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PERFORMANCE OF WASTEWATER STABILIZATION PONDS AT DIFFERENT DEPTHS

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Abstract. Investigations were made on wastewater ponds (cement cisterns) operated at 1.22, 1.83, and 2.44 m depths. Results revealed the layering of microorganisms at various depths. BOD and nutrient values and bacterial counts were maximum in the bottom layers and minimum at the surface in all the ponds. Concomitant with these variations, increases in pH and DO content were observed at the upper layers of the ponds. The activities of catalase, phosphatase, protease and amylase were directly related to microbial growth and activity. Low enzyme activity was recorded in the upper layers, whereas it increase with the increase in depth of the pond. From the present study, it is inferred that the pond depth could be increased beyond a generally acceptable value of 1.22 m particularly in tropical countries where enough light is available.

1. Introduction

For the last four decades, world wide studies on wastewater stabilization ponds have been conducted. Emphasis has been given to the reduction in BOD, nutrients and bacteria (Fitzgerald and Rohlich, 1958; Dave and Jain, 1967; Arceivala *et al.*, 1970; Gloyna, 1971; Ganapati, 1974; Patil, 1979; Kurshed and Chughtai, 1981) than the influence of depth on the biochemical activities in the pond. The 1.22 m depth has been accepted as standard depth for the operation of stabilization ponds. There are a few studies (Dodakundi *et al.*, 1973; Hosetti and Rodgi, 1985; Halakatti and Rodgi, 1985) which mention the possibility of increasing the depth of the ponds. If 1.22 m depth is regarded as an optimum, larger area may be required for the treatment of large quantities of wastewater. This imposes limitations on the treatment of wastewater in stabilization ponds, especially for the larger communities.

The purpose of this work is to investigate the influence of depth on the performance of stabilization ponds in the treatment of wastewaters.

2. Materials and Methods

Studies of stabilization ponds were carried out using three model cement cisterns, operated at 1.22 m (A), 1.83 m (B), and 2.44 m (C) depths, each of 0.92 m diameter (Figure 1). Cisterns were installed adjacent to the field stabilization pond functioning on the University Campus. All the model ponds were provided with outlets at every

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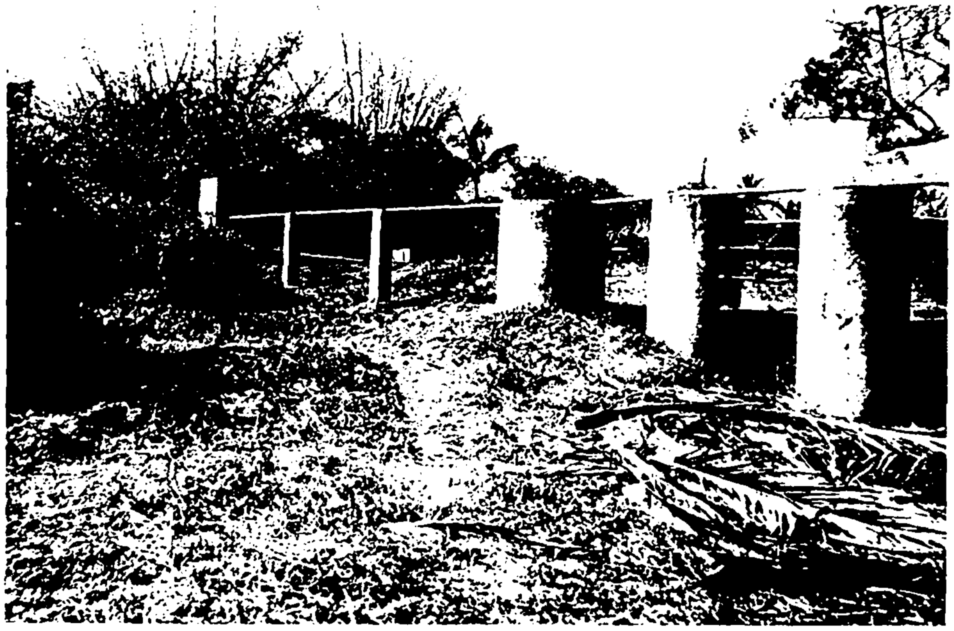

Fig. 1. Stabilization ponds made of cement cisterns operated at 1.22 m (A), 1.83 m (B), and 2.44 m (C) depths.

0.31 m depths for sample collection. The ponds operated in a continuous flow mode. The raw wastewater from the staff quarters and the gents hostel flows to the field stabilization pond for the treatment. A portion of it was diverted into these model ponds. The detention period of the model ponds was about 10 days. Samples collected weekly at the surface and at every 0.31 m depth from all the ponds were analyzed. Temperature was recorded immediately after the collection of samples. The pH was measured with digital pH meter. The DO, BOD_5 at 20 °C, NH_3N, PO_4 and bacterial counts were estimated as per the methods described in 'Standard Methods' (APHA, 1980). Catalase (Euler and Josephson, 1927), phosphatase (Verstraete *et al.*, 1976), protease (Lenhard, 1967) and amylase (Noelthing and Bernfield, 1948) activities were estimated. Algal cell number was enumerated by using a haemocytometer.

3. Results

The raw wastewater is slightly yellowish in color and has following characteristics: 35 to 65 × 10^6 mL^{-1} bacteria, O.0 to 1.5 mg L^{-1} of DO, approximately 302 mg L^{-1} of BOD, pH ranging between 6.9 to 7.5, NH_3N 19 mg L^{-1} and PO_4 8.62 mg L^{-1}. Catalase activity of influent wastewater varied between 25.2 to 30 units, phosphatase from 6.9 to 8.7 units, while protease and amylase activities ranged from 90 to 130 units and 186 to 346.5 units, respectively (Table I).

TABLE I

Characteristics of raw wastewater

Time (week)	DO mg L^{-1}	pH	Temp. °C	NH_3N mg L^{-1}	PO_4 mg L^{-1}	BOD mg L^{-1}	Bacteria $\times 10^6$ m L^{-1}	Catalase (1)	Phosphatase (2)	Protease (3)	Amylase (4)
1	0.0	6.9	29.0	21.0	8.9	320.0	65.0	29.2	8.7	129.7	346.5
2	1.0	7.2	30.0	18.0	8.4	310.0	45.0	30.0	7.5	122.6	293.6
3	0.5	7.3	30.0	21.0	9.3	298.0	35.0	26.8	6.9	90.8	186.0
4	1.5	7.5	29.0	17.0	8.1	284.0	48.0	25.2	7.6	95.0	186.0
5	1.0	6.9	28.0	18.0	8.4	296.0	40.0	26.0	7.8	100.0	240.0
Average values ± SD	0.8 ± 0.6	7.2 ± 0.3	29.2 ± 0.8	19.0 ± 1.9	8.6 ± 0.5	301.6 + 13.8	46.6 ± 11.4	27.4 ± 2.1	7.7 ± 0.6	107.6 ± 17.4	250.4 ± 69.8

(1) μmol of H_2O_2 decomposed min^{-1} 100 mL^{-1} of sample.
(2) μg of paranitrophenol liberated min^{-1} 100 mL^{-1} of sample.
(3) μg of tryptophan liberated min^{-1} 100 mL^{-1} of sample.
(4) μg of maltose liberated min^{-1} 100 mL^{-1} of sample.

The DO of the raw wastewater was very low, but it was observed that at the bottom of the ponds A, B, and C, a little over 7 mg L^{-1} of DO was recorded. This clearly indicated the growth of algae and their activity even at the bottom of these ponds. The algal cell number in the surface samples of pond A and pond B was found to be more than twice the number of cells at the bottom of these ponds. However, in pond C cell count increased from 90 x 10^3 at the bottom to 244 x 10^3 mL^{-1} at the surface. It is evident from the Table II that the algal densities at the surface layers were higher than

TABLE II

Changes in physical, chemical and biological parameters of wastewater in pond A, B, and C (average values ± SD)

Depth (m)	DO mg L^{-1}	pH	Temp. °C	NH_3N mg L^{-1}	PO_4 mg L^{-1}	BOD mg L^{-1}	Algae × 10^3 mL^{-1}	Bacteria × 10^4 mL^{-1}
Pond A (1.22 m)								
0	14.3 ± 0.7	9.6 ± 0.3	28.2 ± 0.8	1.4 ± 0.4	2.0 ± 0.2	58.2 ± 8.2	288.8 ± 9.4	9.4 ± 1.1
0.31	14.3 ± 0.7	9.5 ± 0.5	28.2 ± 0.8	1.4 ± 0.4	2.0 ± 0.2	58.2 ± 8.2	287.2 ± 9.9	9.8 ± 1.3
0.61	11.4 ± 0.8	9.0 ± 0.4	27.6 ± 0.8	2.0 ± 0.3	2.8 ± 0.5	65.9 ± 7.5	232.6 ± 14.7	13.4 ± 2.1
0.91	9.2 ± 0.3	8.2 ± 0.1	26.8 ± 0.7	3.8 ± 0.9	3.8 ± 0.3	85.0 ± 9.8	182.0 ± 15.0	23.2 ± 1.9
1.22	7.2 ± 0.2	7.2 ± 0.2	26.4 ± 0.6	6.1 ± 0.6	5.2 ± 0.4	129.4 ± 15.8	124.2 ± 9.0	64.8 ± 6.3
Pond B (1.83 m)								
0	14.0 ± 1.2	9.4 ± 0.2	28.2 ± 0.8	1.7 ± 0.4	2.3 ± 0.3	68.6 ± 2.1	263.4 ± 13.2	10.0 ± 1.0
0.31	13.9 ± 1.2	9.4 ± 0.2	28.2 ± 0.8	1.7 ± 0.4	2.3 ± 0.3	68.8 ± 2.1	262.0 ± 12.6	11.4 ± 1.9
0.61	12.9 ± 0.9	9.1 ± 0.2	27.7 ± 0.6	2.3 ± 0.4	3.0 ± 0.5	71.9 ± 2.6	245.4 ± 12.2	13.2 ± 1.3
0.91	12.0 ± 0.5	9.0 ± 0.1	27.7 ± 0.8	2.5 ± 1.2	3.4 ± 0.1	85.3 ± 4.8	228.0 ± 12.7	21.4 ± 3.1
1.22	10.4 ± 0.2	8.3 ± 0.1	26.7 ± 0.7	3.6 ± 0.5	4.2 ± 0.2	96.5 ± 10.3	214.0 ± 47.3	27.2 ± 2.4
1.52	8.1 ± 0.1	8.5 ± 0.2	25.6 ± 0.5	4.1 ± 0.4	4.6 ± 0.5	106.0 ± 13.7	137.6 ± 14.3	42.2 ± 3.9
1.83	7.1 ± 0.2	7.3 ± 0.2	25.6 ± 0.5	5.7 ± 0.5	5.9 ± 0.2	130.8 ± 4.8	119.6 ± 12.4	66.4 ± 2.7
Pond C (2.44 m)								
0	12.5 ± 1.2	9.2 ± 0.2	28.2 ± 0.9	2.8 ± 0.5	2.8 ± 0.3	72.2 ± 4.9	244.7 ± 9.7	10.6 ± 2.7
0.31	12.0 ± 0.9	9.1 ± 0.2	28.2 ± 0.8	2.8 ± 0.4	2.8 ± 0.3	72.2 ± 7.1	245.0 ± 4.6	10.6 ± 2.7
0.61	11.5 ± 0.2	9.1 ± 0.2	27.3 ± 0.8	3.3 ± 0.4	3.3 ± 0.3	85.6 ± 7.1	236.8 ± 4.6	13.1 ± 2.7
0.91	10.0 ± 0.5	8.7 ± 0.1	27.4 ± 0.8	3.3 ± 0.4	3.3 ± 0.4	87.2 ± 7.2	234.0 ± 7.5	16.4 ± 2.6
1.22	9.2 ± 0.5	8.5 ± 0.1	26.7 ± 0.7	4.1 ± 0.5	3.7 ± 0.2	100.4 ± 3.3	197.2 ± 5.9	16.6 ± 2.4
1.52	8.5 ± 0.2	8.2 ± 0.1	26.6 ± 0.5	4.6 ± 0.6	4.7 ± 0.3	103.0 ± 7.8	182.4 ± 8.3	24.6 ± 2.2
1.83	7.5 ± 0.3	8.3 ± 0.1	26.4 ± 0.6	5.3 ± 0.4	6.3 ± 1.0	128.4 ± 6.7	150.0 ± 8.7	25.6 ± 3.0
2.13	7.2 ± 0.2	7.2 ± 0.1	25.9 ± 0.4	6.4 ± 0.4	7.0 ± 0.5	130.0 ± 4.5	126.8 ± 9.4	36.0 ± 5.1
2.44	7.0 ± 0.2	7.0 ± 0.6	25.8 ± 0.4	8.0 ± 0.6	7.4 ± 0.3	144.0 ± 11.8	90.6 ± 5.0	75.4 ± 5.7

at the bottom. In all the ponds, temperature varied between 25.6 to 28.2 °C. A gradual decrease in temperature from the surface to the bottom typical of a thermocline was observed in these ponds. The pH values in all the ponds remained around 7 at the pond bottoms. A gradual increase in pH from bottom to surface was observed. The difference in pH levels of the pond A was greater than the values observed in the rest of the two ponds. The higher pH values were recorded up to the depths of 0.91 m, 1.52 m and

1.83 m levels in the ponds A, B and C, respectively. The pH value at 1.83 m depth recorded in pond C was 8.32 (Table II). The increased pH in pond A up to 0.91 m indicated the presence of an euphotic zone. The euphotic zone was pushed further up to 1.52 m in pond B and 1.83 m in pond C (Table II).

TABLE III

Percent removal of ammonia nitrogen, phosphates, bacteria, and BOD

Depth (m)	NH_3N	PO_4	Bacteria	BOD
Pond A				
0	92.5	76.3	99.8	80.7
0.31	92.5	76.5	99.8	80.7
0.61	89.3	67.9	99.7	78.2
0.91	79.9	55.9	99.5	71.9
1.22	68.1	40.3	98.6	57.2
Pond B				
0	90.8	73.2	99.8	77.2
0.31	90.8	73.2	99.8	77.2
0.61	87.9	65.4	99.7	76.2
0.91	87.5	60.4	99.5	71.7
1.22	80.9	50.8	99.4	68.0
1.52	78.6	47.1	99.1	64.9
1.83	69.9	30.9	98.6	56.6
Pond C				
0	85.2	67.2	99.8	76.1
0.31	85.2	67.2	99.8	76.1
0.61	82.4	61.9	99.7	71.6
0.91	82.4	61.5	99.6	71.1
1.22	78.5	57.5	99.6	66.7
1.52	75.6	45.2	99.5	65.8
1.83	72.2	28.3	99.5	57.4
2.13	66.1	19.4	99.2	56.9
2.44	58.0	13.7	75.4	52.3

Reductions in NH_3N and PO_4 were recorded at different levels in all ponds. Rapid decline in the nutrients was observed from the 0.93 m depth in pond A, from 1.52 m in pond B and from 1.83 m depth in pond C (Table III). The BOD at the surface was found to be 58.2 mg L^{-1} in pond A, 68.0 mg L^{-1} in pond B and 72.2 mg L^{-1} in pond C, while BOD of the raw wastewater was approximately 300.0 mg L^{-1}. Higher BOD values were observed at the bottom of the ponds than at the surface. It is evident that in all the cases BOD was reduced to approximately half of the values at the bottom (Table II). Due to photosynthetic activity bicarbonates available in the media are

TABLE IV

Changes in the activities of enzymes in different ponds

Enzyme	Depth (m)								
	0	0.31	0.61	0.91	1.22	1.52	1.83	2.13	1.44
Pond A									
Catalase	5.8 ± 1.3	5.8 ± 1.3	6.7 ± 1.3	10.2 ± 1.6	18.4 ± 2.6	—	—	—	—
Phosphatase	5.7 ± 0.6	5.7 ± 0.6	5.6 ± 0.2	5.8 ± 0.2	7.0 ± 0.4	—	—	—	—
Protease	5.9 ± 1.2	5.9 ± 1.2	7.0 ± 1.0	9.7 ± 1.2	18.7 ± 2.4	—	—	—	—
Amylase	10.7 ± 14.6	10.7 ± 16.6	29.3 ± 21.9	57.7 ± 10.2	80.8 ± 9.5	—	—	—	—
Pond B									
Catalase	8.5 ± 1.2	8.5 ± 1.2	10.3 ± 1.5	11.7 ± 1.3	14.3 ± 1.5	16.2 ± 1.1	23.1 ± 3.3	—	—
Phosphatase	4.7 ± 0.2	4.7 ± 0.2	5.5 ± 0.3	5.8 ± 0.2	5.8 ± 0.2	6.5 ± 0.3	7.6 ± 0.3	—	—
Protease	6.4 ± 0.2	6.4 ± 0.2	6.9 ± 0.3	9.6 ± 0.9	10.6 ± 1.4	14.6 ± 1.6	22.4 ± 2.1	—	—
Amylase	5.3 ± 7.3	10.7 ± 14.6	32.0 ± 15.2	56.4 ± 6.9	77.7 ± 5.1	77.7 ± 5.1	88.4 ± 12.2	—	—
Pond C									
Catalase	12.3 ± 2.8	12.3 ± 2.8	14.8 ± 2.8	18.4 ± 1.0	18.8 ± 1.4	21.7 ± 0.9	21.7 ± 0.8	27.3 ± 0.9	34.8 ± 2.5
Phosphatase	6.0 ± 0.4	6.0 ± 0.4	6.4 ± 0.2	6.7 ± 0.3	6.7 ± 0.2	7.1 ± 0.3	7.1 ± 0.3	7.6 ± 0.2	8.4 ± 0.3
Protease	9.9 ± 2.0	9.9 ± 2.0	11.7 ± 1.8	17.8 ± 1.6	17.8 ± 1.6	18.7 ± 1.7	18.7 ± 1.7	42.1 ± 3.8	47.2 ± 3.0
Amylase	5.3 ± 11.9	5.3 ± 11.9	16.0 ± 13.8	32.4 ± 28.3	59.1 ± 24.4	67.1 ± 13.4	89.2 ± 8.4	112.0 ± 11.9	133.3 ± 37.7

Units of enzyme activities are the same as mentioned in Table I.

utilized in the metabolic activity of algae, causing a reduction of bacteria in wastewater. Increased bacterial growth was observed between 2.14 m and 2.44 m depth. A similar trend was observed at the bottom layers of ponds A and B. This was reflected in the higher values of catalase, phosphatase, protease and amylase in bottom layers of all the ponds (Table IV). It is revealed from this study that highly active euphotic zone exists up to 0.91 m depth in pond A, up to 1.52 m depth in pond B and up to 1.83 m depth in pond C.

4. Discussion

The factors such as light intensity and temperature directly influence the algal growth and activity and O_2 production, hence, the 'pond performance' (Dodakundi and Rodgi, 1974). Reduction in BOD and nutrients at the surface layers by the algal population, and availability of nutrients and higher BOD values observed at the lower strata of the ponds, certainly depicts their complementary nature in pond operation (Dodakundi *et al.*, 1973; Hosetti *et al.*, 1984).

Observations made on deeper ponds (B and C) indicated that the algal activity along with higher values of DO and pH extend up to 1.52 m depth in pond B and up to 2.14 m depth in pond C, which manifests the penetration of light at deeper layers and stimulation of algal activity at the layers. This showed that the ponds can be operated at 2.44 m depth, since 7.0 mg L^{-1} of O_2 was present at the bottom of the pond under investigation.

The activity of catalase, phosphatase, protease and amylase increased with the depth of the ponds. This increase in enzyme activity at the bottom layers may be attributed to the high bacterial growth and activity. Activity of these enzymes was gradually reduced and reached minimum values at the surface layers. This showed that stabilization of the major portion of the organic matter in the wastes corresponds to the lowing of enzyme activity. This observation agrees with the findings of Siddiqui *et al.* (1967), Kadke and Raman (1979), and Gaddad *et al.* (1982).

From the present study, it appears that the activity of catalase, and phosphatase can be used as an index of the microbial activity and protease and amylase activity may be correlated with the ability of the microorganisms to degrade biological wastes.

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