Treatment of domestic wastewater in shallow waste stabilization ponds for agricultural irrigation reuse

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Abstract Stabilization ponds are a well established wastewater treatment system being considered by World Health Organization as one of the most appropriated technology for domestic wastewater when agricultural reuse is considered, especially in developing countries. This study was performed in a series of pilot-scale stabilization ponds, being one facultative and three maturation ponds, with depts. Varying from 0.44 to 0.57m. The substrate being treated was composed of a mixture of domestic wastewater and previously anaerobicaly treated leachate. The experimental system was monitored in two different phases, in which the hydraulic retention times was 15 (phase 1) and 10 days (phase 2). Termotolerant coliform removal efficiency were 3.8 log_{10} units in both phases while organic matter (BOD_5) removal was 87 and 68% for phases 1 and 2 respectively.
Key word: domestic wastewater, treatment, agricultural reuse, shallow ponds

INTRODUCTION

Well designed and operated waste stabilization ponds (WSP) systems can satisfactory remove undesired constituents from wastewater such as biodegradable organic matter, suspended solids and pathogenic microorganisms, besides to promote the retention of nutrients which favourably contributes to the use of such effluents in agricultural irrigation (Mara, 2001).
WSP are a well known technology for the treatment of domestic wastewater and is considered by the World Health Organization (WHO) as the most appropriated means of wastewater treatment when agricultural reuse is considered (WHO, 1989) specially for developing countries, due to its construction, operation and maintenance low costs (Arthur, 1983). Research developed by Silva (1982), have shown the high degree of treatment reached by the effluent of waste stabilization ponds, both in terms of organic matter and pathogenic microorganisms. The high hydraulic retention times (HRT), which are common in WSP systems, in conjunction with adverse factors to microorganisms, is the main cause of the high bacteriological quality effluent, which have also the characteristic of presenting high level of nutrients, being therefore, suitable for agricultural irrigation (Mara, 1996).
According to Arthur (1983), WSP are the most suitable wastewater treatment option for developing countries located in tropical or subtropical regions, where generally land is available and ship and climate is favourable for the treatment process. The idea of reusing treated wastewater has being developing to be part of the rational use of water resources, besides being an important practise in arid and semi-arid areas (Shilton, 2005), such as the northeast Brazil.
In Brazil, the indirect and uncontrolled reuse of wastewater is a routine practise. This activity is more evident in semi-arid areas in the northeast Brazil, where the lack of wastewater treatment is

rapidly negatively affecting the water resources. On the other hand, this region of Brazil, due to its geographic and economical characteristics, have favourable conditions for the wastewater reuse and leads small and medium farmers to use a non conventional water to replace the lack of water for irrigation. Furthermore, the wastewater reuse presents other advantage, such as: water pollution control, water and fertilizers savings, recycle of nutrients and the increase in agricultural production (Athayde Júnior, 1999)
In this context, the objective of this paper is to evaluate the performance of a series of shallow WSP treating domestic wastewater for the production of an effluent suitable for agricultural irrigation according to legal aspects.

MATERIAL E METHODS

The research was conducted in *Estação Experimental de Tratamentos Biológicos de Esgotos Sanitários – EXTRABES*, located in Campina Grande – PB, Brazil. The experimental system comprised four ponds, being the first a facultative one and more three maturation ponds. The series of WSP were preceded by an UASB which received a mixture of raw sewage and leachate. The UASB effluent was mixed with raw sewage before going to the WSP series. Figure 1 schematically shows the pond system, while Table 1 shows the operational features.

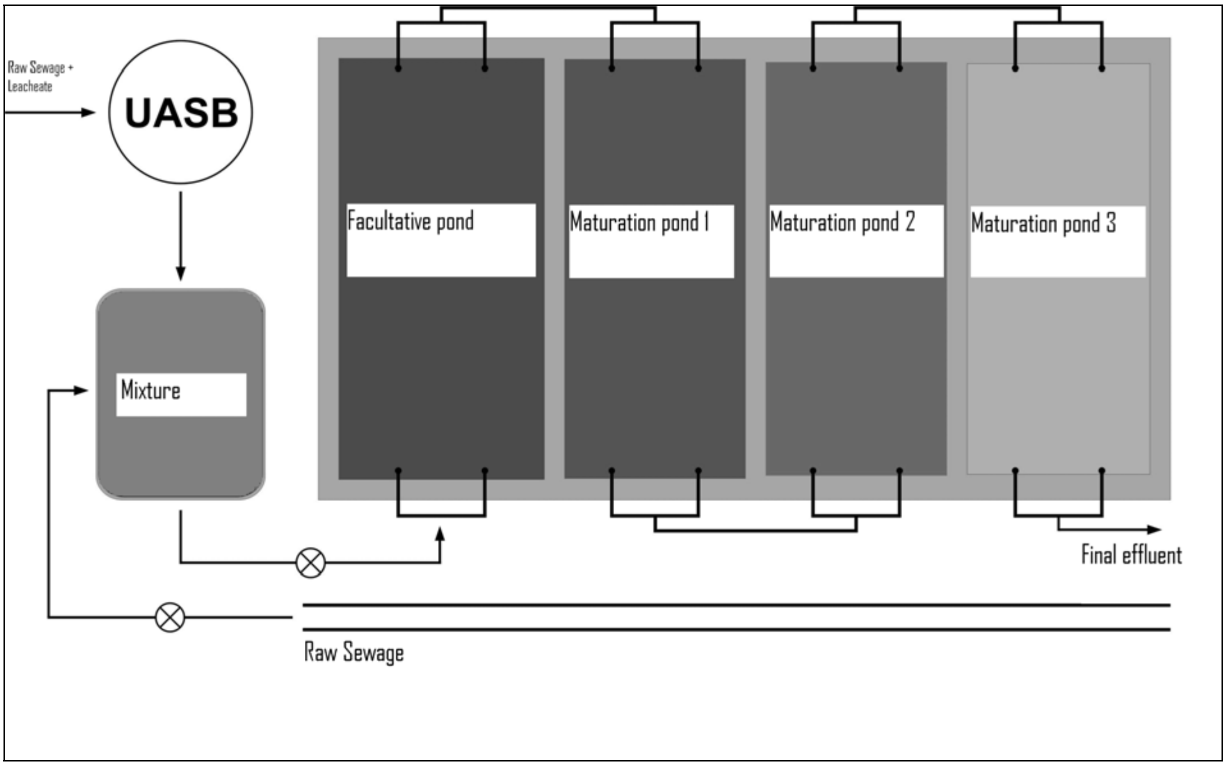

Figure 1: Scheme of experimental WSP system

Table 1: Physical and operational features of the WSP system

pond	Width (m)	Length (m)	Depth (m)	Surface area (m^2)	Volume (m^3)	HRT (days)	
						Phase 1	Phase 2
Facultative	1,00	2,05	0,57	2,05	1,17	4,7	3,1
Maturation 1	0,88	2,04	0,53	1,79	0,95	3,8	2,5
Maturation 2	0,88	2,01	0,48	1,76	0,84	3,4	2,3
Maturation 3	0,89	2,00	0,44	1,78	0,78	3,1	2,1

The parameters analyzed were: pH, COD, BOD_5; termotolerant coliform, total solids, volatile total solids, suspended solids, volatile suspended solids, total alkalinity, volatile acids, ammonia, nitrate, total phosphorus, soluble orthophosphate. Physico-quemical and microbiological analyses were performed in accordance with APHA et al (1995), with excepition for chrorophyll a, which was determined according to Jones (1979) and sampling occurred weekly during five and four months in phase 1 and 2 respectively.

RESULTS

Table 2 shows the results for the characterization of the substrate from the mixture tank, while Table 3 show the results for the final effluent (maturation pond 3), both for phase 1.
Analysing data from Table 2, it can be noticed that the substrate used to fed the WSP system presented good conditions for biological treatment, since pH values were around 7,8, with high alkalinity values and low volatile acids concentration. BOD_5 varied from 126 to 262 mg/L while mean value for total solids was 1422 mg/L. BOD_5/COD ratio was 0,41, indicating some biodegradable material. Termotolerant coliform numbers were around 10^6 CFU/100 mL.

Table 2. Mixture tank substrate characterization – phase 1

Parameter	Unit	*n*	minimum	maximum	mean[1]
pH	-	18	7,7	8,1	7,8
Total alkalinity	$mgCaCO_3.L^{-1}$	18	282	980	642
Volatile acids	$mgH_{AC}.L^{-1}$	18	34	110	72
BOD_5	$mg.L^{-1}$	16	126	262	183
COD	$mg.L^{-1}$	17	304	661	445
Total solids	$mg.L^{-1}$	18	1007	2114	1422
Volatile total solids	$mg.L^{-1}$	18	208	1144	398
Suspended solids	$mg.L^{-1}$	18	92	196	141
Volatile suspended solids	$mg.L^{-1}$	14	83	167	118
Ammonia	$mg.L^{-1}$	18	29	117	77
Total phosphorus	$mg.L^{-1}$	16	5,7	18,2	12,0
Soluble orthophosphate	$mg.L^{-1}$	16	3,4	11,2	7,0
Termotolerant coliform	$CFU.100ml^{-1}$	18	$1,8.10^6$	$2,4x10^7$	$6,5x10^6$

[1]Arithmetic mean for all the parameter except for termotolerant coliform, which was used the geometric mean.

Table 3 shows the final effluent quality in phase 1. This effluent was alkaline, with maximum pH of 9,4, due to the photosynthetic activity of algae, which were characterized by chlorophyll a values of up to 678 μg//L. BOD removal efficiency was 89%, with final effluent concentration of 20 mg/L. For termotolerant coliform, the removal efficiency was 3,8 log_{10} units what indicates a possible high reduction for pathogenic microorganisms and the good microbiological quality of the final effluent.
Therefore, in general, the effluent of the pond series, operated with 15 days of HRT, presented an effluent suitable for irrigation, resulting in several benefits such as economical, social and environmental ones.

Table 3. Physico-quemical and microbiological characterization of final effluent – phase 1

Parâmetro	Unit	*n*	minimum	maximum	mean
pH	-	18	7,8	9,4	8,6
Total alkalinity	$mgCaCO_3L^{-1}$	18	236	629	407
Volatile acids	$mgH_{AC}L^{-1}$	18	13	32	22
BOD_5	$mg.L^{-1}$	16	2,7	34,0	20,1
COD	$mg.L^{-1}$	17	61	615	208
Total solids	$mg.L^{-1}$	18	788	1998	1207
Volatile total solids	$mg.L^{-1}$	18	68	843	202
Suspended solids	$mg. L^{-1}$	18	20	109	49
Volatile suspended solids	$mg.L^{-1}$	14	2	95	38
Ammonia	$mg.L^{-1}$	18	1,7	22,0	7,8
Total phosphorus	$g L^{-1}$	16	2,5	9,1	4,6
Soluble orthophosphate	$mg L^{-1}$	16	2,0	6,2	3,6
Termotolerant coliform	$CFU.100ml^{-1}$	18	130	$6,6x10^3$	$1,0x10^3$
Chorophyll *a*	$\mu g.L^{-1}$	18	71	678	263

[1]Arithmetic mean for all the parameter except for termotolerant coliform, which was used the geometric mean.

Table 4 shows the final effluent quality in phase 2. In general, in comparison to the substrate of phase 1, the substrate in phase 2 presented lower levels of parameters concentration. BOD_5 /COD ratio was 0,36 (as compared to 0,41 in phase 1).
Table 5 shows the final effluent quality in phase 2. The BOD_5 removal efficiency was 68% in comparison to 89% in phase 1. Suspended solids also presented lower removal efficiency in phase 2. These lower removal efficiency may be associated with the lower BOD_5 /COD ratio in phase 2. For termotolerant coliform, the removal was of 3,8 log_{10} units, which was the same as in phase 1, resulting in less than 10^3 $CFU.100mL^{-1}$ with a cumulative HRT of 10 days.

Table 4. Mixture tank substrate characterization – phase 2

Parâmetro	Unit	*n*	minimum	maximum	mean
pH	-	18	7,7	8,5	8,0
Total alkalinity	$mgCaCO_3.L^{-1}$	18	264	392	329
Volatile acids	$mgH_{AC}.L^{-1}$	18	7	56	24
BOD_5	$mg.L^{-1}$	18	13	73	44
COD	$mg.L^{-1}$	18	42	203	149
Total solids	$mg.L^{-1}$	14	614	767	708
Volatile total solids	$mg.L^{-1}$	14	50	137	92
Suspended solids	$mg.L^{-1}$	14	41	106	68
Volatile suspended solids	$mg.L^{-1}$	14	34	88	57
Ammonia	$mg.L^{-1}$	18	14,3	73,3	41,7
Total phosphorus	$mg.L^{-1}$	16	1,1	10,2	5,0
Soluble orthophosphate	$mg.L^{-1}$	16	3,1	4,8	3,8
Termotolerant coliform	$CFU.100ml^{-1}$	18	$6,0x10^4$	$7,5x10^6$	$2,2x10^6$

[1]Arithmetic mean for all the parameter except for termotolerant coliform, which was used the geometric mean.

Table 3. Physico-quemical and microbiological characterization of final effluent – phase 2

Parâmetro	Unit	*n*	minimum	maximum	mean
pH	-	18	8,1	9,3	8,7
Total alkalinity	$mgCaCO\ L^{-1}$	18	194	284	237
Volatile acids	$mgH_{AC}.L^{-1}$	18	8	20	13
BOD_5	$mg\ L^{-1}$	18	3	27	14
COD	$mg\ L^{-1}$	18	15	285	120
Total solids	$mg\ L^{-1}$	14	636	777	713
Volatile total solids	$mg\ L^{-1}$	14	12	74	37
Suspended solids	$mg\ L^{-1}$	14	11	69	32
Ammonia	$mg\ L^{-1}$	18	2,6	15,0	7,3
Total phosphorus	$mg\ L^{-1}$	16	1,1	7,5	4,6
Soluble orthophosphate	$mg.L^{-1}$	16	1,4	7,2	3,8
Termotolerant coliform	$UFC.100ml^{-1}$	18	22	$3,1x10^3$	$3,7x10^2$
Chorophyll *a*	$\mu g.L^{-1}$	17	74,6	1.215,8	271,0

[1]Arithmetic mean for all the parameter except for termotolerant coliform, which was used the geometric mean.

CONCLUSION

Waste stabilization ponds showed to be suitable for the combined treatment of leachate and domestic wastewater. The series of shallow ponds showed to be very efficient in terms of termotolerant coliform removal, being needed about 10 of HRT for the effluent to reach the treatment level which is considered suitable for the reuse in irrigation. The substrate BOD_5/COD ratio and the HRT poses influence on the treatment efficiency. Furthermore, the nutrient level found in the final effluent is another aspect which is favourable for the reuse in agricultural irrigation, resulting in water conservation.

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