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An Activated Sludge Based Bench Scale Bioreactor for Sewage Treatment

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In the present study, a bench scale activated sludge system was developed for the treatment of sewage water. In this model, the stabilisation period was 324 hr and BOD was reduced to 30 mg/L. Floc formation was observed after 120 hr. The optimum flow rate of the influent for removal of BOD and COD was 250 ml/hr. Among the microbes isolated, *Pseudomonas* sp. was effective in the removal of BOD; however, the mixed cultures purified the wastewater in a shorter residence time.

INTRODUCTION

Rapid urbanisation and population growth have resulted in higher wastewater generation and higher pollution load. With the increased discharge of progressively large quantities of sewage, polluted streams became a serious menace to public health. The total volume of wastewater produced per head depends on the water usage, the type of sewage system used and the level of infiltration. Sewage consists primarily of used water with hardly 0.1 % of solids made up of inorganic and organic matter. It is a complex mixture of mineral and organic matter in many forms, including large and small particulate matter, substances in solution, in suspension and in colloidal, pseudo - colloidal dispersion. The sewage also contains living matter especially bacteria, viruses and protozoa. The higher organic loading of sewage into receiving water may deplete the dissolved oxygen from the water body and leads to the death of aquatic organisms (Turk and Turk, 1984).

Turbid waste water will reduce the penetration of light and reduce the rate of photosynthetic activity. The domestic waste water mainly contains soap and detergent wastes which are rich in phosphates. This leads to eutrophication in aquatic system bringing in algal bloom (Halaver *et al.*, 1984). When the sewage mixes with drinking water it causes serious health problems (Rana and Kansal, 1985). The sewage is normally disposed either to lakes and rivers or on land for irrigation after treatment. Conventional sewage treatment is a combination of physicochemical and biological processes designed to remove organic matter. Activated sludge system is currently the most widely used biological wastewater treatment process in the developed world for treating both domestic and industrial wastewaters (Gray, 1990). In the present study a bench scale activated sludge system for treating Coimbatore city sewage water was developed.

MATERIAL AND METHOD

Sewage wastewater samples were collected from Coimbatore city corporation sewage farm and the inoculum sludge was collected from sewage treatment plant at Sulur, Coimbatore. The bench scale activated bioreactor consists of a flat bottomed 10 L round flask containing 5 L of mixed liquor and a separate sedimentation unit with a diameter of 15 cm and a volume of 700 ml. Sludge recycling was attempted by a peristaltic pump and the level of the liquid in the aeration unit was equilibrated with a siphon. Homogeneous mixing of compressed air and the liquor was ensured by magnetic stirring paddle. The influent solution (sewage) was added to the activated sludge through gravity flow system. For the stabilisation of bench scale activated sludge system flocs from wastewater treatment plant of the Sulur military colony and pure cultures of *Arthrobacter* sp., *Zoogloea* sp. and *Pseudomonas* sp. isolated from the floc were used inoculum in the stabilised treatment plant. By periodical analysis of BOD, COD, SVI and MLSS, the stabilisation of the reactor was assessed (1981). The capacity of the bench scale activated sludge system to remove dissolved organic matter was determined by

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Table 1. *Effect of retention time of BOD removal in activated sludge based bench scale bioreactor (Mixed culture system)*

Retention period, day	BOD, mg/L	
	Influent	Effluent
0	770	770
1	765	720
2	750	630
3	720	590
4	790	530
5	695	480
6	755	390
7	765	330
8	750	270
9	740	210
10	770	150
11	750	90
12	710	90
13	730	90
14	790	60
15	710	35
16	750	35
17	730	35
18	760	35
19	760	35

Table 2. *Effect of flow rate on BOD removal in activated sludge based bench scale bioreactor (Mixed culture system)*

Retention period, day	Flow rate, ml/hr			
	100	250	500	1000
0	770	770	770	770
1	640	640	640	640
2	460	440	560	640
3	290	260	490	640
4	210	120	440	640
5	170	120	400	640
6	150	120	390	640
7	100	120	390	640
8	90	120	390	610
9	80	105	399	640
10	40	90	390	640
11	30	85	390	640
12	30	80	390	640
13	30	75	390	640
14	30	60	390	640
15	30	60	390	640
16	30	30	390	640
17	30	30	390	640
18	30	30	390	640

using a defined (Glucose 2 %) influent (Prakasam and Dondero, 1970).

RESULT AND DISCUSSION

Activated sludge system is employed as a wastewater treatment method for nearly hundred years. The basic aerobic process has been adopted to treat both domestic and industrial wastewater, further developed to include unique flexibility of operation (Alleman and Prakasam, 1983). The activated sludge process relies on a dense microbial population in suspension with wastewater under aerobic conditions. The microbial population is mixed with the wastewater in a single reactor. Nearly, 60 - 65 % of the organic matter present in the sewage is utilised by microbial biomass for their growth and energy snd thus purifies the wastewater. During the process of oxidation of organic matter, the particulate, colloidal and bacterial cells aggregate to form floc. The cells and undegraded organic constituents settle as sludge; a part of the sludge is recycled to maintain cell load and for rapid oxidation of organic matter in the wastewater. The advantage of activated sludge based system is the ability of the system to tolerate shock loads and for production of uniform quality of wastewater. The problem of 'sludge bulking' due to the presence of filamentous bacteria like *Sphaerotilus natans* could be overcome by proper maintenance of the system. The ecology of the activated sludge system is complex and bacteria, protozoans, nematodes, etc., play a major role in purification of wastewater. The period of stabilisation is very critical for development of a successful treatment system, which is dependent on the role played by each of this group of microorganisms.

In the present study, with continuously fed bench scale activated sludge system, the stabilisation reached in a period of 360 h., when the BOD of the influent was around 730 mg/L. Whereas, BOD of the wasrewater after treatment was around 30 mg/L uniformly indicating the acclimation of the sludge for the particular wastewater at that feed level (Table 1). Good flocculent growth is important for successful operation of the system (Gray, 1990) and the floc formation in the system after 120 hr indicated the initiation of stabilisation of the system. At stabilised stage, the BOD reduction was more than 90 %. Nearly 30 - 35 % of the sus-

Table 3. *Characteristics of sewage water at a stabilized state by the floc based activated sludge treatment system with mixed culture system* (25 *ml/hr*)

Sample	Retention period, day	BOD, mg/L	Total solids, gm/L	TDS, gm/L	MLSS, gm/L	pH
Influent	1	740	2.20	0.72	2.15	7.4
	2	750	2.10	0.71	2.05	7.3
	3	740	2.15	0.76	2.10	7.5
	4	760	2.00	0.74	2.15	7.4
	5	730	2.05	0.69	2.20	7.3
	6	730	1.90	0.70	2.10	7.4
Reactor	1	740	2.25	0.69	0.65	7.6
	2	760	2.00	0.67	0.69	7.5
	3	770	1.80	0.68	0.71	7.5
	4	760	1.95	0.70	0.72	7.6
	5	750	1.90	0.71	0.76	7.5
	6	720	1.90	0.71	0.70	7.6
Effluent	1	30	0.87	0.70	0.37	7.6
	2	30	0.91	0.69	0.35	7.5
	3	30	0.90	0.68	0.36	7.6
	4	30	0.89	0.68	0.35	7.6
	5	30	0.86	0.67	0.34	7.4
	6	30	0.90	0.68	0.33	7.6

pended solids removed is the mixed liquor which indicated the need for optimising the flow rate. The flow rate 100 - 1000 mL/h showed that more than 90 % BOD reduction occurred in the case of low influent flow rate (100 - 250 mL/h). In the case of 500 ml/h and 1000 ml/h, there was no significant reduction of BOD and could be due to wash out of the mixed liquor bacteria due to higher flow rate (Table 2). This further confirmed the requirement of optimum flow rate for higher BOD reduction and consequent water purification, as the ability of the system is evaluated based on the change in water quality between inflow and outflow of the wastewater (Gray, 1989). In a highly optimised activated sludge reactor the retention time is regulated to 6 - 12 h.

The characteristics of the sewage water was analysed after subjected to treatment in the floc based activated sludge treatment with mixed cultures. The results revealed that the BOD was reduced from 740 to 30 mg/L within one day of retention period; total solids content was reduced from 2.2 to 0.87 g/l and MLSS was removed from 2.15 to 0.37 g/l; but the total dissolved solids were not effectively removed. There was not much change in the pH level of the wastewater during this process; it remains at neutral through out the process. As mentioned, the bacteria are the major groups in the activated sludge system. The bacteria are present either as individual free swimming cells dispersed in liquid phase, floc forming forms and as dispersed non floc forming bacteria. The heterotrophic bacteria form the basic ecological unit of activated sludge processes (Gray, 1990). In the present study total aerobic heterotrophic population was in the range of 108 cells/ml of sample. Earlier reports indicated that the viable heterotrophic population in the mass was in the range of 1 to 5 x 10^{10} cells/g/ml (Takil, 1977). Gray (1990) reported that the type of heterotrophic bacteria varied and it depended on the nature of wastewater, pH, temperature, dissolved oxygen, nutrients concentration, sludge loading and sludge age. Though *Zoogloea ramigera* was identified as the bacterium responsible for floc formation, later studies revealed the presence of many species belonging to *Pseudomonas, Flavobacterium, Arthrobacter, Bacillus, Alcaligenes* were also involved.

In the present study, many bacterial strains were isolated and 3 predominant organisms were characterised. Based on the colony characteristics, cell morphology and biochemical characters, the organisms were identified as *Arthrobacter* sp. *Zoogloea* sp. and *Beggiatoa sp.* (Balows *et al.*, 1992). The presence of *Arthrobacter sp* and *Zoogloea sp.* in activated sludge system have been widely reported by several workers (Benedict and Carlson, 1971; Pike, 1972; Verstraete and Van Varenberg, 1989). In the present study, *Beggiatoa sp.*, was also isolated which is not widely reported in activated sludge system. But *Beggiatoa sp.* is widely distributed in a variety of environments rich in sulphate and the presence of sulphate in the range of 100 - 200 mg/L in this study might have favoured the organism. As the sewage derives the black colour during storage the presence of sulphur compounds and the organisms using it can be positively speculated. The evaluation of the performance of the isolated organism, namely, *Arthrobacter sp.* and *Zoogloea sp.* in addition with *Pseudomonas sp.* from previous study (Ramasamy, 1980) showed that the cultures performed better in the degradation of organic matter and subsequent BOD removal. Of the 3 organisms, *Pseudomonas sp.* performed better follo-

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Table 4. *Characteristics of sewage water before and after treatment with mixed and pure cultures in activated sludge based bench scale bioreactor*

Parameter	Mixed culture	Arthrobacter	Zoogloea	Pseudomonas	Control
pH	7.5	7.5	7.5	7.5	7.3
Turbidity, NTU	10.0 (92.24)	8.0 (96.19)	8.0 (96.19)	8.0 (96.19)	210
Total solids, mg/L	950 (55.81)	910 (57.67)	900 (58.14)	890 (58.60)	2150
TDS, mg/L	680 (6.85)	670 (8.22)	675 (7.53)	670 (8.22)	730
BOD, mg/L	30 (96.0)	20 (97.33)	25 (96.97)	25 (96.97)	750
COD, mg/L	75 (92.72)	60 (94.17)	70 (93.20)	70 (93.20)	1030
MLSS, gm/L	3.6 (76.77)	1.5 (90.32)	0.5 (96.77)	0.2 (98.71)	15.50
SVI, mg/L	100	120	160	150	–

Note : 1. Percent decrease over control is given in parenthesis
2. Flow rate = 250 ml/hr

wed by *Arthrobacter sp.* The permissible limit of 30 mg/L of BOD was attained in a period of 168 h by *Pseudomonas sp.* and 192 h by *Arthrobacter sp.* Similarly around 65 % of the suspended solids in mixed liquor was also removed by both organisms, where as *Zoogloea* removed around 50 % of suspended solids from mixed liquor. However, in the case of turbidity removal all the 3 organisms Performed similarly (96.2 % removal) and it was slightly better than the mixed culture. Similar results were reported for the removal of total solids and total dissolved solids. Gray (1990) reported that the presence of viable population in the mixed liquor always resulted in significant decrease in removal of solids and consequent BOD and COD reduction.

In the present study is was observed that in the activated sludge based bioreactor, the turbidity of the sewage could be removed by 96 %; total solids removal was in the range of 55.81 - 5860; MLSS was removed by 76.77 - 98.71 %; BOD and COD were removed to the level of 97 and 94 %; but total dissolved solids were removed only by 6.85 - 8.22 %. During this process the sludge volume index was increased by 100 - 160 mg/L (Table 3). The removal of total solids and MLSS by the organisms could be attributed to the formation of well characterized floc systems. The floc formation favours the removal of turbidity in wastewater besides the BOD reduction. Several factors are associated with the pure chance process of aggregation leading to flocculation (Bossier and Verstraete, 1996); (a) stimulated by physical encounters with floc surface, (b) cell sensing the vicinity of a floc, (c) metabolic adjustment leading to adherence, (d) environmental factors such as substrate gradient, (e) physical and chemical stress and (f) predation triggered aggregation.

In this investigation flocculation was observed by microscopy and the floc characteristics varied with cultures. *Arthrobacter* formed good settling sludge due to flocculating characteristics. Sparse flocs were formed by *Zoogloea,* most probably due to slimy outer layer of the bacteria. However, transmission electron microscopic observation indicated the aggregation of *Pseudomonas* with fibrillar network, suspected to be the glycocalyx involvement (Wrangstadh *et al.,* 1989). Present observation clearly showed that there existed little change in flocculation due to starvation or overfeeding. But the cell surface might play a role in flocculation. This speculation is supported by previous observation by Hantula and Bamford (1971). The results revealed that the bench scale activated sludge based bioreactor developed in the present study could be recommended for treating city corporation sewage water for effective removal of BOD, COD, total solids and MLSS.

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