Innovative low cost activated sludge process

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ACTIVATED SLUDGE PROCESS (ASP) is a versatile biological treatment process. Inspite of 75 years of Progress in ASP technology, it is not possible to claim an improvement in process efficiency and hence a level of saturation has reached in understanding of the process technology, and in its performance. Further research should emphasize towards economising the process in terms of capital and operation costs.

In the system of ASP Plant Aeration Tank (ART), Secondary clarifier (SRC) are process units and are mandatory, Recirculation Pump House (RPH) is a physical unit. With the help of RPH required concentration of Mixed Liquor Suspanded solids (MLSS) are maintained in ART. Effort could be made to maintain such levels of MLSS by arresting the flow of activated sludge in the effluent of ART and to keep them in suspension only, pumping of sludge from SRC to ART is not required, which results in lot of savings (Table 1 and 2).

Objective

To evolve cost effective Innovative ASP to remove organic matter from the raw wastes without recycle of Activated Sludge, by Pumping.

Innovative ASP

The new ASP is similar to that of clariflocculator (Figure 1), with the central portion functioning as ART with surface Aerator and the circumscribing unit serving as SRC. The influent to the ART will be discharged at the centre and at top which after undergoing the biological treatment escapes from underneath of the tank with low velocity into the SRC, where clarified effluent is produced. The settled sludge will slide back into the ART to maintain desired concentration of MLSS, with little adjustments in sludge wasting system. New system is innovative because it work efficiently with low cost and more flexibly even without the help of one prime unit, RPH, which was hitherto considered as essential part of ASP system.

Process analysis

Mass balance for the micro-organisms in the system

$$\frac{dx}{dt}.V = Q.X_0 - [Q_w.X + Q_eX_e] + V.r^{|}g$$

cell concentrations in the influent is zero and steady state conditions prevail.

$$Q_w.X + Q_eX_e = V\ r^{|}g$$

$$r^{|}g = -Y.r_{su} - k_d.X$$

$$\frac{Q_w.X + Q_eX_e}{VX} = \frac{-Y}{X}\ r_{su} - k_d$$

$$r_{su} = \frac{-(S_0 - S)}{\theta}, \frac{1}{\theta_c} = \frac{Q_{w.}\ X + Q_eX_e}{V}$$

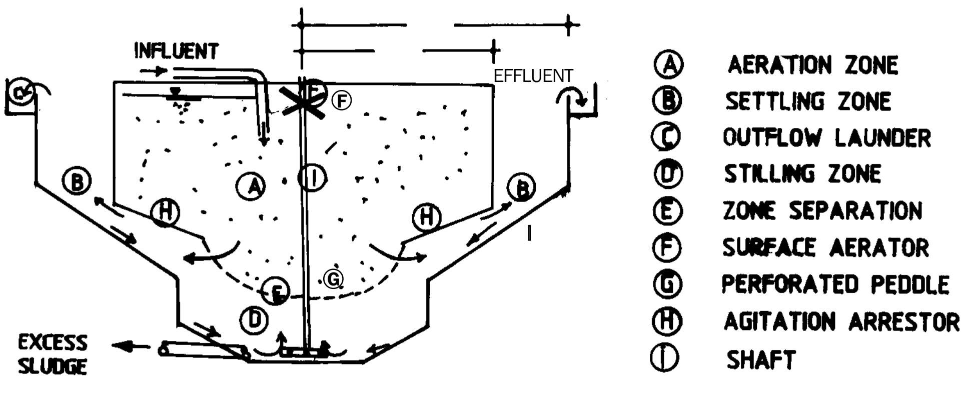

Figure 1. Schematic of low-cost ASP

Table 1. Capital and operating costs of activated sludge process plants*

Plant Capacity MLD	Aeration Tank		Secondary Clarifier		Recirculation Pump House		Total		Remarks
	CC	OC	CC	OC	CC	OC	CC	OC	
1.8	14.35	2.87	9.40	0.85	5.60	2.53	29.35	6.25	Details are obtained from the existing plants in India. capital costs are suitably updated.
3.5	26.10	4.79	17.20	1.46	9.12	4.15	52.42	10.40	
6.0	41.70	7.71	27.10	2.07	16.26	6.09	85.06	15.87	
10.5	67.20	12.09	43.65	3.39	26.45	9.86	137.30	25.34	
14.0	85.40	15.20	55.53	4.24	33.30	12.31	174.23	31.75	
18.0	105.75	18.69	71.77	5.99	43.82	14.17	221.34	38.85	
20.5	117.87	20.03	76.61	6.27	47.97	16.17	242.45	42.44	

Table 2. Comparison of costs of conventional and innovative ASPs*

Capacity of plants MLD	Conventional ASP		Innovative ASP		Percent Saving		Energy Saving Kw-hr/ year
	CC	OC	CC	OC	CC	OC	
1.8	29.35	6.25	20.54	4.06	30	35	63,070
3.5	52.42	10.40	37.79	6.78	28	35	122,500
6.0	85.06	15.87	62.09	10.42	27	34	210,060
10.5	137.30	25.34	100.24	16.49	27	35	275,625
14.0	174.23	31.75	132.86	24.76	24	32	367,510
18.0	221.34	38.85	166.13	27.08	25	30	393,750
20.5	242.45	42.44	184.30	28.80	24	32	448,430

Table 3. Details of pilot plant

Flow rate, Lit/day	:	50,000
MCRT, days	:	10
MLSS, ppm	:	3500
HRT in ART, hours	:	4.04
Aerator, HP	:	1.00
SRC over flow rate m^3/m^2-day	:	10.00
HRT in SRC, hours	:	1.60
weir loading m^3/m-day	:	4.0
Influent BOD_5, ppm	:	250

*All cost figures are Indian Rupees in Lakhs
[1 Rupee=0.0276 US dollar, 30-12-1996]

Table 4. Comparative cost of innovative ASP with cost estimate of conventional ASP (50,000 lit/day)*

Items	New ASP	Conv. ASP
Civil	1.21	1.89
Mechanical	0.76	1.21
Electrical	0.47	0.88
Instrumentation	0.20	0.46
Pipings	0.15	0.47
Channels	0.23	0.23
Total CC	3.02	5.14
OC	0.198	0.275
SavingsCC -	40%	
OC -	28%	

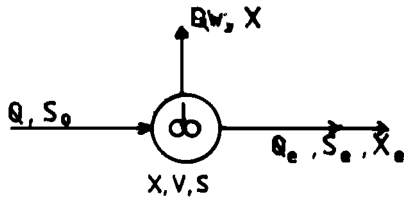

Figure 1. Schematic of low-cost ASP

$$\frac{1}{\theta_c} = \frac{Y(S_0 - S)}{X \theta} - k_d$$

Assuming Solids concentrations in effluent is low and if sludge wasting is from ART, then $\theta_c = V/Q_w$. The use of θ_c, as process control parameter is based on the fact, to control the growth rate of micro-organisms and their degree of waste stabilisation, a specified percentage of the cell mass in the system must be wasted each day.

Pilot plant

Unit was designed as per standard practice (Figure 1 and Table 3). The floors of the ART and SRC are steeply sloped to push the sludge back into the aeration zone. Around the bottom periphery of the ART wall, a projection is provided into the ART which prevents the, aerator zone of agitation reaching the ART effluent draining into SRC. This will ensure smooth travelling of both effluent and sludge in two layers of opposite directions without any disturbances.

The zone of influence of the aerator (0.81 kg O_2/hour, 60RPM) depth wise is 0.85 meters. To keep the sludge in suspension and to avoid stagnation of sludge beyond the zone of aeration perforated peddle with a shaft from aerator is provided, at the bottom.

Advantages

Design, and construction of innovative ASP is simple, with low capital and operative costs (Table 4). As one major unit i.e. RPH is eliminated, the operation of the system will be easy. Food to micro-organisms ratio will be uniform throughout the tank. The effluent flow from underneath of ART is spread over the entire periphery of the wall, hence escape velocity will be very low, which results in sucking of less solids into the effluent.

Disadvantages

ART and its cirumscribing unit SRC has to be of circular shape only which occupies more space. The system is doubtful to work for larger flows because larger diameters are required which results in sludge to travel longer distances and may contribute to high solids concentration in effluent. The SRC does not conform the design of conventional SRCs (not rational). But weir loading is kept well within the stipulated range.

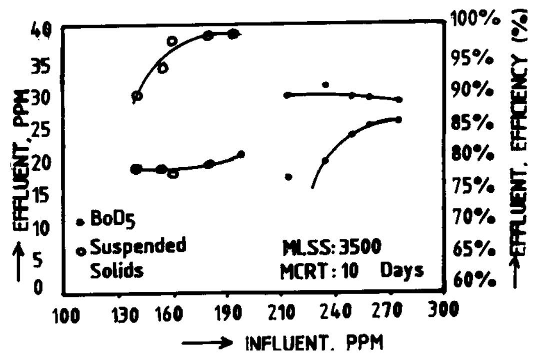

Figure 3. Performance of new ASP

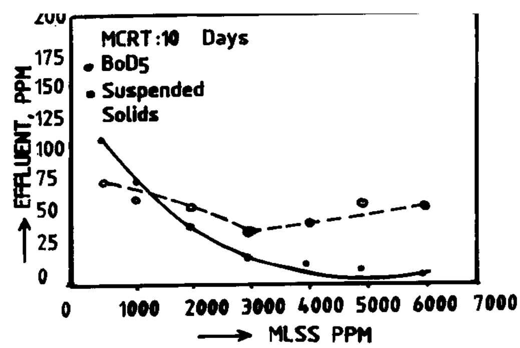

Figure 4. Relation between MLSS and efficiency of process

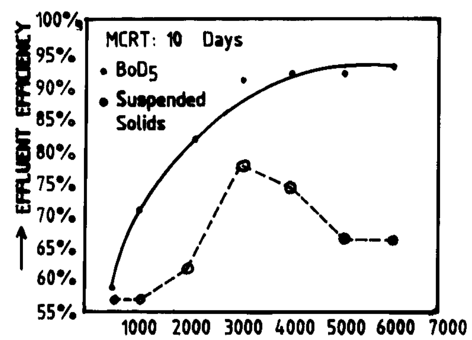

Figure 5. Relation between MLSS and efficiency process

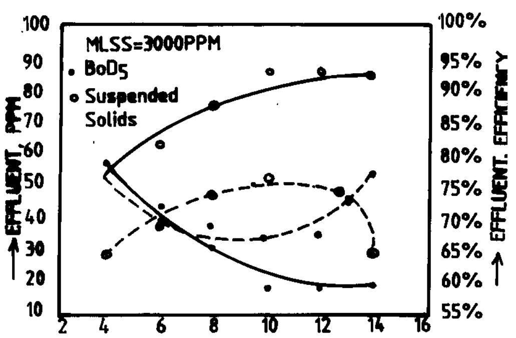

Figure 6. Relation between MCRT and efficiency of process

Method

The unit was put into operation with the primary clarifier effluent. After Stabilisation of the unit Influent and Effluent qualities were analysed for pH, BOD_5 and Suspended solids (Table 5). Further experiments were carried by varying MLSS and MCRT to ascertain the robustness of the new system (Figures 4, 5 and 6). The process control parameter MCRT, was affected by wasting a specified quantity of sludge continuously, from the ART.

Results and discussion

The unit is 90 per cent efficient in BOD_5 removal, but with lower capital and operative costs, though suspended solids removal efficiency touched only 78 per cent (because of insufficient depth of SRC). Maximum efficiency was attained with MLSS concentration of 3000 ppm and MCRT of 10 days. However with increasing MLSS Concentration, the effluent solids concentration also increases.

The experiments though conducted on Pilot Plant, considering its capacity of 50,000 lit/day which can treat the wastewater generated by population of 1000 in Indian rural context, the results can be accepted as on Prototype.

Conclusion

The recycle of Activated sludge to maintain MLSS concentration in the ART only by pumping is not essential. The results obtained are in total agreement with the results obtainable on conventional system of ASP. Hence Innovative ASP will be a more appropriate and economical system in wastewater treatment schemes. MCRT can be conveniently used as process control parameter.

References

METCALF and EDDY, 1991, "Wastewater Engineering" McGraw-Hill Publications New York.

RAVINDRA, P.N., 1991, "Optimisation of Activated Sludge Process" Dissertation submitted to University of Mysore for fulfillment for requirements of Masters degree.

Notations

CC = Capital cost in Lakh Rupees per year
OC = Operating cost in Lakh Rupees per year
k_d = micro-organism decay coefficient, M/M/T

Table 5. Performance of new ASP system

Parameter	Influent ppm	Effluent ppm	Percent removal
pH	6.8	7.4	
	6.9	7.4	
	7.0	7.5	
	7.1	7.6	
	7.2	7.6	
Suspended solids	140	30.8	78.0
	155	34.4	77.8
	160	37.6	76.5
	170	36.5	78.5
	195	38.8	80.1
BOD_5	215	17.8	91.7
	235	19.0	92.0
	250	22.8	90.8
	260	24.4	90.6
	275	27.3	90.0

Note: MLSS = 3500 ppm, MCRT = 10 days

MLD = Million litres per day
Q = Influent flow rate, L^3/T
Q_e = Effluent flow rate, L^3/T
Q_w = Waste Sludge flow rate
$r'g$ = net rate of bacterial growth, $M/L^3/T$
r_{su} = Substrate utilisation rate, $M/L^3/T$
S_o = Influent BOD_5, M/L^3
S = Effluent BOD_5, M/L^3
V = Volume of Aeration Tank, L^3
X = MLSS, M/L^3
X_e = Solids Concentration in Effluent M/L^3
Y = growth yield coefficient, M/M
θ = Hydraulic retention time, T
θ_c = MCRT , T

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