Studies on the treatment of dairy wastes in an algal pond

J S Kilani
Department of Civil Engineering, University of Durban-Westville, Private Bag X54001, Durban 4000, South Africa

Abstract

A comparative study of the treatment of synthetic milk waste and actual yoghurt waste in six laboratory-scale facultative stabilisation ponds was undertaken. Three of the ponds operated at detention times of 7,9; 10,5 and 18,1 d and at a temperature of 20°C and were fed on synthetic milk waste while the remaining 3 operated at the same detention times and temperature and were fed on waste water from a yoghurt manufacturing plant.

The results show that both the synthetic milk waste and the yoghurt waste were highly biodegradable. There was little difference between the percentage COD reductions achieved for yoghurt waste and synthetic milk waste based on filtered effluent data. However, when unfiltered effluent data were used, COD removals achieved for the synthetic milk waste were significantly higher than for the yoghurt waste.

Introduction

Waste stabilisation pond systems have been recognised to be one of the most efficient (Mara, 1978) and cheapest (Arceivala, 1972) means of waste-water treatment in small communities and in areas where land is not a premium and climatic conditions are favourable. The economic problems faced by most developing countries coupled with their dwindling foreign reserves or mounting foreign debts have led more and more countries to recognise the inherent advantages possessed by pond systems over conventional treatment methods. The ability of pond systems to absorb high organic loads makes them particularly suitable for the treatment of industrial wastes. Most industrialised nations are now resorting to the use of ponds wherever feasible, especially for the treatment of industrial effluents.

The performance of waste stabilisation ponds has undergone extensive study, although not always in a comprehensive manner. Many of the laboratory investigations into the performance of model waste stabilisation ponds were conducted using synthetic organic feeds (Canter et al., 1969; Kilani and Ogunrombi, 1984; Mangelson and Watters, 1972; Uhlmann, 1979). While it is generally believed that results obtained from laboratory- or pilot-scale ponds are useful in predicting the performance of full-scale ponds (Arthur, 1981), the impact of using actual wastes as influent feeds on such results has often not been fully assessed.

The study reported in this paper had two main objectives: to investigate the treatability of yoghurt wastes in laboratory model algal ponds and to compare the performances of such model ponds when receiving synthetic and real wastes. This study was part of a 3-year research programme on the treatment of organic industrial waste water in facultative ponds (Kilani, 1985).

Abbreviations

BOD = Biochemical oxygen demand
COD = Chemical oxygen demand
DO = Dissolved oxygen
Eff. = Effluent
Inf. = Influent
SCOD = Soluble COD
SS = Suspended solids
TCOD = Total COD

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Experimental investigations

The model facultative ponds consisted of rectangular plastic boxes having a length of 57 cm and a width of 37 cm. Each pond was fitted with an inlet pipe which discharged as close as possible to the bottom of the pond and 3 outlet pipes located at depths of 8, 13 and 18 cm. This was to allow the ponds to be operated at different depths if desired, although the part of the study reported in this paper was conducted at the maximum depth of 18 cm.

The ponds were arranged on a bench and were isolated from the laboratory environment by an enclosure, the top of which was about 50 cm above the liquid surface. The light requirement for algal photosynthesis was supplied by 6 2,34 m long Osram liteguard 125 W white fluorescent tubes fitted to the inner surface of the enclosure top. These tubes provided an average light intensity of 1 600 lux at the pond surface. The tubes were operated on a 12-h on and 12-h off cycle to simulate day and night. The 2 short sides of the enclosure and one of the long side (the outlet side) were covered with 12 mm thick hardboard. The remaining long side (the inlet side) was covered with black polythene sheets to facilitate access to the ponds. An electric fan heater was fitted at the top of one of the short sides and although this heater provided some wind effect, it was primarily required to maintain a range of pond operating temperatures as controlled by a thermostat.

Influent feeds

The synthetic milk waste was made from powdered calf milk manufactured by the Midland Shires Limited, County Mills, Worcester. The manufacturers gave the composition of the milk powder as protein (24%), oil (16%), fibre (0,25%), vitamin A 30 000 iu/kg), vitamin D (4 000 iu/kg), vitamin E (25 iu/kg), selenium (0,2 mg/kg) and zinc bacitracin (80 mg/kg). Because of the presence of selenium and zinc bacitracin in the calf milk, it was suspected that the milk powder might be toxic to micro-organisms. Preliminary tests were therefore conducted to estimate the rate of biological growth in various concentrations

TABLE 1
SUMMARY OF RESULTS FOR YOGHURT AND SYNTHETIC MILK WASTE

Sample	Det. time (days)	pH run no. 1	2	3	DO run no. 1	2	3	Alkalinity run no. 1	2	3	SS run no. 1	2	3	Total COD run no. 1	2	3	Soluble COD run no. 1	2	3
Yoghurt																			
Influent	-	5,2	5,6	5,0	2,5	1,8	2,1	3,4	6,1	3,2	299	407	488	383	1568	2010	-	-	-
Pond A Eff.	18,1	8,1	8,2	7,8	8,6	8,7	8,4	143	147	128	113	166	153	299	421	530	112	166	223
Pond B Eff.	10,5	8,1	7,8	7,6	8,0	7,7	7,6	144	130	107	188	171	151	405	456	568	119	213	334
Pond C Eff.	7,9	8,2	7,6	7,3	8,9	7,6	5,3	165	135	102	200	170	152	422	466	577	137	241	364
Synthetic																			
Influent	-	6,6	6,8	6,9	8,8	8,8	8,9	22	30	40	295	407	508	838	1363	1877	-	-	-
Pond D Eff.	18,1	7,5	7,7	7,8	8,2	8,4	8,2	48	52	55	43	52	44	155	178	225	109	139	160
Pond E Eff.	10,5	7,5	7,6	7,4	7,6	7,9	7,6	46	50	46	56	21	83	175	244	299	103	135	196
Pond F Eff.	7,9	7,4	7,2	7,9	6,2	6,0	4,7	44	38	35	57	83	85	184	243	295	98	137	193

All parameters in mg/ℓ except pH

TABLE 2
SUMMARY OF RESULTS FOR TWO DIFFERENT WASTES

Sample	pH	DO	Alkalinity	SS	Total COD	Soluble COD
Yoghurt 1 Influent	5,0	1,4	3,0	581	2388	-
Pond B Eff. (no scum cover)	7,2	5,5	89	119	702	412
Pond C Eff. (scum cover)	7,2	5,3	89	103	685	418
Yoghurt II Influent	5,1	1,6	3,0	603	2570	-
Pond D Eff. (no scum cover)	7,2	5,7	96	124	719	437
Pond E Eff. (scum cover)	7,2	5,3	94	113	708	439

All parameters in mg/ℓ except pH

of the milk solution. The increase in bacterial population after 24-h growth in the milk solutions was high enough to remove any suspicion of the powdered milk being toxic to bacteria. The question of whether the powdered milk was toxic to algae or not was, however, left to be determined during operation on the basis of prevailing pond conditions. Preliminary analyses were also carried out to correlate the organic strength (BOD, COD) of the synthetic milk solution with the respective milk powder concentration used for making the solution. The results of tese analyses were used to determine the concentration of powdered milk required in each influent feed solution to give desired influent COD.

The yoghurt waste was obtained from a company in Coventry. It was a composite sample of the waste water discharged by the yoghurt processing plant. Preliminary analysis showed that the yoghurt waste had an average COD of 25 000 mg/ℓ. The required organic loadings were obtained by diluting the yoghurt waste with tap water. Since both the synthetic milk and the yoghurt wastes were observed to degrade rapidly when not refrigerated, influent feeds were prepared on a daily basis throughout the study.

Treatment studies

The 6 ponds labelled A, B, C, D, E and F which had been receiving synthetic waste for about 18 months prior to the start of the study were thoroughly cleaned, after their contents had been emptied into separate containers. The contents were then thoroughly mixed and distributed equally into all the ponds, which were then filled up to the maximum 18 cm depth with tap water.

Ponds A, B and C were fed with the yoghurt waste while ponds D, E and F continued to receive the synthetic milk waste. Ponds A and D, B and E, and C and F were fed at average flow rates of 2,1, 3,6, and 4,8 ℓ/d, giving average detention times of 18,1 10,5 and 7,9 d respectively. The two influent wastes were intially made to a strength of about 1 000 mg/ℓ COD and the ponds were fed with this strength for 6 weeks. Then the influent COD was increased first to 1 500 mg/ℓ and then to 2 000 mg/ℓ at 4-week intervals. Areal organic loading rates ranged from about 100 to about 450 kg COD/ha·d.

At the end of these runs, a significant difference was observed

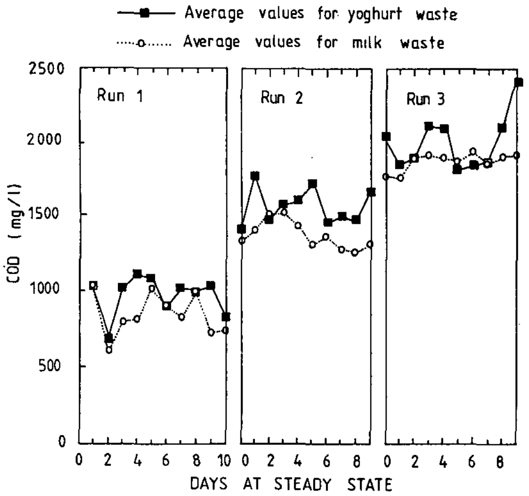

Figure 1
Influent COD during study

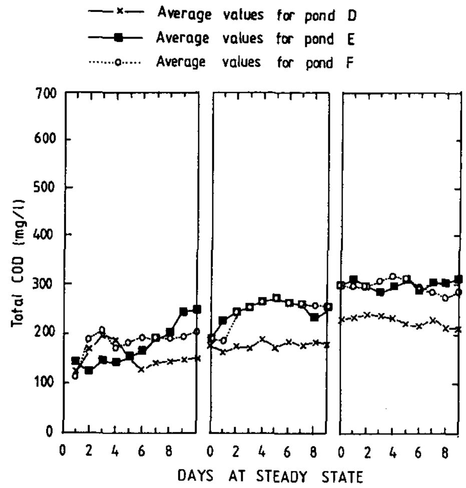

Figure 3
Total COD for synthetic milk waste effluent

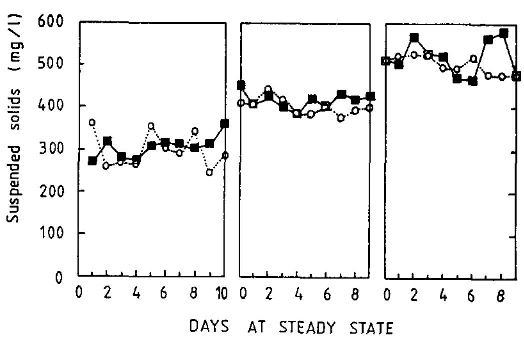

Figure 2
Influent SS during study

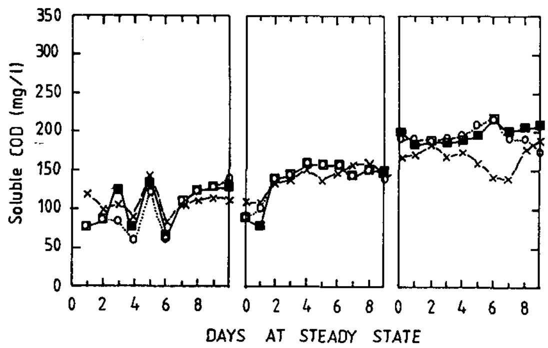

Figure 4
Soluble COD for synthetic milk waste effluent

between the algal concentrations within the 2 sets of ponds. It was then decided that it was necessary to compare the treatment of the yoghurt waste with that of another yoghurt waste from a different company, but using a similar process. Only ponds B, C, D and E were used for this purpose and they were all fed at a flow rate of 3,6 ℓ/d. While ponds B and C continued to receive the original yoghurt waste, ponds D and E were fed with the second yoghurt waste. The 2 wastes were made to a strength of about 2 500 mg/ℓ COD and the 4 ponds were operated for a further 6 weeks at the same temperature of 20°C.

The influent feeds and the corresponding effluent samples were analysed on alternate days for total COD, soluble COD, SS and alkalinity in accordance with Standard Methods (1975); pH using pH meter manufactured by W G Pye and Co. Limited; and DO using a YSI model 57 oxygen meter. The contents of the ponds were analysed twice a week for chlorophyll *a* concentration, also in accordance with Standard Methods (1975).

Results and discussion

The average characteristics of the influents and effluents from the ponds are summarised in Tables 1 and 2. Figures 1 and 2 show the variations in the COD and suspended solids, respectively, for both yoghurt and the synthetic milk wastes. The variations in the characteristics of the effluents from the ponds receiving the synthetic waste are shown in Figs. 3 to 5. Effluents from the ponds receiving the yoghurt waste varied in characteristics as shown in Figs. 6 to 8. Figure 9 shows the average chlorophyll *a* concentration in each pond at various areal organic loadings. For all 3 detention times, the chlorophyll *a* concentrations in the ponds receiving the yoghurt waste were consistently higher than those in the ponds receiving the synthetic waste at all the applied organic loadings.

Observations of the ponds' conditions showed that the treatment of the yoghurt wastes in the laboratory models was as successful as that of the synthetic milk waste. The percentage COD removals at various loading rates for the yoghurt and the synthetic milk wastes are shown in Table 3.

The results show that there was little difference between the percentage COD reductions achieved for both wastes based on filtered effluent COD data (SCOD). However, when unfiltered effluent COD data (TCOD) were used, COD removals achieved

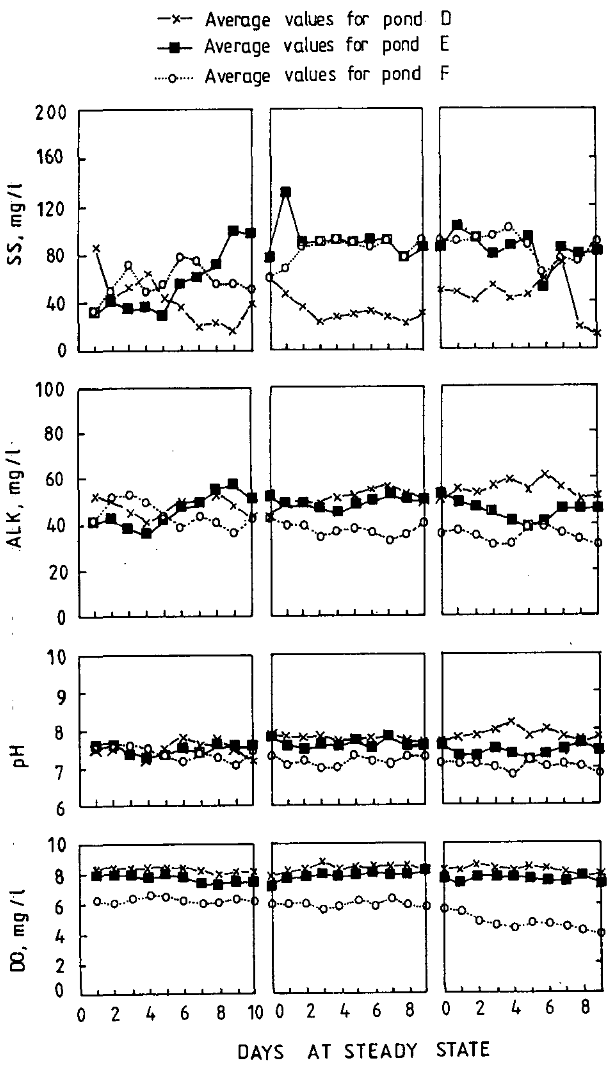

Figure 5
Effluent characteristics for synthetic milk waste

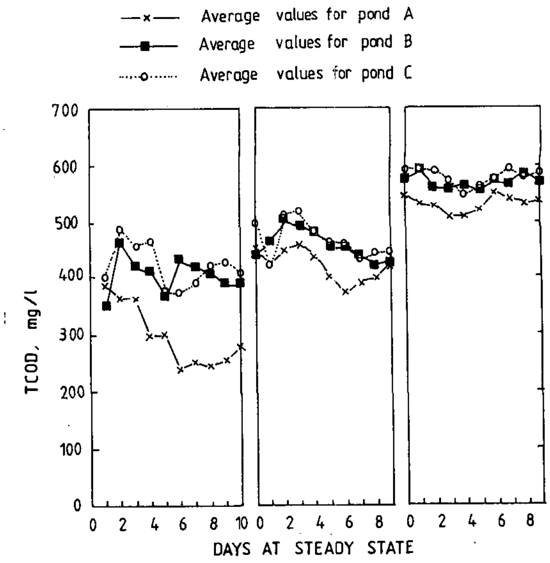

Figure 6
Total COD for yoghurt effluent

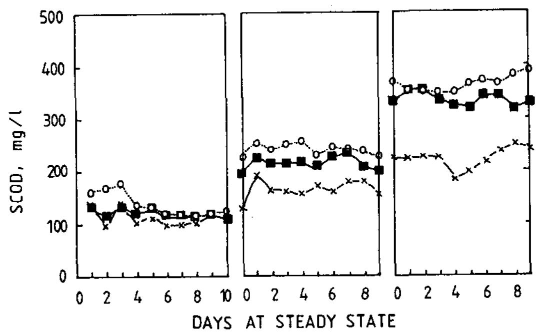

Figure 7
Soluble COD for yoghurt effluent

TABLE 3
COD REMOVAL PERFORMANCE

Det. time (days)	Yoghurt wastes Loading (kg COD/ ha·d)	Yoghurt wastes COD remoal (%) SCOD	Yoghurt wastes COD remoal (%) TCOD	Synthetic milk waste Loading (kgCOD/ ha·d)	Synthetic milk waste COD removal (%) SCOD	Synthetic milk waste COD removal (%) TCOD
18,1	97,9	88,6	69,6	83,5	87,1	85,7
18,1	156,2	89,4	73,2	135,7	89,8	87,2
18,1	200,2	89,0	73,7	186,9	91,0	87,8
10,5	167,8	87,9	58,8	143,1	87,1	77,4
10,5	267,7	86,4	70,9	232,6	89,8	82,0
10,5	343,2	83,4	71,7	320,3	89,4	84,1
7,9	223,7	86,9	57,1	190,8	87,0	77,9
7,9	356,9	84,6	70,2	310,1	89,9	82,3
7,9	457,6	81,9	71,3	427,1	89,9	84,3

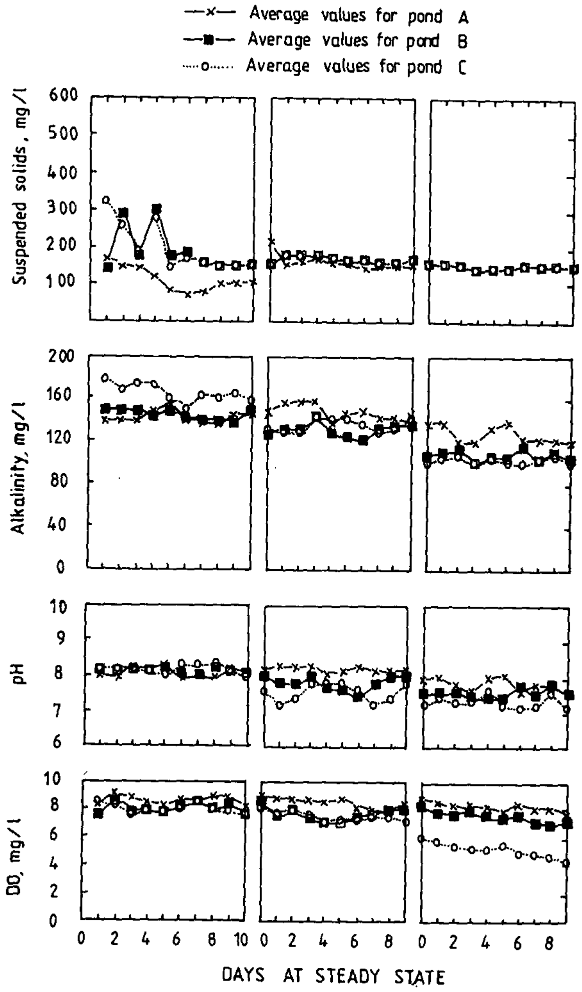

Figure 8
Effluent characteristics for yoghurt effluent

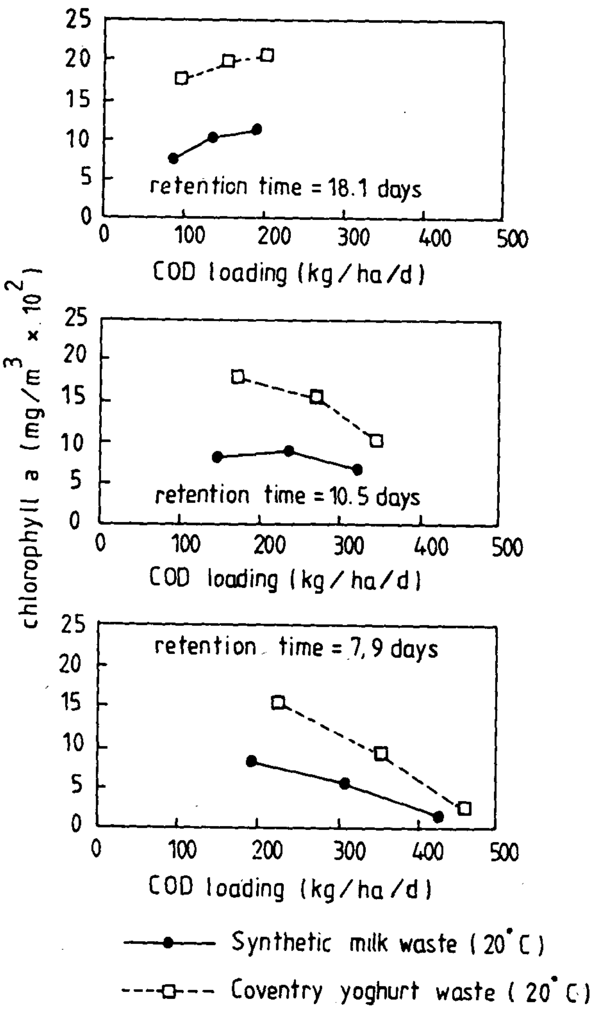

Figure 9
Chlorophyll a concentrations

with the synthetic waste were much higher than with the yoghurt waste.

These large differences observed in the values of unfiltered effluent COD removal for the ponds treating yoghurt waste and those treating the synthetic waste could be due to the large differences in the concentration of algae (as indicated by chlorophyll *a* within the 2 sets of ponds (Fig. 9). The high algae production observed in the ponds receiving the yoghurt waste resulted in relatively high concentrations of suspended solids in the effluents from these ponds as shown in Table 4.

The large difference between the chlorophyll *a* content of the 2 sets of ponds may be ascribed to two main reasons: nutrient availability, and differences in bacterial population in the feeds. The concentration of organic nitrogen in the yoghurt waste was very much higher than in the synthetic waste. The average COD:N ratio observed for the yoghurt waste was 35,8:1, compared to a value of 84,1:1 for the synthetic waste. This meant that more nutrient was available in the yoghurt waste than in the synthetic waste for algae production, a process noted to involve the utilisation of both ammonia and nitrate (Pano and Middlebrooks, 1982).

Also, since the yoghurt waste originally contained a considerable bacterial population as compared with the synthetic waste, made simply by dissolution of powdered milk in tap water, the ponds receiving the yoghurt waste have higher bacterial populations than those receiving the synthetic waste. There was, therefore, probably more production of the carbon dioxide required for algal photosynthesis in the ponds treating the yoghurt waste. The results obtained for a second yoghurt waste from a different company were similar to those of the first yoghurt waste.

The relatively higher algal bloom observed for the ponds treating yoghurt waste was, however, noted not to be accompanied by a correspondingly higher reduction of soluble COD, thus suggesting that an optimum algal concentration exists, above which increased algal activity does not necessarily result in better treatment.

Conclusion

The treatment of an actual yoghurt waste in laboratory-scale facultative stabilisation ponds was found to be very successful. The results suggest that total COD removal of above 70 per cent and soluble COD removal of above 80 per cent could be achieved when the yoghurt waste or wastes of similar characteristics are treated in facultative ponds with a detention time as low as 7,9 d and organic loading rates as high as 450 kg COD/ha·d.

A similar order of organic loading rate was achieved for pilot-

TABLE 4
SUSPENDED SOLIDS REMOVAL PERFORMANCE

Det. time (days)	Yoghurt wastes Inf. SS (mg/ℓ)	Yoghurt wastes Eff.SS (mg/ℓ)	Yoghurt wastes SS Rem. (%)	Synthetic milk waste Inf.SS (mg/ℓ)	Synthetic milk waste Eff.SS (mg/ℓ)	Synthetic milk waste SS Rem. (%)
18,1	299	113	62,2	295	43	85,4
18,1	407	166	59,7	408	34	91,7
18,1	488	153	68,6	508	44	91,3
10,5	299	188	37,1	295	56	81,0
10,5	407	171	58,0	408	91	77,7
10,5	488	151	69,0	508	83	83,7
7,9	299	200	33,1	295	57	80,7
7,9	407	170	58,2	408	83	79,6
7,9	488	152	68,8	508	85	83,3

scale facultative stabilisation ponds by Arthur (1981), who concluded that most design formulae used for facultative pond design in tropical climate often result in over-design of system capacity.

The use of synthetic milk waste in laboratory pond studies, in addition to being convenient, adequately simulates the treatment of wastes with similar composition and characteristics. However, due consideration must be given to the low levels of suspended solids, bacterial population, and some essential nutrients that may be encountered with synthetic wastes.

Results obtained from laboratory models and pilot-scale ponds could reasonably be used to assess the performance of full-scale ponds (Arthur, 1981), as limitations such as shallow depth in laboratory models only allow a conservative estimate of performance. In other words, actual field conditions could only lead to improved performance in full-scale ponds as compared to the performance of simulated models.

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