PRODUCTIVITY OF ALGAL BIOMASS IN PONDS TREATING PIGGERY WASTE

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ABSTRACT This work aims to calculate the productivity of algal biomass in a high rate algal pond (HRAP), two maturation ponds (MP1, MP2) and a water hyacinth pond (WHP) to treat piggery waste. The ponds were disposed in series and the work was developed during 32 weeks. Physicochemical variables were monitored. The performance of the treatment system, in relation to seasonal variations, was segment in two experimental periods: good solar radiation - **period 1** (P1) = radiation ≥ 80 cal cm^{-2} d^{-1} and lower solar radiation - **period 2** (P2) = radiation < 80 cal/ cm^{-2} d^{-1}. The average productivity of algal biomass was 10 gTSS m^{-2} d^{-1} in HRAP and it didn't reach this value in the two maturation ponds. The productivity of algal biomass was lower than 0.2 gchl-a m^{-2} d^{-1} in the studied ponds. In general, the productivity, presented higher in period P1 in all ponds, being that HRAP and MP2 presented productivity of 30 to 40% (gSST m^{-2} d^{-1}) higher in this period in relation to P2.

Keywords: Chlorophyll a; High rate algal pond; maturation pond; Piggery waste; Seasonality; Water hyacinth pond.

INTRODUCTION

Piggery waste is extremely concentrated, reaching values of 30,000 mg COD L^{-1}, 2,500 mg total nitrogen L^{-1} and 600 mg total phosphorus L^{-1}, generating a strong environmental impact in the piggery production region (Costa and Medri, 2002). The treatment using stabilization ponds results from a complex symbiosis between bacteria and algae, being the activity of these microorganisms dependent on pH daily variations, luminous intensity, dissolved oxygen and temperature.

The difficulty of modeling the productivity of algal biomass in ponds was related by Mesplé et al. (1995), because of the determination of functional relation between the phytoplankton and the zooplankton. The algal biomass productivity can be determined by the suspended solids (Oswald, 1988). But, there are numerous combinations, which caused difficulties in the modeling. When the pond has lower concentration of zooplankton, it does not have differences in the calculus of chlorophyll *a* and the modeling can be effectuated without errors. Thus, Fallowfield et al. (1992) compared two models probabilistic to the algal growth and obtained good correlation with measures of chlorophyll *a* in high rate algal ponds located in France and in Scotland.

In this context, the present work aims to calculate the productivity of algal biomass, verifying the seasonal variation, in a high rate algal pond (HRAP), maturation ponds (MP1, MP2) and a water hyacinth pond (WHP) working in continuous system to treat piggery waste.

MATERIALS AND METHODS

The piggery waste was previously treated in a system consisting of an equalization tank, a decanter and two anaerobic ponds disposed in series; in the sequence, the effluent passed through the secondary treatment, performed by a high-rate algal pond (HRAP), then continued on to the tertiary units of treatment: two maturation ponds (MP1 and MP2) and a water hyacinth pond (WHP). The ponds flow rate was 600 L d^{-1}, when exiting MP1 about 200 L d^{-1} were destined to MP2, forming ***System A***, and the rest (400 L d^{-1}) was discharged in WHP, forming ***System B*** (Figure 1), according to Barthel (2007). Ponds dimensions and operational conditions are presented in Table 1. In HRAP, the liquid mass mixing was 0.50 m s^{-1}.

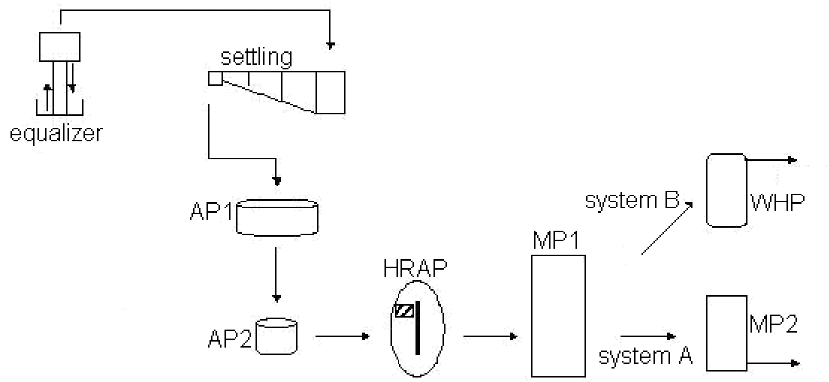

Figure 1. Schematic diagram of the pilot ponds system

Table 1. Pond dimensions and operational conditions

Pond	Depth (m)	Area (m^2)	Volume (m^3)	Flow rate ($m^3\ d^{-1}$)	HRT (days)	Surface loading rate (KgCODs $ha^{-1}\ d^{-1}$)
HRAP	0.50	12	6.3	0.60	10.5	357
MP1	0.70	60	42	0.60	70	32
MP2	0.70	6	3.44	0.20	17.2	90
WHP	0.70	6	3.44	0.40	8.6	148

This work was conducted at the Experimental Unit for Piggery Waste Treatment of EMBRAPA (Brazilian Agricultural Research Corporation), located in the city of Concórdia, in the State of Santa Catarina, Brazil (south latitude 27°14’03” and longitude 52°01’40”). The physicochemical analyses: pH, dissolved oxygen (DO), total suspended solids (TSS), biochemical and chemical oxygen demand (BOD and COD) total (t) or soluble (s), nitrogen (TKN, NH_4-N, NO_2-N and NO_3-N) and total phosphorous (TP) were diagnosed according to the *Standard Methods* handbook (APHA, AWWA, WEF, 1998). The chlorophyll *a* (chl-a) was determined according to Nusch (1980). The samples were collected fortnightly, in the morning, at the outlet of each treatment stage. The work was developed over 32 weeks (February to October/2003).

The performance of treatment system, in relation to seasonal variations, was segmented into two experimental periods: good solar radiation - **period 1** (P1) radiation ≥ 80 cal $cm^{-2}\ d^{-1}$ (February/March/April/September/October) and lower solar radiation - **period 2** (P2) radiation < 80 cal $cm^{-2}\ d^{-1}$ (May/June/July/August).

The productivity of algal biomass (Pr) was estimated in terms of total suspended solids (gTSS $m^{-2}\ d^{-1}$), calculated by equation 1, developed by Oswald (1988):

$$Pr = d * C/\varnothing \quad (1)$$

where:

Pr = productivity of algal biomass (gTSS m^{-2} d^{-1}); d = depth of pond (m); C = algal concentration, measured by Total Suspended Solids (gTSS m^{-2} d^{-1}); ∅ = residence time (days).

The productivity of algal biomass (Pr) utilizing the chlorophyll *a* (gchl-a cm^{-2} d^{-1}) was calculated by the equation 2, developed by Fallowfield et al. (1992):

$$Pr = \{(Chl\ aA - Chl\ aE) * V\} * 40/(\varnothing * A) \qquad (2)$$

where:

Pr = productivity of algal biomass (gchl-a m^{-2} d^{-1}); Chl *a*A = chlorophyll *a* concentration in the pond influent; Chl *a*E = chlorophyll *a* concentration in the pond effluent; V = pond volume (m^3); ∅ = residence time (days); A = pond area (m²).

RESULTS and DISCUSSIONS

Table 1 and 2 show the results of the variables measured in P1 and P2 period, respectively (average values, standard-deviation and efficiency).

The average water temperature in liquid mass remained around 17.3 and 19.5ºC in P1 in the ponds. In this period the highest values of DO and pH were found in MP1, being of 5.10 and 9.19 mg L^{-1}, respectively. The average water temperature in liquid mass remained around 15ºC in P2, in all ponds and the highest values of DO and pH were 5.83 and 8.76 mg L^{-1}, respectively, in MP1.

Table 1. Average values, standard-deviation and efficiency obtained to P1. (n = 12)

Pond	HRAP Influent	HRAP Effluent	MP1 Effluent	MP2 Effluent	WHP Effluent
Temper. (°C)	17.3 ±4.7	17.9 ±4.0	18.6 ± 3.7	18.7 ± 3.6	19.5 ± 3.3
DO (mg L^{-1})	0.5+0.2	3.78± 1.5	5.10 ± 2.60	3.8 ±0.4	2.0±1.2
pH	7.15± 0.54	8.53 ±0.5	9.19± 0.23	8.92 ±0.7	7.67 ± 0.4
CODt (mg L^{-1})	783±560	885 ±603	435 ±140	406±108	295±144
ε (%)	-	-	51	7	32
CODs (mg L^{-1})	558±405	661±688	288 ±159	241±91	203±125
ε (%)	-	-	56	16	30
$BOD_{5,s}$ (mg L^{-1})	159± 172	36± 23	28 ±16	48± 33	50± 29
ε (%)	-	77	22	-	-
TSS (mg L^{-1})	200 ±165	301±162	89 ±30	111±43	91±59
ε (%)	-	-	70	-	-
TKN (mg L^{-1})	988±1192	324±410	83±145	45±60	68±91
ε (%)	-	67	74	46	18
NH_4-N(mg L^{-1})	579±219	195±107	28±43	10 ±16	29±28
ε (%)	-	66	86	64	-
NO_2-N (mg L^{-1})	0.32 ±0.46	216 ±184	170 ±267	68 ±151	22 ±48
ε (%)	-	-	21	60	87
NO_3- N (mg L^{-1})	2.6 ±4.9	270±453	93±144	60 ±152	63 ±160
ε (%)	-	-	66	35	32
TP (mg L^{-1})	23 ±17	20±10	5 ±4	3.6±3	7±4.3
ε (%)	-	13	75	28	-

Table 2. Average values, standard-deviation and efficiency obtained to P2. (n = 10)

Pond	HRAP Influent	HRAP Effluent	MP1 Effluent	MP2 Effluent	WHP Effluent
Temper. (°C)	15.69± 0.99	15.54 ± 1.0	15.33 ± 1.31	15.26 ± 1.06	15.5 ± 1.2
DO (mg L^{-1})	0.4+1.7	2,.5 ± 1.6	5.83 ± 2.73	4.3 ± 2.0	1.8± 2.1
pH	6.97 ± 0.4	8.62 ± 0.7	8.76 ±1.0	8.71 ± 1.2	7.54 ± 0.7
CODt (mg L^{-1}) ε (%)	1057 ±242 -	1508±1143 -	467 ±78 69	450±84 4	304±100 35
CODs (mg L^{-1}) ε (%)	698 ±276 -	774 ±262 -	364 ±186 53	302±54 17	243±63 33
$BOD_{5,s}$ (mg L^{-1}) ε (%)	281± 85 -	48± 34 83	30± 24 38	63± 58 -	73± 77 -
TSS (mg L^{-1}) ε (%)	263 ±95 -	183±77 30	78 ±40 57	72 ±29 8	74±73 5
TKN (mg L^{-1}) ε (%)	842±171 -	266±107 68	67±25 75	41±22 39	37±19 45
NH_4-N(mg L^{-1}) ε (%)	752±142 -	225 ±54 70	54±31 76	31 ±26 43	28±19 48
NO_2-N (mg L^{-1}) ε (%)	1.03 ±0.9 -	429 ±74 -	103 ±26 76	57 ±21 45	25 ±31 76
NO_3- N (mg L^{-1}) ε (%)	3.0 ±1.8 -	626 ±506 -	180±127 71	112 ±88 38	123 ±134 32
TP (mg L^{-1}) ε (%)	32 ±8 -	27±13 16	9.5 ±2.6 65	9.64±25 -	5.6 ±3 41

During the two periods, the values of CODt and CODs in HRAP were higher in relation to the influent concentration, due to the algal development and the increase of TSS concentration. The increase of the concentration fraction soluble of BOD (or COD) could be occasioned by the presence of tissue and algal pigments in decomposition and the environment with bacteria biomass production. The average concentration of TSS was higher in P1 to the System A (exit with MP2), being that in P2 similar values were found in the exit of the two systems (A and B). In P1 an increase of average concentration of TSS in HRAP (301 mg L^{-1}) was observed in relation to the influent (200 mg L^{-1}), probably due to algal production in this pond.

In relation to nitrogen compounds, it was observed that HRAP presented nitrification, with excellent ammonia nitrogen removal performance. The ammonia presented lower concentrations in the other ponds. The nitrite and nitrate formed in HRAP showed much lower concentrations in MP1, due to possible algal assimilation in this pond. TP was better removed in the tertiary ponds (MP1, MP2 and WHP). The favorable environmental conditions to the phosphorus removal mechanism, like high pH and DO, favored a precipitation removal. In MP1 this variable had the higher reduction due to the higher values of pH (9.19 in P1 and 8.76 in P2) and DO (5.10 mg L^{-1} in P1 and 5.83 mg L^{-1} in P2).

The Figure 2 shows temporal variation of productivity of algal biomass (expressed in TSS) in different ponds studied.

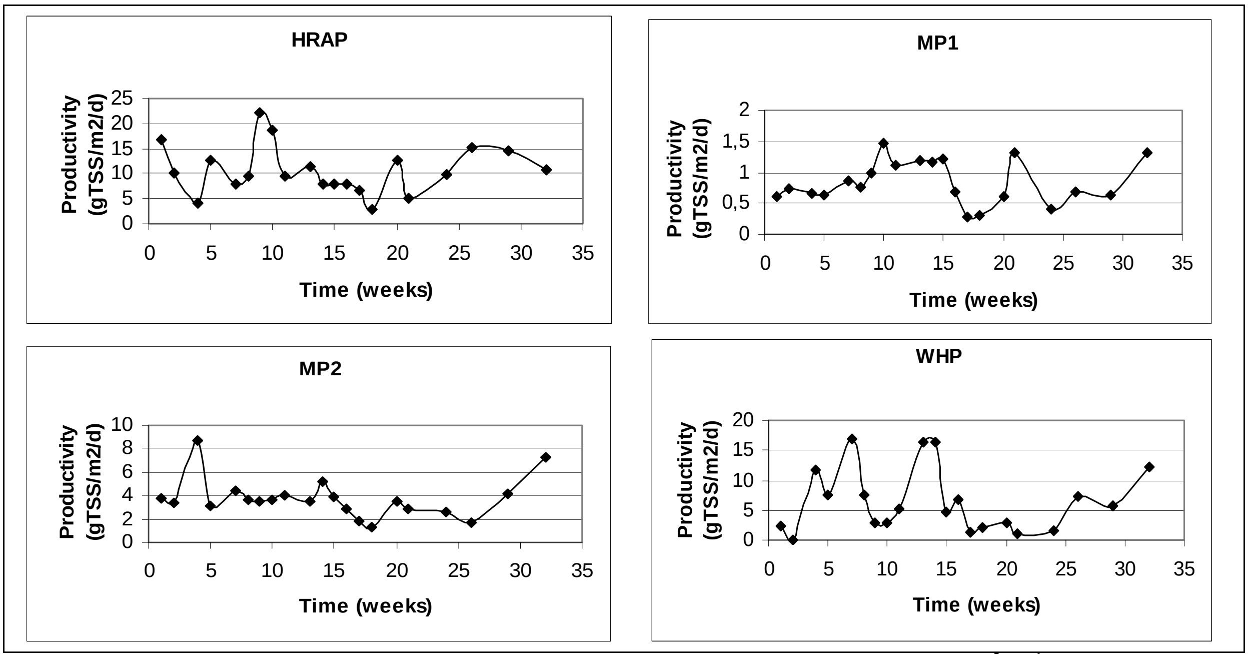

Figure 2. Temporal variation of the productivity of algal biomass (gTSS m^{-2} d^{-1}) in the ponds.

The average productivity of algal biomass was 10 gTSS m^{-2} d^{-1} in HRAP, being lower than 1.5 gTSS m^{-2} d^{-1} in MP1 and around 4 gTSS m^{-2} d^{-1} in MP2. In WHP, the productivity presented great variation during the experimental period, with an average of 8 gTSS m^{-2} d^{-1}. König (2000) reported that the factors controlling the displacement and the distribution of the algae in the water column were, mainly, the temperature and light intensity. The lower productivity in MP1 could be consequence of the long residence time (70 days), according to Garcia et al. (2002) and Zulkifi (1992). This latter author obtained 125 gTSS m^{-2} d^{-1} in pond A (residence time = 2 to 3 days) and values lower than 25 gTSS m^{-2} d^{-1} in pond B (residence time = 8 days), in two high rate algal ponds, showing that when the residence time is longer the productivity is lower. Garcia et al. (2002) registered productivity of algal biomass of 12.7 gTSS m^{-2} d^{-1} (residence time = 7 days) and 14.8 gTSS m^{-2} d^{-1} (residence time = 3 days) in two high rate algal ponds with domestic effluent. Bassères (1990) related 10.45 gTSS m^{-2} d^{-1} in piggery waste pilot ponds with 10 days of residence time.

The Figure 3 shows the temporal variation of the productivity of algal biomass (expressed in gchl-a m^{-2} d^{-1}) in the different ponds studied, calculated according to equation 2 from Fallowfield et al. (1992) model.

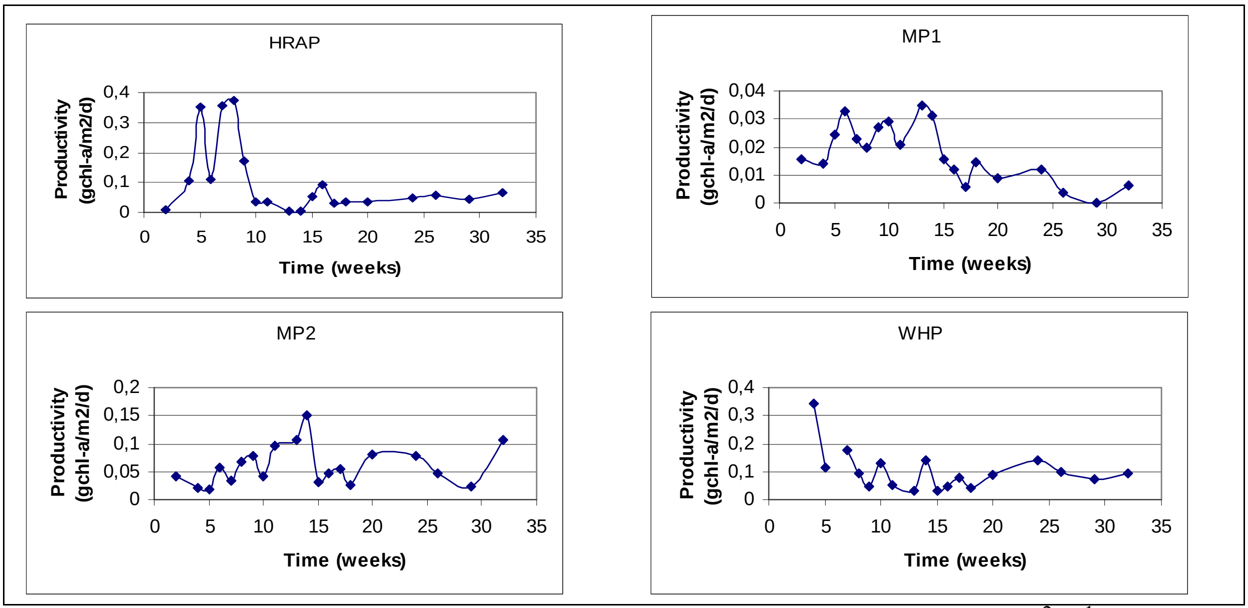

Figure 3. Temporal variation of the productivity of algal biomass (gchl-a m^{-2} d^{-1}) in the ponds.

The productivity of algal biomass (gchl-a m^{-2} d^{-1}) was higher in HRAP, with peaks around 0.4 gchl-a m^{-2} d^{-1} in the first ten weeks, then productivity decreased in the next few weeks. WHP presented peaks around 0.4 gchl-a m^{-2} d^{-1} in the first five weeks and decreased in productivity after. Maturation ponds presented lower productivity of algal biomass. Zulkifli (1992) obtained, in high rate algal ponds, maximum productivity of 0.6 gchl-a m^{-2} d^{-1} and average productivity of 0.05 gchl-a m^{-2} d^{-1} in pond A (residence time of 2 to 3 days), and in pond B (residence time of 8 days) this productivity was <0.05 gchl-a m^{-2} d^{-1}. The values found in HRAP, MP2 and WHP, in this work (Figure 3), placed near that obtained by this author in pond A, but were employed for a longer residence time. The obtained values to MP1 (residence time = 70 days) were similar to those obtained by this author in pond B.

In relation to the seasonal variation, the average values obtained to the productivity of algal biomass are show in Table 3.

Table 3. Average values of the productivity of algal biomass (Pr) in the ponds during P1 and P2 periods.

	Pr (gTSS m^{-2} d^{-1})	Pr (gTSS m^{-2} d^{-1})	Pr (gchl-a m^{-2} d^{-1})	Pr (gchl-a m^{-2} d^{-1})
	P1	P2	P1	P2
HRAP	12.5	8.7	0.15	0.04
MP1	0.89	0.78	0.02	0.01
MP2	4.5	2.90	0.05	0.07
WHP	6.77	6.0	0.13	0.08

The average results obtained to the productivity of algal biomass in HRAP in P1 and P2 were 12.5 and 8.7 gTSS m^{-2} d^{-1}, respectively; MP1 presented the minor averages, probably in relation to the longer residence period (70 days), as much as in P1 and in P2: 0.89 and 0.78 gTSS m^{-2} d^{-1}, respectively; while that MP2 presented 4.5 gTSS m^{-2} d^{-1} to P1 and 2.9 gTSS m^{-2} d^{-1} to P2. In WHP the productivity presented greater variation during the experimental period, it is observed average productivity of 6.77 gTSS m^{-2} d^{-1} to P1 and 6.0 gTSS m^{-2} d^{-1} to P2. The average values found the algal activity in terms of gchl-a m^{-2} d^{-1} in the different ponds were lower than 0.2 gchl-a m^{-2} d^{-1}, as much as in P1 and P2, except in HRAP in P1.

The productivity of algal biomass models developed by Oswald (1988) and Fallowfield et al. (1992), with TSS and chlorophyll *a*, respectively, applied in this work, showed evidence of seasonal influence, especially in HRAP.

CONCLUSIONS

The values of the productivity of algal biomass in ponds for piggery waste treatment, in this study, were lower those found by others authors in ponds with domestic waste (Zulkifli, 1992; Garcia et al., 2002). The lower productivity in MP1 could be due to the long residence time (70 days). The chlorophyll *a* concentration and the productivity of algal biomass were elevated in the high rate algal pond that received the high organic load. The seasonal variation in the first weeks of the experimental period, in the studied ponds, was evident because of the higher solar radiation and temperature. Concerning the seasonality, in general, the productivity of algal biomass presented higher values in P1 (good solar radiation) in all ponds, evidencing the photosynthesis function in the studied ponds.

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