# Utilization of a Shallow Pond for Ammonia Nitrogen Removal from Facultative Pond Effluent

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**Abstract** The main objective of this work was to evaluate the effects of depth, pH, temperature and loading rates on ammonia nitrogen removal from a facultative pond effluent. The experimental work was conducted at the city of Lins, Sao Paulo State, Brazil. A real scale system composed of anaerobic pond followed by facultative pond was utilized. Two pilot scale ponds were built with different depths and were operated in parallel with the facultative pond effluent, which had pH around 8.0 and a temperature of 25°C. The 0.5 m depth pond was more efficient in the removal of ammonia than the 1.0 m depth pond when one compared the necessary surface areas to have the same percent removal of ammonia. Hydraulic residence times of 7.5 days were long enough to reduce the effluent ammonia concentration below 10 mg $N.L^{-1}$.
**Keywords:** Shallow ponds; ammonia removal; tertiary treatment

## INTRODUCTION.

Stabilization pond systems are extensively employed in Brazil to treat sewage from small municipalities. The dilution capabilities of natural water bodies in several regions are too low during dry weather periods. Thus, it is very difficult to achieve enough dilution to meet the ammonia nitrogen concentration limit in such bodies. This study investigated the removal of ammonia nitrogen from a facultative, photosynthetic pond effluent by means of complementary shallow ponds. Ammonia nitrogen (N) removal capabilities of the complementary ponds were looked into; the loading rate was associated with the final effluent quality. The effect of other operational parameters of interest such as temperature and pH was also evaluated; one wishes to come to an understanding of what the major mechanisms are and their relative importance.

One major reference for this work was the model proposed by Pano & Middleborough Apud Bastos (2007), which associated ammonia N removal with the surface hydraulic load, depth, pH and temperature, with the reckoning that volatilization is the main mechanism. One work by Yánez (2001) linked ammonia N removal to the BOD and TKN application rates, thus establishing an experimental model.

## MATERIALS AND METHODS

This research work involved characterization of the wastewater (sewage) at the entrance and exit points of the real scale, anaerobic and facultative ponds and also of the two pilot scale, post-treatment ponds. They were subjected to different facultative pond effluent flow rates and water depths, but keeping constant the surface area.

### Real Scale Stabilization Pond Monitoring

Field work was at an experimental SABESP site in Lins, SP, Brazil composed by three parallel modules of anaerobic pond followed by facultative pond. They treat the municipality´s sanitary sewage, generated by 65,000 inhabitants. This work focused on Module No. 1, the one highest above ground, according to the State´s Sanitation Company (SABESP) recommendations. Operational conditions for the anaerobic and facultative ponds were, respectively: effective depths: 4.1 and 1.9 m; surface areas 6.827 $m^2$ and 31.469 $m^2$; net volumes 23.227 $m^3$ and 55.529 $m^3$; detention times 5.8 and 13.9 days; surface BOD loading rates 1,471 kg/ha.day and 160 kg/ha.day and volumetric BOD application rates 0.043 kg/$m^3$.day and 0.009 kg/$m^3$.day.

Monitoring was set for the inlets and outlets of the ponds. Temperature, pH, total alkalinity, solids series, BOD, COD, TKN, ammonia N and total P were determined weekly. Sampling was done during influent peak flow times. On some occasions 24-hour composite samples were taken.

### Pilot Pond Operation to Remove Ammonia N

The real scale facultative pond effluent was fed to the tertiary pilot scale ponds by gravity. The flow rate was controlled by means of a constant level device in such a way to result in the desirable detention times. The pilot scale ponds were 8 m in length and 2 m wide. They were operated with different effective depths of 0.5 m and 1.0 m.

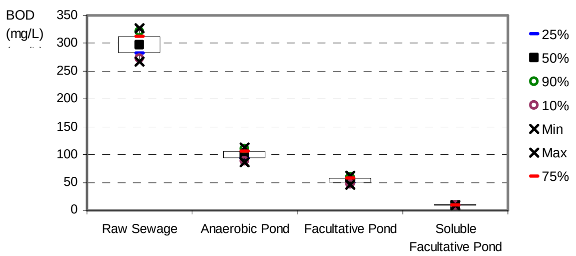
Four experimental Phases were defined, in which the detention times in the pilot ponds were 5; 7,5; 10 and 15 days. Surface TKN loads were in the range 25 to 110 $kgN.ha^{-1}.day^{-1}$. Each stage lasted 06 (six) months. Pilot pond affluents and effluents were analyzed for temperature, pH, OD, TKN, ammonia N, nitrite, nitrate, BOD, COD, total alkalinity, solids, chlorophyll-a, total coliforms, *E.coli* and helminth eggs, on a weekly basis.

## RESULTS

### Real Scale Pond Monitoring

Figures 1 through 4 show *box-whisker* diagrams of the main results from the four sampling stages or Phases of the real scale ponds. It was noted that the treatment system was operating under normal conditions. Median values of BOD for anaerobic and facultative pond effluents were close to 100 e 50 $mg.L^{-1}$, respectively, typical of fully loaded ponds at the loading rates verified in this work. (Figure 1). The anaerobic pond COD effluent varied around 200 $mg.L^{-1}$whereas COD around 250 $mg.L^{-1}$ for the facultative pond effluent denoted effect of algal biomass loss.

Regarding N-compounds (Figure 2), the raw sewage (sample collection after grit chamber) presented TKN concentration around 60 $mgN.L^{-1}$, reaching values in the order of 100 $mgN.L^{-1}$. The anaerobic pond effluent, as expected, had TKN concentration of the same magnitude as the raw sewage, with increase in the ammonia N concentration to values in the order of 50 $mgN.L^{-1}$ because of the anaerobic process.



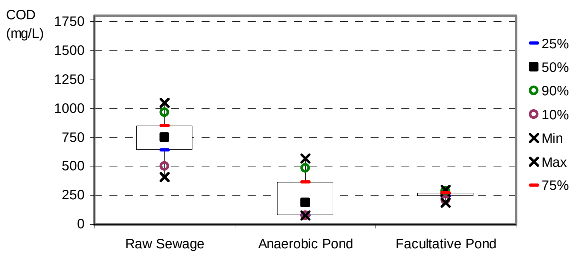



**Figure 1:** BOD and COD of raw sewage and real scale pond effluents

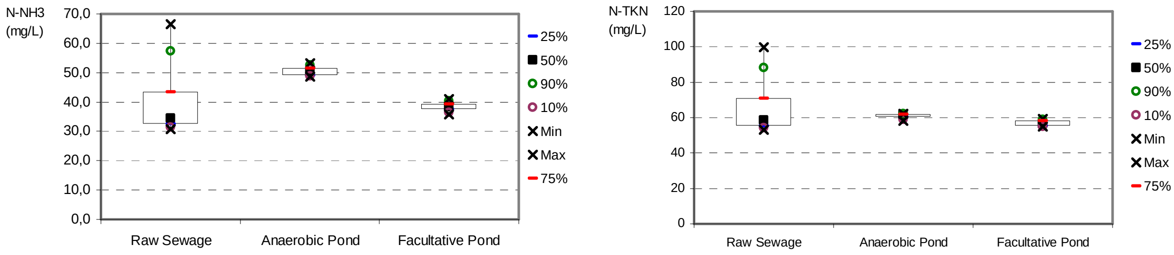



**Figure 2:** Ammonia N and TKN of raw sewage and real scale pond effluents

Ammonia N levels in the facultative pond effluent reached 40 mg $N.L^{-1}$. A slight acidification of sewage in the anaerobic pond due to its biochemical process and the significant raise in pH in the facultative pond also represent normal operative conditions. Determinations were done with day light, with prevalence of photosynthesis over respiration, thus leading to decreasing dissolved $CO_2$ levels in water, a classical scenario. pH values were slightly above 8.0 (Figure 3), with very little variation; this is very relevant in the evaluation of ammonia desorption process in the pilot ponds and nitrification process in biological filters. According to Anthonissen (2001), a pH value around 8.3 is ideal to inhibit nitritation.

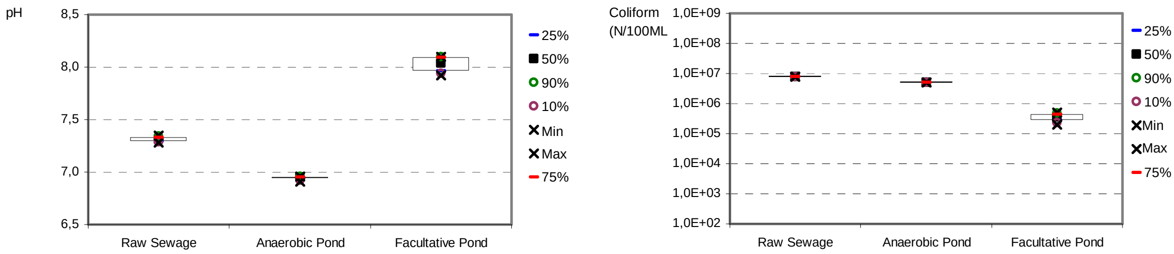



**Figure 3:** pH and thermotolerant coliforms in raw sewage and real scale pond effluents

The thermotolerant coliform density in the facultative pond effluent was in the range $10^5$ and $10^6$ MPN/100mL, thus demonstrating that ponding systems without maturation ponds show low efficiencies. This is an important fact for this research work because ideal conditions for ammonia desorption from tertiary ponds were sought and such conditions must be compatible with coliform reduction, another important goal; attainment of multiple quality objectives is highly desirable.

**Operational Results, Pilot Ponds – Phase 1**

In phase 1 the two pilot ponds (depths of 0.5 m and 1.0 m) were operated in parallel, receiving the real scale facultative pond effluent under the following conditions: detention time of 5 days; TKN volumetric loading rate : 0,011 $kg/m^3.day$; TKN surface loading rates: 0.011$kg/m^2.day$ (1.0 m deep pond) and 0.0055$kg/m^2.day$ (0.5 m pond).

Figure 4 depicts the main operational conditions imposed to the ponds. Some variation in the imposed numbers was observed, as a function of deviations in the calibration of the control system.

Figure 5 depicts pH, temperature, alkalinity and DO in the pilot ponds. High temperatures are common in the region; one notices the high pH values, particularly in the 0.5 m deep pond. Both favor ammonia volatilization. The high OD concentrations point at high photosynthetic rates during the day.

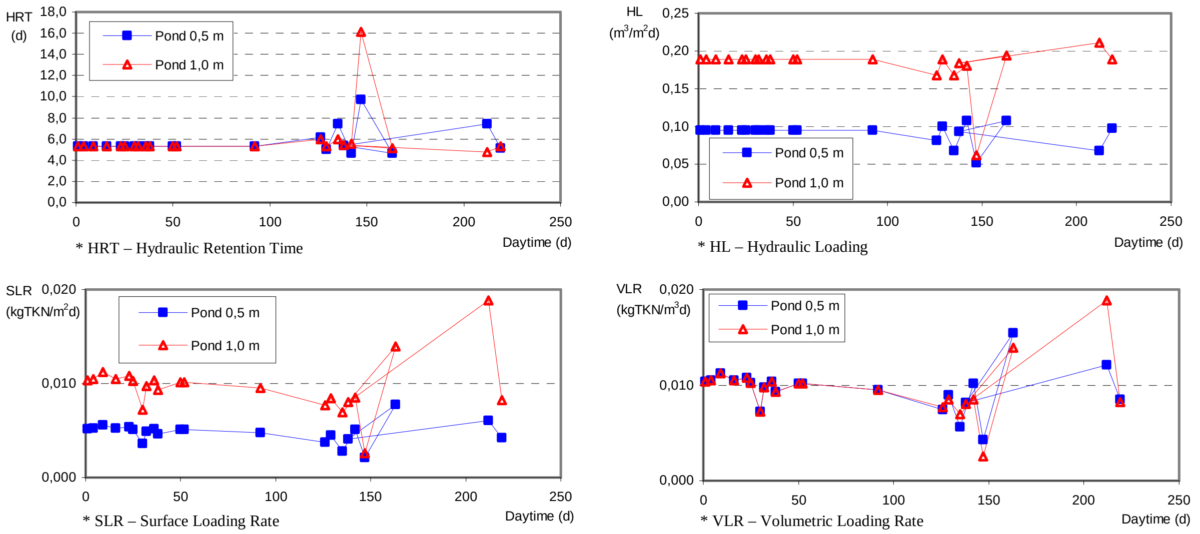



**Figure 4:** Operational Conditions for the Pilot Ponds (1rst Phase) - `

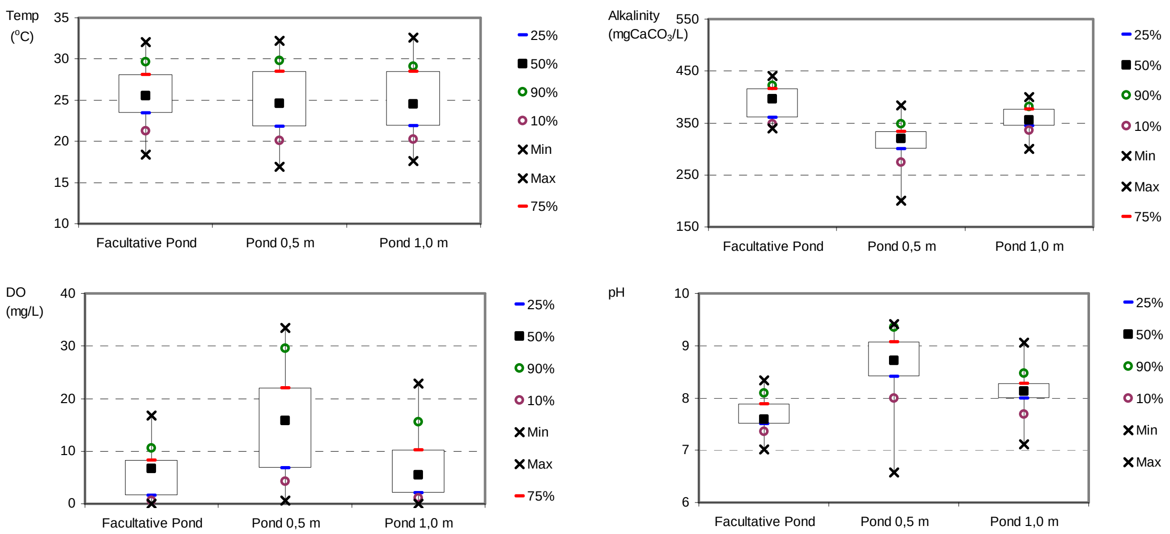



**Figure 5:** pH, temperature, alkalinity and DO in Pilot Ponds (1rst Phase)

Ammonia N concentrations were plotted as historical series and box-whisker diagrams in Figure 6.

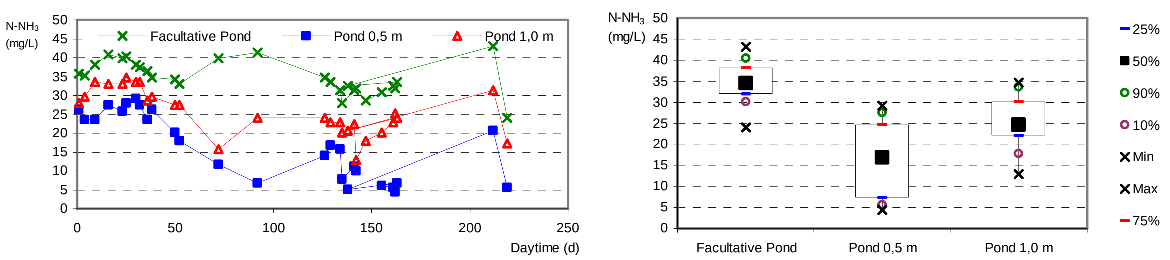



**Figure 6:** Ammonia N – Historical Series and Box-Whisker Diagrams (1rst Phase)

The historical data showed that the ponds reached steady state after day no. 100 of operation, with ammonia N concentrations around 10 mg N/L and 20 mg N/L in the 0.5 m deep and 1.0 m deep pond effluents, respectively. All data were employed in the box-whisker diagrams, resulting in increasing degree of difficulty to meet the standard of 20 mg N/L.

Finally, one must mention that the BOD, COD, solids, phosphorus and chlorophyll a results did not point at significant additional removal gains. The resuls from the biological indicators shall be presented eventually.

## Operational Results – Pilot Ponds – Phase 2

In Phase 2 the two pilot ponds were operated in parallel with the facultative pond effluent. Operation conditions were: detention time: 10 days; volumetric TKN loading rate: 0.005 kg/m$^3$.day; surface NKT loading rates: 0.05kg/m$^2$.day and 0,0025kg/m$^2$.day (1.0 m deep pond and 0.5 m deep pond, respectively).

Figure 7 depicts the main operational conditions imposed to the pilot ponds. In Phase 2 the detention time in both ponds was 10 days. The volumetric loads were the same but the hydraulic and surface TKN loads for the 1.0 m deep pond were twice as big as the respective loads for the 0.5 m deep pond. In this phase the flow rates were half the phase 1 flow rate, in an effort to increase ammonia removal.

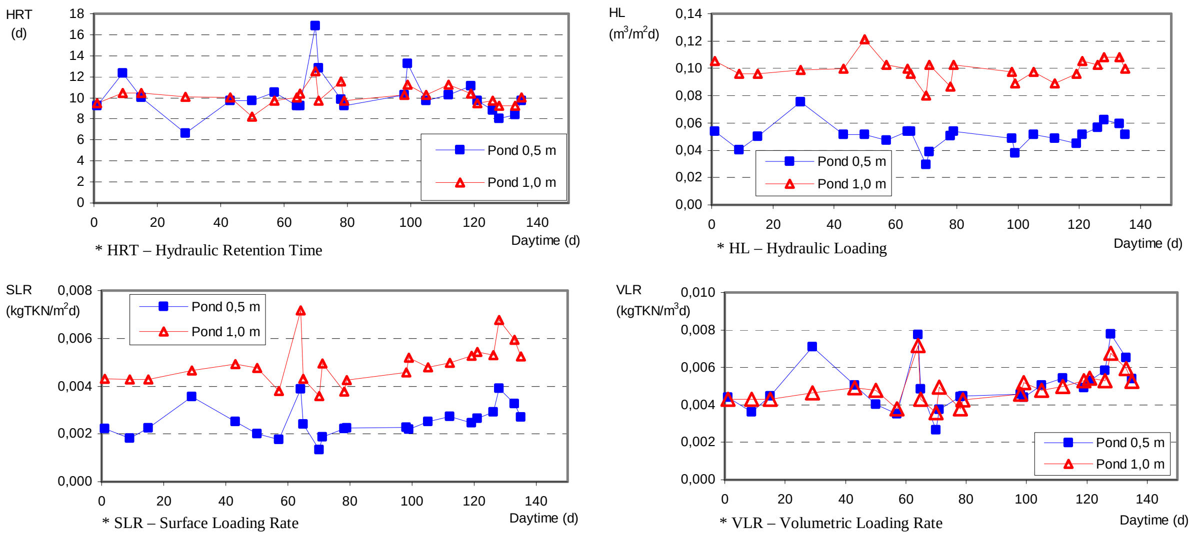



**Figure 7:** Operational Conditions Imposed to the Pilot Ponds (TKN) (2nd Phase)

In Figure 8 the Controlled Environmental Conditions are shown. During Phase 2 a temperature drop acted against ammonia volatilization, whereas the higher pH values, particularly in the 0.5 m deep pond, were favorable. The high DO concentrations in the pilot ponds characterize several DO supersaturation episodes during daytime.

The ammonia N results are presented as data series and box-whisker diagrams in Figure 9. The historical data series indicated that the 0.5 m deep pond effluent presented lower ammonia N concentrations (kept almost all the time below 10 mg N/L), while the 1.0 m deep pond effluent presented higher concentrations, surpassing 20 mg/L by the end of phase 2, probably because of the temperature drop. One can visualize in the box-whiskers diagrams how the results meet or do not meet the quality standard of 20 mg N/L.

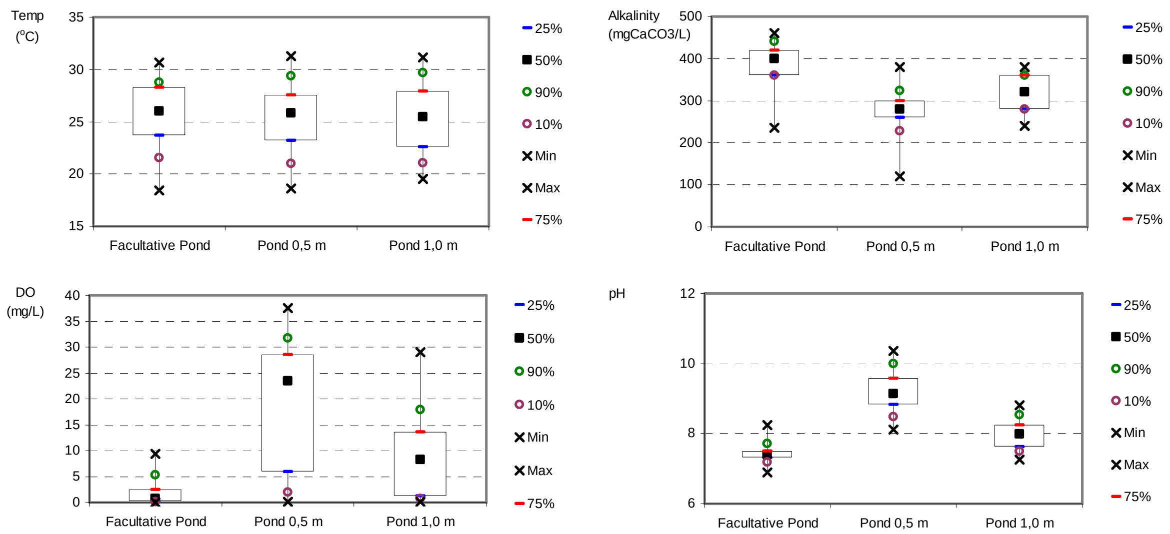



**Figure 8:** pH, temperature, alkalinity and DO in the Pilot Ponds (2nd Phase)

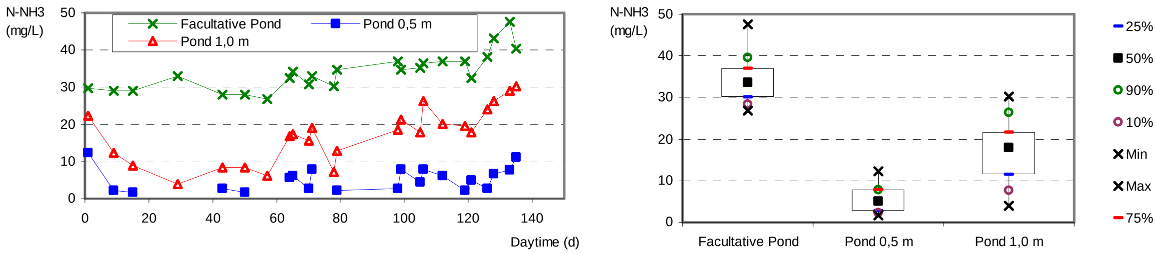



**Figure 9:** Historical Data Series and Ammonia N Box-Whisker Diagrams (2nd Phase)

Another aspect of ammonia N is with regard to the ammonia N concentration behavior along the length of the pilot ponds. Results pointed that the ammonia concentration profile showed a sudden drop from the first meters along the ponds´ length, and stayed that way until the final stretch, thus demonstrating a complete mix reactor behavior in spite of the large length/width ratio. The decay rate of the thermotolerant coliform number density was less expressive in the 0.5 m deep pond, in which one log removal was obtained with regard to the facultative pond effluent. The 1.0 m deep pond achieve a two log removal efficiency.

## Operational Results, Pilot Scale Ponds – Phase 3

In Phase 3 the detention times were 7.5 days and 15 days in the 0.5 m and 1.0 m deep pond. The surface TKN loading rate was 0.004 kg/m$^2$.day for both ponds and the volumetric TKN loading rates were 0.004 kg/m$^3$.day and 0.008 kgNKT/m$^3$.day, respectively. Figure 10 shows the main operational conditions.

Figure 11 shows the main controlled environmental conditions. In Phase 3 it was observed the continuity of high pH values in the pilot ponds, which favored ammonia volatilization, as well as high DO concentrations (above saturation level), especially in the 0.5 m deep pond, also favoring ammonia stripping.

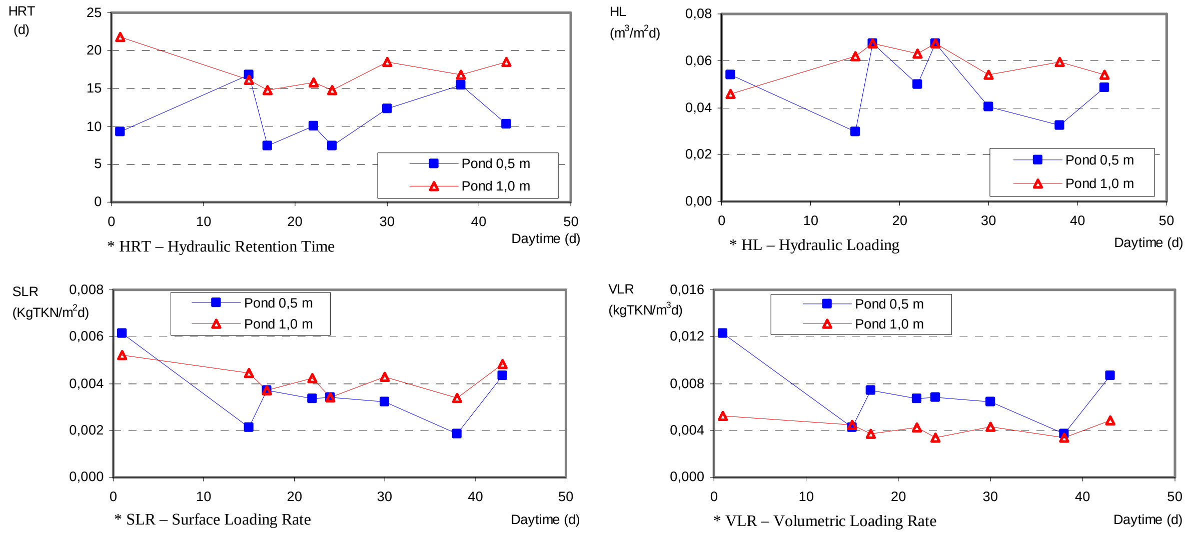



**Figure 10:** Operational Conditions For the Pilot Ponds (Obs: TKN loads) (3rd Phase)

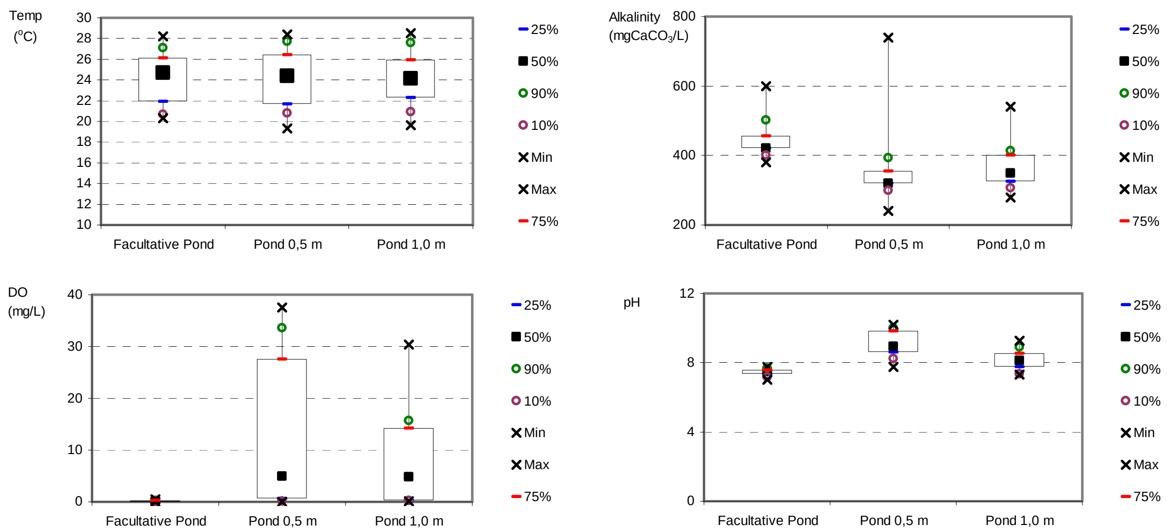



**Figure 11:** pH, temperature, alkalinity and DO Results in Pilot Ponds (3rd Phase)

The ammonia N data were plotted as historical data series and box-whisker diagram in Figure 12.

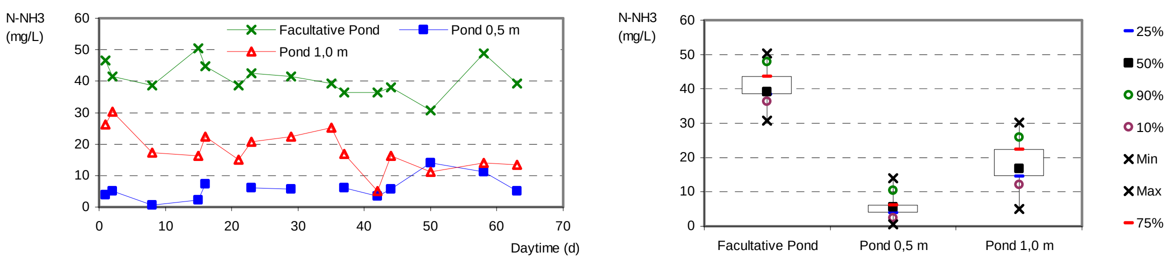



**Figure 12:** Historical Data Series, Box-Whisker Diagram for Ammonia N (3rd Phase)

From the historical data series it was noted that the 0.5 m deep pond effluent presented lower ammonia N concentrations (below the 10mgN/L standard almost all the time), while the 1.0 m deep pond effluent always presented higher concentrations, surpassing the 20 mg/L mark on some occasions. These results were very expressive, in light of the fact that during this Phase the feeding flow rate and the surface area were the same for both ponds – the results obtained with the 0.5 m deep pond were more favorable for the same surface area of the 1.0 m deep pond. In this Phase the

0.5 m deep pond effluent presented about 5mg/L of nitrite and about $10^3$ CFU/100 mL of nitritant bacteria.

In Figure 13 these results were compared with results from Phases 1 and 2. Box-whisker diagrams of the results from the facultative and pilot ponds are shown. The better behavior of the 0.5 m deep pond was confirmed; also in Phase 3 the hydraulic surface loading rate was basically the same for both pilot ponds.

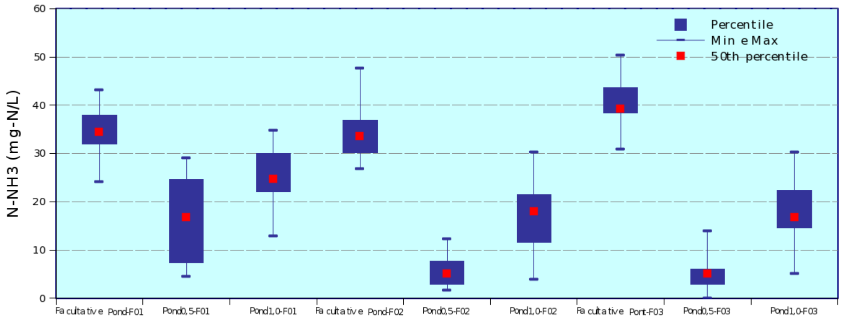



**Figure 13**: Comparative Box-Whisker Diagrams for Ammonia N - Phases 1, 2 & 3.

## CONCLUSION

The shallow, pilot scale ponds were adequate to reduce ammonia N in the facultative pond effluent. The 0.5 m deep pond with detention time of 7.5 days produced effluent with ammonia concentrations consistently below below 5 mg N.$L^{-1}$, whereas the 1.0 m deep pond with detention time of 15 days presented difficulties to meet the standard, reference concentration of 20 mg N.$L^{-1}$. Indications of nitritation took place in the 0.5 m deep pond. The experimental work will proceed, in order to verify whether or not such unexpected result can be confirmed.

Thermotolerant coliform removals in the 0.5 m deep pond were lower than in the 1.0 m deep pond, for equivalent surface areas, thus demonstrating that the utilization of shallow ponds did not favor meeting multiple quality objectives; the same finding was verified with respect to the removal of biodegradable organic matter.

Phase 4 of the experimental work is still on. Regardless of that, the experimental results have demonstrated that shallow tertiary ponds are capable of reducing (by desorption) the ammonia nitrogen concentration in the effluent under relatively short detention times. Biological filters of percolation allowed nitrification of the facultative pond effluent. Special attention must be given to the possibility of occurrence of oxidation of ammonium ion to nitrite only.

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