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Cotreatment of sewage and septage in waste stabilization ponds

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Abstract A one year study was carried out in a waste stabilization ponds system where septage and sewage are cotreated. The system consists of two septage ponds which operate alternately followed by two ponds in series which receive the combined effluent. The septage ponds also act as evaporation ponds for the accumulated sludge. The monitoring program was divided in two phases. The results of the first phase indicate that the effluent of septage ponds has an adequate quality to be discharged into the waste stabilization ponds designed to treat sewage and that is possible to use the septage ponds to dry the accumulated sludge. Further investigation is needed to find suitable post-treatment of the sludge in order to use it in agriculture.

Keywords Effluent quality; septage; sewage; sludge; waste stabilization ponds; vacuum trucks

Introduction

In 1987 a system of two waste stabilization ponds in series was put into operation in the town of Alcorta, which is located 92 km from Rosario, Argentina. Alcorta has a population of 4000 inhabitants; 1400 inhabitants are connected to a sewerage network, while the rest have individual systems of septic tanks and cesspools, which are emptied by vacuum trucks. Both wastewater and septage were cotreated in a pond stabilization system with two ponds in series. The vaccum trucks discharge directly into the first pond. A monitoring program started in 1994 by the Centro de Ingeniería Sanitaria, Universidad Nacional de Rosario (CIS/UNR) indicated that, as a consequence of the high contents of solids of septage, the primary pond had reduced its capacity by half. Based on the previous investigations made at CIS/UNR (Ingallinella *et al.*,1996), the construction of two septage ponds was proposed. The ponds with the new configuration began to work in July 1998.

In the same year a collaboration contract was signed with EAWAG/SANDEC in order to evaluate the above mentioned system. A monitoring program was proposed with the following general objectives.

- To study the feasibility of the use of septage ponds as a primary treatment in a system where cotreatment of septage and sewage takes place.
- To determine the possibility of using the septage ponds as drying sludge ponds.

The monitoring program was divided in two phases, A and B. The results obtained in the Phase A are presented in this paper.

Methodology

Description of the system and sampling points

The system evaluated includes two ponds for vacuum trucks (C1 and C2) and two ponds treating combined effluent (L1 and L2). The system monitored and the sampling points (1 to 5) are shown in Figure 1.

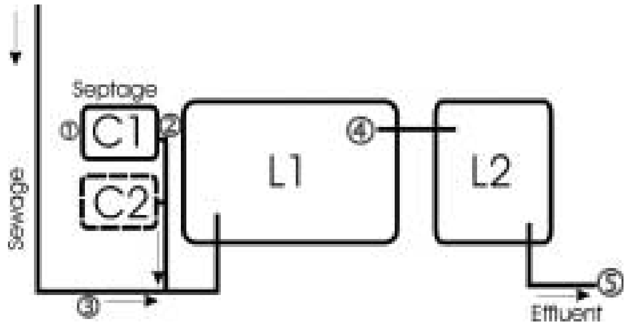

Figure 1 Layout of the waste stabilization ponds

C1 and C2		L1		L2	
Length (m):	25.00	Length (m):	83.00	Length (m):	38.00
Width (m):	11.00	Width (m):	57.00	Width (m):	53.00
Depth (m):	1.50	Depth (m):	1.20	Depth (m):	1.30
Baffles:	No	Baffles:	No	Baffles:	Yes

The sampling points and the methodology used for the extraction of samples are described below.

Liquid transported by vacuum trucks. Composite samples were taken on every sampling occasion. They were obtained for each truck by taking each time approximately 500 ml at the beginning, in the middle, and at the end of the discharge, trying to cover the marked differences that this kind of liquid presents (regarding especially settleable solids) during the discharge.

Septage pond effluent. Grab samples were taken at the outlet of ponds C1 or C2 (depending on which was working). The flow from C1 or C2 to L1 was not steady because, during the discharge from trucks, it presented a peak which reduced practically to zero after minutes. This is why no samples were taken from the composite liquid (sewer system + effluent of C1or C2) entering L1. Moreover, the flow effluent from C1 or C2 is significantly lower than the sewerage flow.

Sewage. The samples were taken from the Parshall flume before mixing with C1 or C2 effluent. The samples were flow-weighted, based on the inlet flow at the time of sampling, from 6:00 AM until 6:00 PM.

L1 and L2 effluent. The sample was taken from the outlet of each pond at 10:00 during summer and at 11:00 during winter.

Sludges. The sludge accumulated in pond C1 or C2 was sampled 10 cm below the surface at two points: in the inlet and outlet zones.

Parameters analysed

These included flow, pH, DO, temperature, biochemical oxygen demand (total and filtered), chemical oxygen demand (total and filtered), settled solids, volatile suspended solids, total phosphorus, total nitrogen, nitrate, sulfate, ammonia, total solids in sludge, volatile solids in sludge, faecal coliforms and helminth eggs. The techniques used are those

Table 1 Meterological data for the first stage (January 1999 – July 1999)

	Months						
Information	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUNE**	**JULY**
Rainfall (mm/day)	56.4	120.7	198.5	40.2	12.1	10.9	12.5
Temperature (°C)	21.7	22.1	21.6	15.2	13.1	10.3	9.1
Wind speed (km/h)	8.7	6.5	8.2	8.7	7.5	2.3	2.6
Evap. (mm/day)	5.1	4.2	2.6	2.0	1.5	1.2	1.1
Sunlight (hrs/day)	8.1	9.1	7.2	5.3	6.3	4.2	5.4

Table 2 Meterological data for the second stage (August 1999 – February 2000)

	Months						
Information	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**
Rainfall (mm/day)	42.4	35.9	62.6	22.5	76.0	70.5	217.7
Temperature (°C)	12.4	13.9	16.7	19.9	22.4	24.2	22.3
Winds (km/h)	13.6	11.1	11.2	10.9	10.2	8.3	7.6
Evap. (mm/day)	2.5	3.1	2.1	5.4	5.8	5.9	0.4
Sunlight (hrs/day)	7.6	6.1	6.6	9.3	8.3	8.8	8.0

in *Standard Methods* (19th edition). For helminth eggs the method developed by Schwartzbrod (1997) was used. The liquid and sludge samples were taken twice a month or monthly according to the parameter.

Climate

The meterological conditions during the monitoring period are presented in Tables 1 and 2.

Results and discussion

Pond perfomance

The septage ponds worked alternately. First, pond C1 was put in operation. After six months of operation, C1 was put out of operation and the supernatant was pumped to pond C2 which began working. So, Phase A of the monitoring program was divided into two stages, the first stage from the moment the operation of C1 started (January 1999) until it was stopped due to the accumulation of sludge (July 1999) The second stage was undertaken from the beginning of operation of pond C2 (July 1999) until February 2000.

Effluent quality. Tables 3 and 4 show the results (mean values) from the analyses carried out during each stage and for each parameter on samples of raw wastewater and pond effluents. Table 5 gives values of the ratios of COD/BOD and VSS/TSS.

The following can be concluded from the above results.

- The great difference in total solids between septage and sewage makes it necessary to pretreat the septage before its discharge into conventional treatment.
- Based on the average value of BOD (tot) of septage, the volumetric pond loadings were 60 and 87g BOD/$m^3 \cdot$ day for the first and second stage, respectively.
- The high value of the CODt/BODt for septage indicates that a large fraction of the organic matter was non-biodegradable or was of low biodegradability. The high value of CODt/CODf for septage indicates that the refractory fraction of organic matter was principally particulate. The ratio presented in Table 5 also indicates the difference in quality between septage and sewage.

Table 3 Summary of the results (average values) for the first stage

Parameter	Units	No.	Septage	C1	Sewage	L1	L2
Flow	m^3/day	9	24		200		
BOD Total	mg/l	14	754	150	198	46	33
BOD Filtered	mg/l	14	213	96	113	21	11
COD Total	mg/l	14	4243	654	531	286	230
COD Filtered	mg/l	14	490	325	291	129	88
TSS	mg/l	14	5934	235	153	122	114
VSS	mg/l	14	3035	207	128	115	101
S Sedim 10'	mg/l	14	34	0.2	2.5		
S Sedim 2h	mg/l	14	46.1	0.5	3.9		
pH	mg/l	14	8	8	8	8	8
N_{tot}	mg/l	7	191	117	76	45	31
P_{tot}	mg/l	7	28	18	13	11	8
$N–NH_3$	mg/l	12	146	104	69	33	25
$N–NO_3$	mg/l	4	1.3	1.2			1.4
$N–NO_2$	mg/l	4	<0.05	<0.05			0.3
Sulfide (S^{2-})	mg/l	8	40	47	31	16	7
Sulfate (SO_4)	mg/l	5	183	57	390	221	260
Total Col	MPN/100ml	10	$6.11\ 10^{7}$	$1.23\ 10^{7}$	$1.15\ 10^{8}$	$3.11\ 10^{6}$	$4.76\ 10^{5}$
Faecal Col	MPN/100ml	10	$1.73\ 10^{7}$	$3.17\ 10^{6}$	$7.87\ 10^{7}$	$9.56\ 10^{5}$	$1.06\ 10^{5}$
DO	mg/l	14	0.00	0.29	0.00	0.20	3.23

Table 4 Summary of the results (average values) for the second stage

Parameter	Units	No.	Trucks	C2	Sewage	L1	L2
Flow	m^3/day		23		220		
BOD Total	mg/l	13	1189	287	208	82	63
BOD Filtered	mg/l	13	303	191	128	30	24
COD Total	mg/l	13	5918	905	603	423	337
COD Filtered	mg/l	13	668	506	314	166	153
TSS	mg/l	13	10644	325	180	179	159
VSS	mg/l	13	5105	235	134	170	131
S Sedim 10'	mg/l	13	67	0.1	2	–	–
S Sedim 2h	mg/l	13	66	0.9	3	–	–
pH	mg/l	13	8	8	8	8	8
N_{tot}	mg/l	6	215	136	83	58	44
P_{tot}	mg/l	6	39	25	13	12	12
$N–NH_3$	mg/l	13	152	143	69	44	35
$N–NO_3$	mg/l	–	–	–	–	–	–
$N–NO_2$	mg/l	–	–	–	–	–	–
Sulfide (S^{2-})	mg/l	12	95	33	20	6	2
Sulfate (SO_4)	mg/l	13	132	41	–	415	424
Total Col	MPN/100ml	12	$6.4\ 10^{7}$	$1.5\ 10^{7}$	$4.0\ 10^{8}$	$5.0\ 10^{6}$	$3.0\ 10^{5}$
Faecal Col	MPN/100ml	12	$6.0\ 10^{6}$	$2.5\ 10^{6}$	$7.0\ 10^{8}$	$1.2\ 10^{6}$	$1.2\ 10^{5}$
DO	mg/l	13				1.26	3.38

Table 5 Ratio between COD/BOD and SSV/SST IN Pond C1 samples

Relations	Septage		Sewage	
	1st stage	2nd stage	1st stage	2nd stage
CODt/BODt	5.63	4.98	2.68	2.90
CODf/BODf	2.30	2.20	2.58	2.45
BODt/BODf	3.53	3.92	1.75	1.62
CODt/CODf	8.65	8.85	1.82	1.92
VSS/TSS	0.51	0.48	0.84	0.74

Table 6 Removal efficiencies in Pond C1

Parameter	Influent	Effluent	Efficiency (%)
TSS	5934	235	96
VSS	3035	207	93
BOD total	754	150	80
COD total	4243	654	85
BOD filterable	213	96	55
COD filterable	490	325	34
total P	28	18	36
total N	191	117	39
NH_3	145	104	29
Faecal coliforms	$1.73\ 10^{7}$	$3.17\ 10^{6}$	82

Table 7 Removal efficiencies in Pond C2

Parameter	Influent	Effluent	Efficiency (%)
TSS	10644	325	97
VSS	5105	235	95
BOD total	1189	287	81
COD total	5918	905	85
BOD filterable	303	191	37
COD filterable	668	506	24
total P	39	25	36
total N	215	137	37
NH_3	146	137	6
Faecal coliforms	$6.0\ 10^{6}$	$2.5\ 10^{6}$	58

Note: All parameters expressed in mg/l, except faecal coliforms (MPN/100 ml)

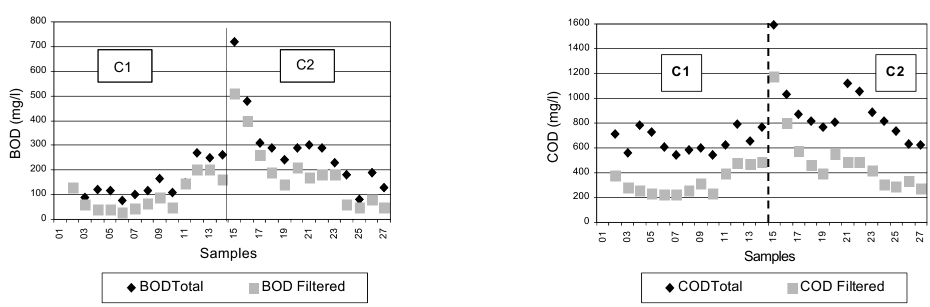

Figure 2 (Left) BOD and (right) COD values for C1 and C2 effluents in each sample

- The effluent quality of the septage pond is very similar to the sewage quality, except for NH_3–N.
- The ratio VSS/TSS indicates that only 50% of the solids of septage are organic, while in sewage the percentage of organic solids is about 80%.

Efficiency. The average values and removal efficiencies for the three ponds are shown in Tables 6 and 7. The efficiency of septage ponds in removal of solids is about 97% for the two stages. The removal efficiency of soluble organic matter during the second stage (based on average values of filtered BOD) was lower than in the first one. This could be attributed to the very low temperature and low sunshine during the winter period.

If the variation of filtered BOD and filtered COD during this time is observed (Figure 2) for C1 and C2, a deterioration in the effluent quality in terms of BOD during sampling occasions 12 to 19 can be seen, corresponding to the winter period (June–September).

Microscopic observation. Qualitative observations were made on the samples taken from Ponds C1, L1 and L2, to determine the species of microorganisms present.

Thiopedia and *Thiocapsa* were found in the three ponds; these are purple photosynthetic bacteria that metabolise sulfide and colour the ponds pink.

Sometimes algae and photosynthetic bacteria were present together in the ponds. In the sampling periods of January, February, March and April 1999, the water of the Ponds L1 and L2 was pink until 10:00 hr, and then changed gradually to green, until it became completely green by 13:00. This phenomenon was observed by other researchers (Veensha *et al.*, 1994). The prevalent genus in C1and C2 was *Chlamydomonas*, which is known to be present in water with high levels of organic matter and low levels of dissolved oxygen, as reported by Almasi and Pescod (1996). During the low temperature months, the number of algae and photosynthetic bacteria decreased very noticeably in Pond C1.

The presence of sulphur bacteria denotes that the septage ponds were anoxic, rather than anaerobic. There is reduction of sulfates in the septic tanks. The concentration of sulfates in the groundwater which is the source of potable water of the population is about 400 mg/l, while in the septage the average values of sulfate were 183 mg/l (first stage) and 132 mg/l (second stage), due to the action of sulfate-reducing bacteria.

Accumulation of solids and sludge quality. Pond C1 was emptied on July 12, 1999. The measured volume of accumulated sludge was 104 m^3 after 203 days of operation. The average sludge depth was 0.48 m.

Monthly accumulation rate (7 months of operation): 15 m^3 per month

Accumulation rate for every m^3 of transported liquid: 0.021 m^3solids/m^3 liquid

The value obtained is similar to those adopted previously in the design of the septage ponds. The sludges were monitored during August 1999 to February 2000, and the results obtained are shown in Tables 8 and 9. The samples were obtained in the inlet and outlet zones.

Table 8 Results of sludge monitoring

Date	Moisture %		VTS %		Nt %		Pt %		Faecal coliforms (MPN/g dry weight)	
	I*	O*	I	O	I	O	I	O	I	O
05-08-99	76	88	45	49	–	–	–	–	–	–
19-08-99	75	83	48	48	1.0	1.1	0.16	0.17	–	–
02-09-99	74	85	53	44	1.2	0.8	0.18	0.18	3.4 10^5	3.4 10^4
15-09-99	72	80	45	52	0.9	1.6	0.15	0.22	7.1 10^4	1.9 10^4
29-09-99	72	79	47	44	1.0	1.4	0.12	0.22	1.2 10^3	1.4 10^4
13-10-99	70	83	49	45	1.4	1.7	0.12	0.16	1.2 10^3	1.4 10^3
27-10-99	72	78	54	44	1.2	1.4	0.18	0.25	6.4 10^2	3.0 10^3
10-11-99	71	80	46	42	1.1	1.6	0.15	0.12	8.0 10	1.2 10^2
24-11-99	69	79	51	43	1.4	0.8	0.15	0.14	1.0 10^2	1.5 10^2
22-12-99	63	78	50	42	–	–	–	–	6.6 10^3	1.9 10^3
10-12-99	65	76	38	39	–	–		–	1.0 10^5	8.0 10^3
04-01-00	58	74	39	44	1.4	1.5	0.30	0.26	8.3 10^2	4.8 10^3
10-02-00	45	74	29	40	1.2	1.9	0.25	0.25	1.5 10^2	3.6 10^2

*I: inlet area; O: outlet area

Table 9 Helminth egg numbers in sludge

Date	Helminth eggs (No./100 g dry wt)
05-08-99	5500
19-08-99	4000
15-09-99	4400
10-11-99	6400
24-11-99	4200
04-01-00	6000

The reduction of volatile solids was 35.5% in the inlet zone and 18% in the outlet zone, corresponding to the degree of drying obtained in each one.

The reduction of faecal coliform bacteria was important, but some results were erratic. This could be attributed to the irregular distribution of bacteria and to the fact that perhaps the samples were not extracted exactly in the same place on each sampling occasion.

With respect to helminth eggs, it is important to point out that besides parasitic nematodes, sludge contains larval and adult stages of free living nematodes which may be mistaken for the former. As the sludges are exposed in drying beds or evaporation ponds to environmental factors, the number of free living nematodes increases greatly making the enumeration of human parasitic forms more difficult.

On the first seven sampling occasions 70–80% of the eggs counted were human parasitic forms (*Necator americanus*, *Ancylostoma duodenale* and *Trichuris trichiura*). The other 20–30% of eggs were probably from animals.

Conclusions

- The quality of septage ponds effluent is suitable for discharge into a system of waste stabilization ponds designed to treat sewage.
- The septage ponds should be designed as sedimentation ponds. The value of 0.02 m^3 of sludge/m^3 of septage previously estimated was correct.
- It is possible to dry the sludge in the same pond. After six months of drying with a layer of sludge not exceeding 0.50 m, the moisture level reached makes the sludge spadeable, irrespective of the season of the year.
- In Phase B it will be necessary to make more studies to determine :
  - the sanitary quality of sludges in relation to the concentration of helminth eggs;
  - the possibility of using the sludge for soil amendment;
  - suitable low cost post-treatment methods for the sludge in order to use it in agriculture.

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