ALGAE BIOMASS EVALUATION IN AERATED FACULTATIVE AND MATURATION PONDS FOR PIGGERY WASTE TREATMENT

Rejane H. R. Costa*, Iria S. Araujo; Paulo Belli Filho ***

*Department of Sanitary and Environmental Engineering, Federal University of Santa Catarina, Florianópolis, Brazil (E-mail: rejane@ens.ufsc.br; belli@ens.ufsc.br)
** EPAGRI – CIRAM Environmental Resources and Hydro-Meteorology Information Center of Santa Catarina, EPAGRI – CIRAM , Florianópolis, Brazil (E-mail: iriaaraujo@epagri.sc.gov.br)

Abstract Piggery waste has significantly contributed to both the degradation of natural resources and to a reduction in the quality of life in the southern region of the state of Santa Catarina, Brazil. The application of alternatives that minimize this damage is necessary. The present work studies an Aerated Facultative Pond (AFP) and a Maturation Pond (MP), in series and real scale, treating piggery waste, through monitoring biological and physical-chemical parameters. The system was monitored during 13 months (from January 2005 to January 2006). The biological parameters investigated were: Chlorophyll *a* (µg/L); counting algae (cells/mL) and algal abundance (%). The results show a variation in the average concentration of Chlorophyll *a* in the ponds, the highest values were found in the MP effluent (906 µg/L). The algal variation ranged between $6x10^3$ - $9x10^6$ cell/mL in the AFP effluent and $3x10^5$ - $1x10^7$ cell/mL in the MP effluent. Predominant algae in the system was *Chlorella sp.* (~75% of the total), which is resistant to the high organic and ammonia load present.
Keywords aerated facultative pond; algae biomass; maturation pond; piggery waste

INTRODUCTION

Piggery waste has provided a significant contribution both to the degradation of the natural resources and to the quality of life in the South region of the state of Santa Catarina, Brazil. These wastes are extremely concentrated and show values in the order of 20,000 mg/L for total solids, 30,000 mg/L for COD, 2,500 mg/L for total nitrogen and 600 mg/L for total phosphorus, generating a strong environmental impact, and thereby affecting the life qualify of the population.

The main advantage of pond treatment for piggery waste is the removal of nitrogen and phosphorus compounds (Medri et al., 2007). Stabilization ponds are large and shallow structures and the treatment is provided from the complex symbiosis of bacteria and algae. The design and management of a waste stabilization pond is in effect the design and management of a small lake. Though waste stabilization ponds may appear to be calm and placid bodies of water they are in fact in a constant state of flux as virtually every conceivable physico-chemical parameter changes in response to the seasonal and diurnal changes in sunlight, wind and temperature as well as the changes in the influent quantity and quality (Paterson & Curtis, 2005).

In an aerated pond according to Brayant (1995) the main processes are: oxidation, clarification and benthic aerobic/anaerobic digestion of the settled particulates. These processes can oscillate within a pond due to seasonal temperature variations, aeration intensity, aeration pattern, benthic feedback, and nutrient availability.

The focus of this study was to determine some physical-chemical and biological parameters that have a direct influence upon these processes, for a more accurate characterization of their behavior in an aerated facultative pond and a maturation pond treating piggery waste.

MATERIALS and METHODS

The treatment system comprised two in-series ponds: an aerated facultative pond (AFP) and a maturation pond (MP), both in real scale dimensions. The aerated facultative pond has a volume of 360 m^3 and is 1.20 m deep; the maturation pond has a volume of 492 m^3 and is 0.60 m deep. Retention time was approximately 40 and 60 days for AFP and MP, respectively.

The influent of the aerated facultative pond comes from an anaerobic treatment (anaerobic pond and UASB reactor), and the effluent was directed to the maturation pond. The final effluent of this pond went through a rock filter.

The experiment was accomplished in Braço do Norte, a city in the south of Santa Catarina, Brazil, with waste originated in a medium-size pig farm. The performance of the ponds was monitored during a 13-month period (January 2005 to January 2006). The parameters investigated were: pH, Dissolved Oxygen (mg DO/L), temperature (°C), Chemical Oxygen Demand (mg COD/L); ammonia (mg N- NH_3/L); phosphate (mg P-PO_4/L); Chlorophyll *a* (µg/L); algae abundance (%) and counting algae (cells/mL). Influent and effluent samples were collected weekly at 11 a.m. All analytical procedures followed APHA (1998) and Nusch (1980). The algae counting and identification was performed using microscopy and Neubauer chamber. The phosphate was analyzed using ionic chromatography (DIONEX 120 DX).

Results of the period evaluation were combined and used for statistical analysis. The box-plots graphics were accomplished using *Statistica 6.0.*

RESULTS and DISCUSSION

Table 1 shows the parameters variation throughout the monitoring, in Influent AFP (Inf. AFP), Effluent AFP (Effl. AFP) and Effluent MP (Effl. MP).

Table 1. Average results in the treatment systems (AFP + MP)

Parameters	Influent AFP	Effluent AFP	Effluent MP	Removal Rates (%)
Temperature (°C)	23 ± 5	22 ± 5	22 ± 5	-
pH	7.7 ± 0.2	8.5 ± 0.3	8.6 ± 0.6	-
DO (mg/L)	0.6 ± 1.4	1.6 ± 1.9	4.7 ± 3.5	-
COD (mg/L)	1977 ± 899*	642 ± 337**	337 ± 166**	83
N-NH_3 (mg/L)	788 ± 360	343 ± 208	119± 87	85
P-PO_4 (mg/L)	146 ± 67	80 ± 45	51± 27	65
Chlorophyll *a* (µg/L)	22 ± 12	488 ± 230	906 ± 511	-
Algae (cells/mL) ***	$1.3x10^4$	$1.2x\ 10^6$	$2.4x10^6$	-
Chlorella sp. - Abundance (%)	74 ± 20	74 ± 19	75 ± 18	-

* COD total (mg/L); ** COD soluble (mg/L); *** geometrical average.

The average temperature was similar in both ponds (22 to 23 °C). In the AFP influent, pH remained 7.7 and DO was low (0.6 mg/L), since the effluent proceeded from the UASB reactor. The AFP and MP effluent showed a DO tendency to increase (1.6 in the AFP Effl. and 4.7 in the MP Effl.), which demonstrates that this parameter is highly influenced by the applied organic load and biomass algae presence. The pH remained high, between 8.5 and 8.6, result of the photosynthesis and stabilization systems.

For the whole system (AFP + MP), the removal efficiencies were high: COD (83%), N -NH3 (85%) and P-PO4 (65%), during the entire year of monitoring. N-NH3 was mainly removed in the AFP through volatilization (nitrification did not occur throughout the monitoring) and removal also occurred in the MP by "stripping" and probably by algal assimilation, because these organisms are autotrophic and have the capacity to absorb nitrogen in the form of ammonia, common feature of *Chlorella sp* (Hoseti & Frost,1998).

The phosphate was removed by assimilation of the biomass (bacterial and algal) and by chemical precipitation (pH above 8.0 in both AFP and MP effluent). When pH is higher (> 7.6), the efficiency has values that are greater than 75% due to precipitation under the form of calcium phosphate (El Halouani et al, 1993).

According to El Halouani et al. (1993), more than 80% of ammonia and 30% of the phosphates can be incorporated in the algal biomass present in stabilization ponds. However, the results reported from Bassères (1990), in pilot ponds treating piggery waste and retention time of ten days, showed that 50% of ammonia was removed by volatilization and that the algae participation in the nitrogen removal was small (5%).

Identification and quantification of algal biomass show the biological diversity of biomass and indicate the organic load of the ponds and the level of treatment. The algal biomass, characterized by the concentration of Chlorophyll *a*, showed a trend of accumulation throughout the monitoring, having a greater concentration in the MP effluent, with values above 1800 µg/L (Figure 1). In both ponds, throughout the whole year, the concentration of Chlorophyll a was high, demonstrating stabilization in the algal population.

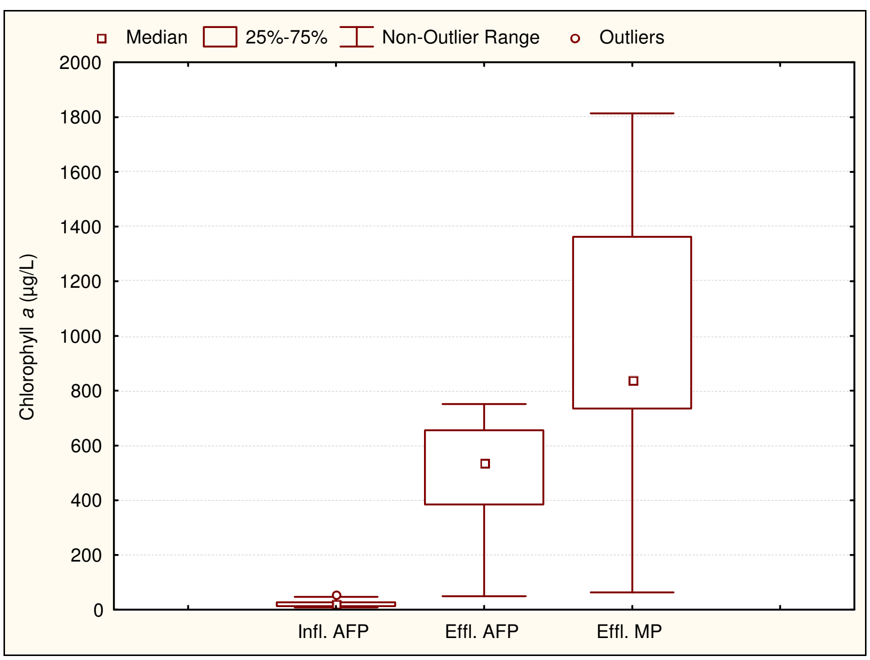

Figure 1 Box-plot of Chlorophyll *a* (µg/L) along the treatment system

Studies conducted by Oliveira (2002) showed concentrations of Chlorophyll *a* ranging between 1200 - 3000 µg/L in a high rate algal pond treating piggery waste in January, when the highest temperatures of the year occur, increasing proliferation of algal biomass. Meneses *et al.* (2005)

found Chlorophyll *a* concentrations between 65 – 3780 µg/L at different depths in the primary facultative ponds for domestic wastewater.

The stabilization system may also be verified by algal counting, since the total algal population remained between $6x10^3$ and $9x10^6$ cell/mL in the AFP effluent and $3x10^5$ to ~$1x10^7$ cell/mL in the MP effluent, during the whole year studied (Figure 2).

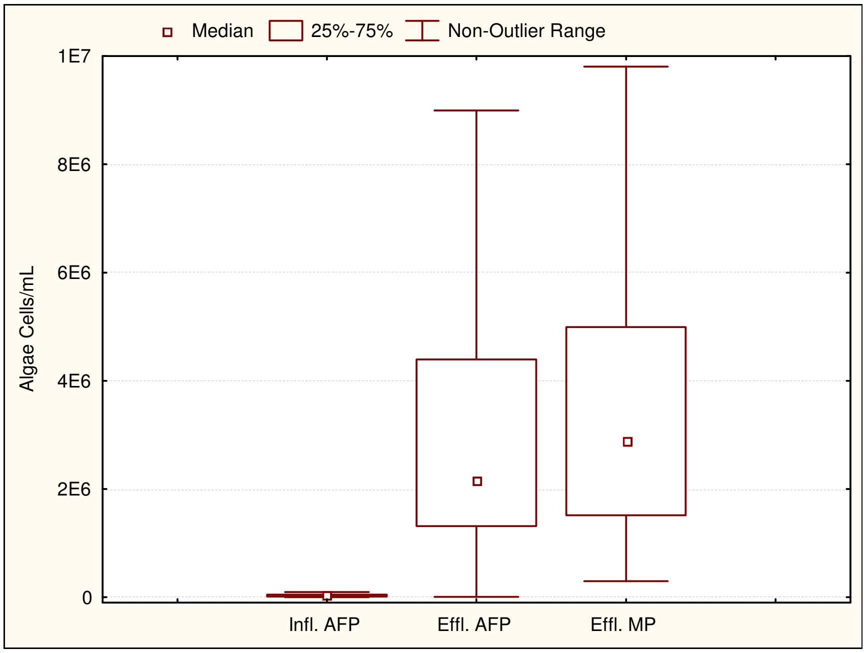

Figure 2 Box-plot of algae cells/mL along treatment system

For the treatment of piggery waste, the experiments conducted by Zanotelli (2002) using facultative ponds, values of *Chlorella vulgaris* ranged between $1.6x10^{11}$ and $2.4x10^{11}$ cells/mL; and Barthel *et al.* (2005) found these values to be between $8.6x10^6$ and $1.5x10^7$ in a high rate algal pond.

The predominance of *Chlorella sp.* occurred during the whole experimental period, with an median abundance between 77 and 80% (Figure 3) and frequency of 100%. Other general algae were found, however with lower frequency: *Chloridella sp., Euglena sp., Ankira sp., Arthrodesmus sp., Carteria sp., Scenedesmus sp., Micractinium sp., Chlorobotrys sp., Chlamydomonas sp., Chloromonas sp., Cosmarium sp., Dunaliella sp., Dysmorphococcus sp., Mesotaenium sp., Monoraphidium sp., Oocystis sp., Planctonema sp.*; *Chlorophyceae.*

The green alga *Chlorella sp.* is commonly found in high-rate ponds and facultative ponds with organic overload for its resistance and high growth rate (Athayde et al., 2000). According to Zulkifli (1992), *Chlorella sp.* is the most tolerant algae for temperature and salinity oscillation, prefers an environment with high organic matter and uses more ammonia than nitrate. Bartosh and Banks (2006) found that *Chorella vulgaris* presents setting mechanisms and maintains the survival even in adverse conditions such as low temperatures and lack of sunlight. Furthermore, in favorable conditions is extremely competitive, appearing in large quantities during the spring-summer.

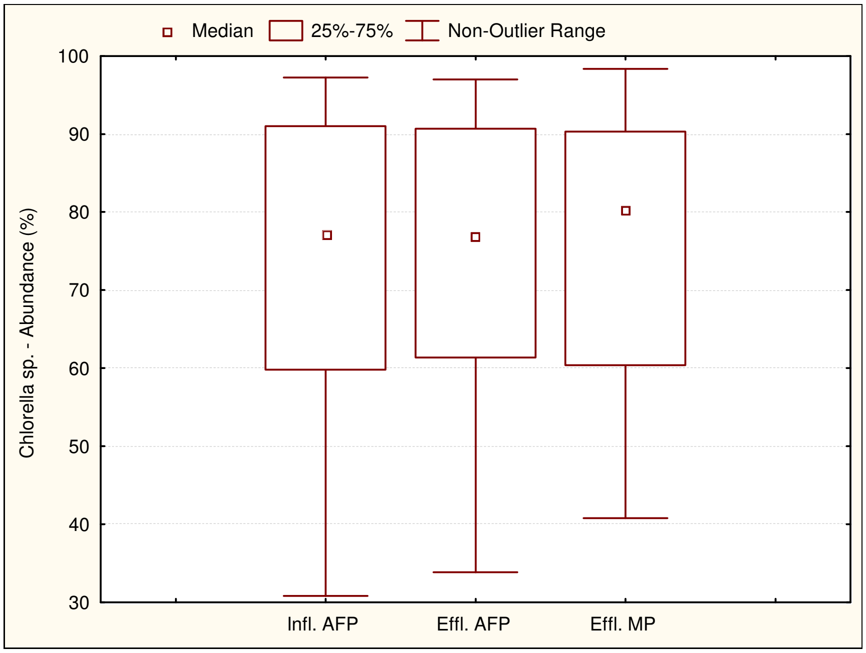

Figure 3. Box-plot of *Chorella sp.* – Abundance (%) along treatment system

CONCLUSIONS

The piggery waste treatment system, consisting of an Aerated Facultative Pond (AFP) and a Maturation Pond (MP) in series, was efficient in the removal of organic substance and nutrients (ammonia and phosphate).

Algal population was not affected by the organic load variation applied during monitoring and showed an increase in the concentration of Chlorophyll *a* throughout the treating system. The predominance of *Chlorella sp.* occurred during the whole experimental period, with median abundance between 70 and 80% and with a frequency of 100%.

The system, after 1 year of operation, showed a trend toward stabilization, with an adequate removal efficiency and maintenance of the algal biomass, even in climatic and organic load variation, a common feature in a real scale piggery waste treatment system.

REFERENCES

Athayde, S.T.S.; Pearson, H.W.; Silva, S.A. (2000). Algological study in waste stabilization ponds. In: *1st IWA Conferencia Latinoamericana en Lagunas de Estabilización y Reuso*. 132-139. Santiago de Cali, Colombia.

Barthel, L., Rangel, K., Machado, I., Oliveira, P.A.V., Costa, R.H.R. (2005). Sistema de Lagoas para remoção de matéria carbonácea e nutrientes de dejetos suínos (Pond system for the removal of carbon matter and nutrients in piggery waste). In: *23° Congresso Brasileiro de Eng. Sanitária e Ambiental*. Campo Grande, Brazil. CD-ROM.

Bartosh, Y. E Banks, C. J. (2006) Algal growth response and survival in a range of light and temperature conditions: implications for non-steady-state conditions in waste stabilization ponds. In: *7th Specialist Conference on Waste Stabilization Ponds*. Bangkok, Thailand. CD-ROM.

Bassères, A. (1990). *Performance des microphytes et des macrophytes dans l´epuration d´effluents organiques a forte charge em ammoniaque* (Performance of microphyte and macrophyte in the treatment of high load ammonium effluent). PhD Thesis, Paul Sebatier University, Montpellier, Toulouse, France.

Brayant, C.W. (1995). A simple method for analysis of the performance of aerated wastewater lagoons. *Water Science and. Technology,* **31** (12), 211-218.

El Halouani, H.; Picot, B. Casellas, C.; Pena, G.; Bontoux, J. (1993). Elimination de l'azote et du phosphore dans um lagunage à haut rendement (Removal of ammonia and phosphorous in a high rate algal pond). *Revue des Sciences de l´eau*, **6**, 47-61.

Hoseti, B. and Frost, S. (1998). A review of the control of biological waste treatment in stabilization ponds. Critical Reviews. *Environmental Science and Technology*, **28** (2), 193-218.

Medri, W.; Costa, R.H.R.; Medri, V.; Belli Filho, P. (2007). Stabilization Pond Systems: Cost Estimation for the Treatment of Piggery Waste. *Transactions of the ASABE*, **50** (4), 1490-1414.

Meneses, C.G.R., Saraiva, L.B., Melo, H.N., Melo, J.S., Pearson, H.W. (2005).Variations in BOD, algal biomass and organic matter biodegration constants in wind-mixed tropical facultative waste stabilization pond. *Water Science and Technology*, **51** (12), 183-190.

Nush, E. A. (1980). Comparation of different methods for chlorophyll and phaeopigment determination. *Arch. Hydrobiol. Beih. Suttgart*, **14**,14-36.

Oliveira, P.J.P. (2002). *Tratamento secundário e terciário de dejetos de suínos utilizando lagoas de alta taxa algal, aerada e maturação* (Secondary and tertiary treatment of piggery waste using high rate algal pond, aerated pond and maturation pond). MSc. Thesis, Environmental Engineering, Federal University of Santa Catarina, Florianópolis, Brazil.

Paterson, C. and Curtis, T. (2005). *Pond Treatment Technology*, (3) Physical and chemical environments. Edited by Andy Shilton, Integrated Environmental Technology Series, IWA Publishing, 49-65, London, UK.

Standard Methods for the Examination of Water and Wastewater (1998). 20th edn, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC, USA.

Zanotelli, T.C. (2002). *Modelagem matemática de nitrogênio e fósforo em lagoas facultativas e de aguapés para tratamento de dejetos de suínos* (Mathematical modeling of nitrogen and phosphorous in facultative ponds and water hyacinth pond in the treatment of piggery waste). PhD Thesis, Production Engineering, Federal University of Santa Catarina, Florianópolis, Brazil.

Zulkifli, H. (1992). *Traitement des eaux usées par lagunage à haut rendement: structure et dynamique des peuplements phytoplanctoniques* (Wastewater treatment through high rate pond: dynamics and structure of the phytoplanctonic population). PhD Thesis, Montpellier I University, Montpellier, France.