caused by wind effects (Fares and Lloyd, 1995; Menezes, et al., 2005) and
- thermal stratification (Pedahzur, et al., 1993).
- Both reduce pond performance.
- In this context the use of longitudinal, transverse and vertical baffles have been studied in an attempt to create in-pond conditions as close to plug flow as possible (Watters, et al., 1973; Shilton and Harrison, 2003).

# Inlet and outlet structures

- The positioning, orientation and depths of the inlet and outlet structures have been considered by Shilton and Harrison (2003).
- They suggested that the positioning of the outlets is critical in terms of hydraulic efficiency because the wastewater tends to circulate around the pond rather than simply move steadily from the inlet to the outlet.

The aim of this study was therefore to evaluate:

- The effect of various configurations of longitudinal baffles and
- The vertical depth of the inlet and outlet structures
- on the treatment efficiency of experimental, tropical, primary facultative ponds.

# Pond physical design

- The pilot-scale pond system, was constructed at EXTRABES in Campina Grande, (7° 13' 11" South, 35° 52' 31" West, 550m above m.s.l.), Paraiba, Brazil.
- The system comprised four independently loaded primary facultative ponds (F1, F2, F3 and F4), with a water depth of 2.3m, each 25.4m in length and between 7.10 and 7.15m wide.
- Three of the ponds(F1-F3) were constructed with baffles and the fourth (F4), without baffles, acting as the control.

## Thus:

- Ponds F1 and F2 contained three and five parallel longitudinal baffles respectively each 22.9m long representing about 90% of the pond length.
- F1 functioned as a set of four channels 1.7m in width
- F2 as a set of six channels each 1.1m wide.
- F3 a round-the-corner system (chicane) which formed a channel 2.3m wide and 75m in length.
- The length to width ratios were therefore:
  - 3.55 for the un-baffled pond F4,
  - 14.85 for pond F1,
  - 23.52 for pond F2 and
  - 32.4 for pond F3.

# Physical Design

- Four PVC inlet pipes of 50mm diameter fed each of Ponds F1 and F4.
- Six similar inlet pipes fed Pond F2 and
- One PVC inlet pipe of 75mm diameter fed Pond F3.

# Physical Design

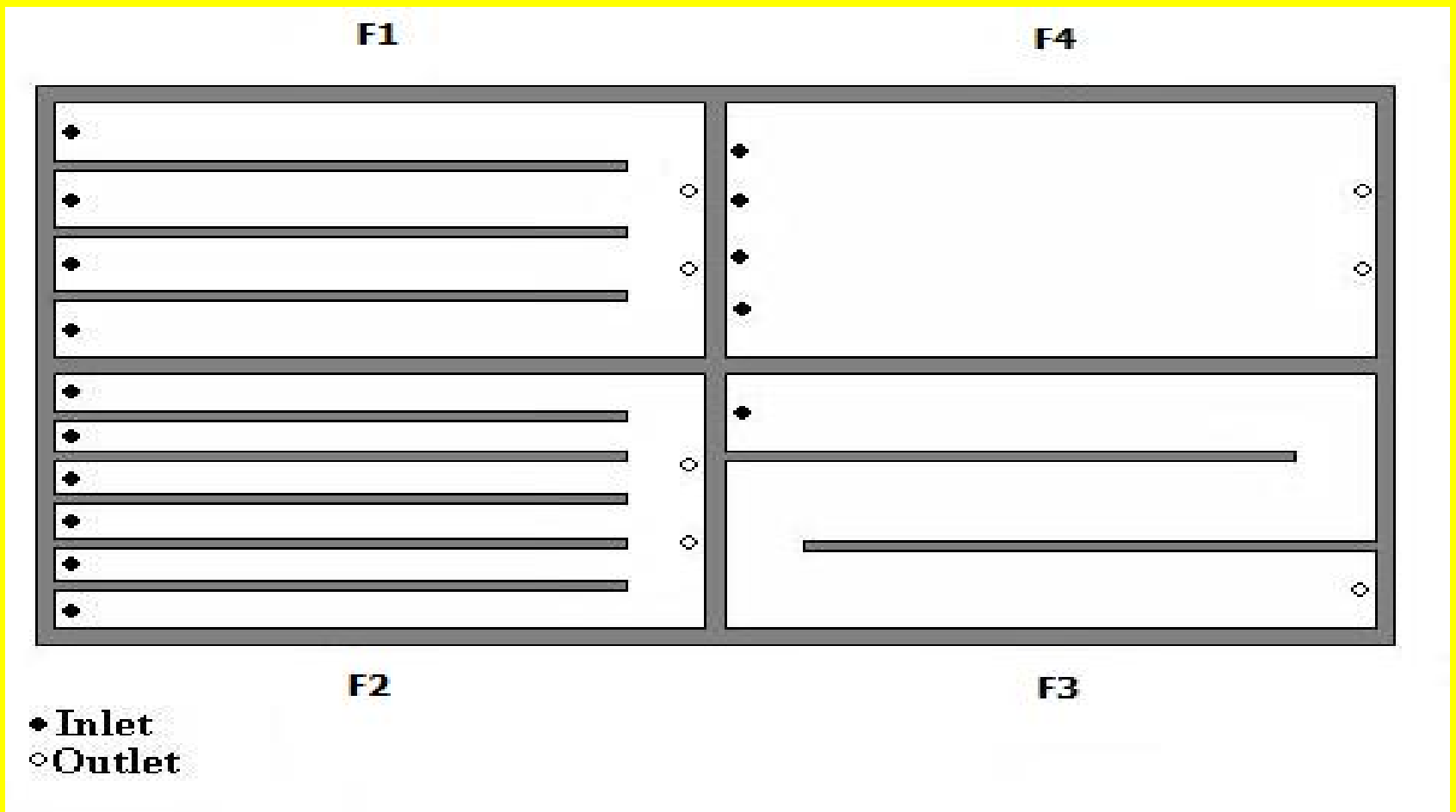
- The sewage was pumped to each pond via horizontal axis pumps at the required flow rate to the V-notch flow splitting boxes made of PVC.
- Thus the flow splitting boxes to ponds F1 and F4 contained four discharging V-notches evenly distributing the sewage to the four inlets of each pond.
- The flow splitting box of F2 contained six discharging V-notches equally dividing the sewage between the six pond inlets.
- In the case of pond F3 the sewage was pumped to the single inlet.
- The flow rates were checked biweekly.

# Physical Design

- Therefore each channel of Pond F1 received one fourth of the hydraulic loading applied to the pond.
- Each channel of Pond F2 received one sixth.
- The whole loading was discharged at the beginning of the long channel of Pond F3 and
- the hydraulic flow was uniformly distributed throughout the breadth of Pond F4.

# Outlets

- The two outlet structures of Ponds F1, F2 and F4 were made of 75mm diameter PVC pipes positioned equidistant along the width of the end wall of each pond.
- In Pond F3 only one 75mm diameter outlet PVC pipe was used for discharging the effluent.
- All the outlets were protected by a 200mm diameter PVC scum guard.



**Figure 1. Schematic representation of the baffled primary facultative ponds at EXTRABES.**



# Experimental Phases

- All four ponds were operated during two different one-year periods at a flow-rate of  $28\text{m}^3.\text{d}^{-1}$  giving a mean hydraulic retention time of  $\sim 15$  days.
- The surface organic loadings were  $330\text{ kg BOD}_5.\text{ha}.\text{d}^{-1}$  during the first experimental period and
- $375\text{ kgBOD}_5.\text{ha}.\text{d}^{-1}$ , during the second as a result of a slight increase in sewage strength.

# Experimental Phases

- During the first monitoring period the vertical *inlet* pipes were positioned at depths of 1.8m below the water surface of the pond and the vertical *outlets* 5cm below the surface.
- During the second monitoring period the pond *inlets* were set at 50cm below the pond surface and the *outlets* at 1.8m.

# Sampling

- Grab samples of raw sewage and pond effluents were collected every ten days at 8 a.m.
- They were analyzed for pH, temperature (T), dissolved oxygen, BOD<sub>5</sub>, COD, suspended solids (SS), thermotolerant coliforms (TC), (*Standard Methods*, 1998).
- Chlorophyll *a* (Chl *a*), was analysed using the 90% methanol extraction technique (Jones, 1979).

# Results

- Mean temperatures of raw wastewater were respectively 27.0 and 26.7 °C in the first and the second monitoring periods.
- Pond effluent temperatures varied between 24.5-25.0 °C and 23.2-23.6 °C respectively during the two monitoring periods.

# Results

- Dissolved oxygen concentrations in the pond effluents varied between 0.6 and 1.65mg.L<sup>-1</sup> during both experimental periods.
- The pH varied between 7.58 and 7.70 in the pond effluents with no difference between the two experimental periods.

# Mean values and standard deviations for analytical parameters determined in raw sewage and pond effluents in both monitoring periods.

Sample	BOD <sub>5</sub> (mg.L <sup>-1</sup> )	COD (mg.L <sup>-1</sup> )	SS (mg.L <sup>-1</sup> )	Chl <i>a</i> (µg.L <sup>-1</sup> )	TTC (cfu.100mL <sup>-1</sup> )
<b>1<sup>st</sup> monitoring period:- Inlets 1.8m deep; outlets 5cm below surface.</b>					
RS	214±66	492±130	226±41	n.d.	(1.20±1.60).10 <sup>8</sup>
F1	55±16	245±92	104±49	737±628	(7.60±12.0).10 <sup>6</sup>
F2	55±14	225±66	90±25	635±414	(7.10±9.90).10 <sup>6</sup>
F3	57±23	225±65	92±32	580±464	(6.40±9.50).10 <sup>6</sup>
F4	62±21	262±64	106±26	606±294	(6,90±8.70).10 <sup>6</sup>
<b>2<sup>nd</sup> monitoring period:- Inlets 50cm deep; outlets 1.8m below surface.</b>					
RS	241±74	503±179	286±98	n.d.	(3.84±2.94).10 <sup>7</sup>
F1	61±13	221±71	82±30	191±96	(8.05±3.88).10 <sup>5</sup>
F2	58±15	217±73	87±35	327±158	(1.21±1.52).10 <sup>6</sup>
F3	60±16	217±39	85±29	337±158	(7.43±5.34).10 <sup>5</sup>
F4	62±13	252±47	108±32	298±125	(1.05±0.37).10 <sup>6</sup>

n.d. – not determine

# Mean percent removals in the facultative ponds in both monitoring periods.

<b>Pond</b>	<b>BOD<sub>5</sub></b>	<b>COD</b>	<b>SS</b>	<b>TTC</b>
<b>1<sup>st</sup> monitoring period</b>				
<b>F1</b>	<b>74.3</b>	<b>50.2</b>	<b>54.0</b>	<b>93.667</b>
<b>F2</b>	<b>74.3</b>	<b>54.3</b>	<b>60.2</b>	<b>94.083</b>
<b>F3</b>	<b>73.4</b>	<b>54.3</b>	<b>59.3</b>	<b>94.667</b>
<b>F4</b>	<b>71.0</b>	<b>46.7</b>	<b>53.1</b>	<b>94.333</b>
<b>2<sup>nd</sup> monitoring period</b>				
<b>F1</b>	<b>74.7</b>	<b>56.1</b>	<b>71.3</b>	<b>97.904</b>
<b>F2</b>	<b>75.9</b>	<b>56.8</b>	<b>69.6</b>	<b>96.849</b>
<b>F3</b>	<b>75.1</b>	<b>56.8</b>	<b>70.3</b>	<b>98.065</b>
<b>F4</b>	<b>74.3</b>	<b>49.9</b>	<b>62.2</b>	<b>97.266</b>

# One factor-analysis of variance at a level of significance of 0.05

- Showed there was no significant difference among the means obtained for the parameters measured in the various pond effluents during both experimental regimes (including TTC), with the ***exceptions*** of suspended solids and Chl *a*.
- Suspended solids in the second monitoring period in the effluent of the unbaffled pond F4 was significantly greater than the means for the other ponds.

# Results

- In terms of percentage improvement it is questionable if the increased cost of baffling is warranted in primary facultative ponds to marginally decrease suspended solids, given that it is the first pond in a series.

# Results

- The reduction in mean chlorophyll *a* concentration in the effluents of the ponds in the second monitoring period (191 and 337 $\mu\text{g.L}^{-1}$ ) compared to the first was significant.
- This difference could be related the deeper position of the outlets at 1.8m below the surface compared to 5cm in the first period since the algae occupy the upper photic region of the pond water column.

# Conclusions

- The installation of longitudinal baffles in primary facultative ponds until a length to breadth ratio of 32.4 did not significantly improve pond performance.
- The combinations of inlet and outlet depths used in this study also had little impact on effluent quality.
- In terms of overall construction, the installation of longitudinal baffles in primary facultative ponds would seem to be an unnecessary additional cost.
- This study only considered primary facultative ponds but the installation of such baffles in maturation ponds where thermotolerant coliform and nutrient removals are important is worthy of investigation.

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