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Laboratory Scale Study of Activated Sludge Process in Jet Loop Reactor for Waste WaterTreatment

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ABSTRACT
The present study was undertaken to evaluate the feasibility of Activated Sludge Process (ASP) for the treatment of synthetic wastewater and to develop a simple design criteria under local conditions. A laboratory scale Compact jet loop reactor model comprising of an aeration tank and final clarifier was used for this purpose.Settled synthetic wastewater was used as influent to the aeration tank. The Chemical Oxygen Demand (COD) of the influent and effluent was measured to find process efficiency at various mixed liquorvolatile suspended solids (MLVSS) and hydraulic retention time (θ). The results of the studydemonstrated that an efficiency of above 95% could be obtained for COD if the ASP is operated atan MLVSS concentration of 3000 mg/L keeping an aeration time of 1 hour.In the present investigation the preliminary studies were carried out in a lab scale Jet loop reactor made of glass. Synthetic waste water having a composition of 1000 mg/L mixed with other nutrients such as Urea, Primary and secondary Potassium phosphates, Magnesium sulfate, Iron chloriderequired for the bacteria was prepared in the laboratory and reduction in COD and the increase inSuspended Solids (SS)and the Sludge Volume Index (SVI) were determined. The performance of theJet loop reactor on a continuous basis was further studied to optimize the reactor for the best CODreduction. The efficiency of the Jet loop reactor to handle the sudden increase in the pollution loading was determined by treating synthetic waste water having increased concentration of the glucoseand other constituents and also by varying flow rates. The data so collected could be further used forstudying the performance characteristics of other mass transfer and energy efficient reactors.
Keywords: Activated Sludge. Synthetic waste water (SWW), COD, Mixed Liquor volatile suspended Solids(MLVSS).

I. INTRODUCTION

An understanding of the nature of waste-water is fundamental for the design of appropriate wastewater treatment plants and the selection of effective treatment technologies. Waste-water originates predominantly from water usage by residences and commercial and industrial establishments, together with groundwater, surface water and storm water. Consequently, waste-water flow fluctuates with variations in water usage, which is affected by a multitude of factors including climate, community size, living standards, dependability and quality of water supply, water conservation requirements or practices and the extent of meter services, in addition to the degree of industrialization, cost of water and supply pressure.In the present study, treatment of waste water was investigated to reduce the level of pollution. Usually the extent of pollution is measured interms of the Biological and Chemical Oxygen Demands (BOD and COD) as well as SuspendedSolids (SS). The treatment is divided into three stages Primary, Secondary and Tertiary (5). Inthe primary stage coarse materials are separated by using filtration (6). During the secondary treatment particularly dissolved organic pollutants are removed by aerobic or anaerobic methodsusing microorganisms (Biological). The treated effluent should have a BOD value of 60 mg/Land a suspended solid content of 30 mg/L (7). In the third stage the BOD and SS are furtherreduced to 20 and 10 mg/L respectively by filtering the treated effluent from the secondarystage through sand, charcoal and/or activated carbon (13).

In the biological stage of waste water treatment plants, the dissolved organic pollutants (in the form of Carbon and hydrogen) are converted to sludge by microorganisms under addition of oxygen (aerobic). The type of equipment’s used for the secondary treatment is big aeration basins containing either diffused or surface aerators. Recently there has been a shift from conventional treatment basins with a water depth of 3-4 m to large-size tower reactors of height between 15 and 30 m like the “Turmbiologie” of Bayer AG, the BiohochReaktor of Hoechst AG, or the deep shaft process of ICI with water depths between 50 and 200m (1). These new developments have greatly reduced the ground surface required as well as the emission airborne pollutants as well as the air intake owing to better oxygen usage. The space-time yield, however, has not improved significantly and the separation of the sludge from the treated water still requires huge clarification or sedimentation tanks (14). The "Hubstrahlreaktor" proposed by Brauer and Sucker (2) and the Compact reactor developed at the Technical University Clausthal (3) demonstrate on the other hand a high space-time yield and improved sludge handling properties and thus may be regarded as high performance reactors with respect to the biological waste water treatment.

Activated sludge(4) is a process dealing with the treatment of sewage and industrial wastewaters and developed around 1912-1914. Atmospheric air or pure oxygen is bubbled through primary treated sewage (or industrial wastewater) combined with organisms to develop a biological floc which reduces the organic content of the sewage. The combination of raw sewage (or industrial wastewater) and biological mass is commonly known as Mixed Liquor. In all activated sludge plants, once the sewage (or industrial wastewater) has received sufficient treatment, excess mixed liquor is discharged into settling tanks and the treated supernatant is run off to undergo further treatment before discharge. Part of the settled material, the sludge, is returned to the head of the aeration system to re-seed the new sewage (or industrial wastewater) entering the tank. This fraction of the floc is called Return Activated Sludge (R.A.S.). Excess sludge which eventually accumulates beyond what is returned is called Waste Activated Sludge (W.A.S.). W.A.S is removed from the treatment process to keep the ratio of biomass to food supplied (sewage or wastewater) in balance. This is called the F: M ratio. W.A.S is stored away from the main treatment process in storage tanks and is further treated by digestion, either under anaerobic or aerobic conditions prior to disposal.

In Secondary treatment of wastewater oxygen and hydrogen are used(8). The oxygen helps the bacteria to digest the pollutants faster. The water is then taken to settling tanks where the sludge again settles, leaving the water 90 to 95 percent free of pollutants, where as in some oil and food waste plants, hydrogenation will be a critical step in the upgrading of bio crude to usable, renewable biofuels. Bio crude has been hydrogenated to minimize its negative aspects. The instability of oil is reduced by reaction of the most unstable functional groups. Concurrently, the oxygenated component of the oil was also reduced, resulting in an improved energy density. Hydrotreatedbiocrude is also more miscible with refined petroleum products.

II. Working of Jet Loop Reactor

A laboratory scale Jet loop reactor made of hollow cylindrical acrylic glass having approximately 15 cm diameter and near about 2m height with an inner draft tube and a height: diameter ratio of about 7:1, making a volume of 18 L with bottom sealed and top opened with a provision of an overflow to hold at least 15L of waste water was used in this study. A central coaxial draft tube was placed inside the column for circulation of gas liquid mixture within the reactor. A two fluid nozzle was fitted at the top of the column for admitting the synthetic wastewater into the reactor. When the liquid forces through the nozzle, it sucks in the atmospheric air through the fine metal tube fitted inside the nozzle. It consists of an aeration tank (bucket) of 15 L capacity. One aerator capable of producing very fine airbubbles and provison for uninterrupted power supply for aeration was used.

Figure 1:- Laboratory scale Compact Jet Loop Reactor

III. MATERIALS AND METHODS

Determination of COD and suspended solids (12) were carried out by using $k_2Cr_2O_7$, ferrous ammonium sulphate, H_2SO_4. The COD was calibrated using exactly 1gpl pure glucose solution (add 1gm glucose in distilled water and make up volume 1 liter). Here the data was collected and studied related to COD only.

IV. EXPERIMENTAL PROCEDURE

The experiment is carried out using 1 GPL synthetic waste water and fixed MLVSS concentration maintained inside the reactor for different reaction time.Initially, 10L of SWW was taken in a 15L bucket and 2L sludge was added to it. The culture was allowed to grow by aeration (without interruption) for 24 hours. The aeration was thenstopped and allowed to settle for 15 minutes. The clear liquid was decanted without losing anysludge. The removed clear liquid was replaced by adding equivalent volume of fresh SWW andthe aeration was continued. This procedure was repeated for 5 days. The suspended solids weredetermined on each day.

The composition of Synthetic Wastewater in mg/L of solution is

Glucose: 1000
Urea: 225
Magnesium Sulfate: 100
Potassium Phosphate: 1000
Calcium chloride: 64
Ferric Chloride: 0.5

Once enough treated sludge was available, 2-3 L sludge was transferred into 18 L column and 12-13 LSWW was added to it. The fresh synthetic waste water was mixed with the recirculation steam and pumped through the two fluid nozzles into the reactor. The hydraulic retention time inside the reactor was maintained by properly adjusting the flow rate of influent. After reaching the process under steady state the sample of treated effluent was carried out for measuring COD and MLVSS. The samples were taken after every 1 hour. This was followed by aeration and the COD was measured(at time 0). After every hour or two hours, the degradation of glucose was determined;mixed liquor volatile suspended solids (MLVSS) values were also determined and plotted. The curvefor both the cases was studied and the observed value of suspended solids at every stage finally determines the amount of excess sludge formed.

V. RESULTS AND DISCUSSION

Table 1:- Determination of COD When Synthetic Waste Water Concentration: 1 GPL, MLVSS = 1000 mg/L and Hydraulic Retention Time = 60 minutes

Time (hr.)	0	1	2	3	4	5
MLVSS (mg/L)	1080	1160	1220	1280	1320	1380
COD (mg/L)	1192	712	475	332	212	142
%COD Reduction	0.00	40.27	60.15	72.15	82.21	88.09

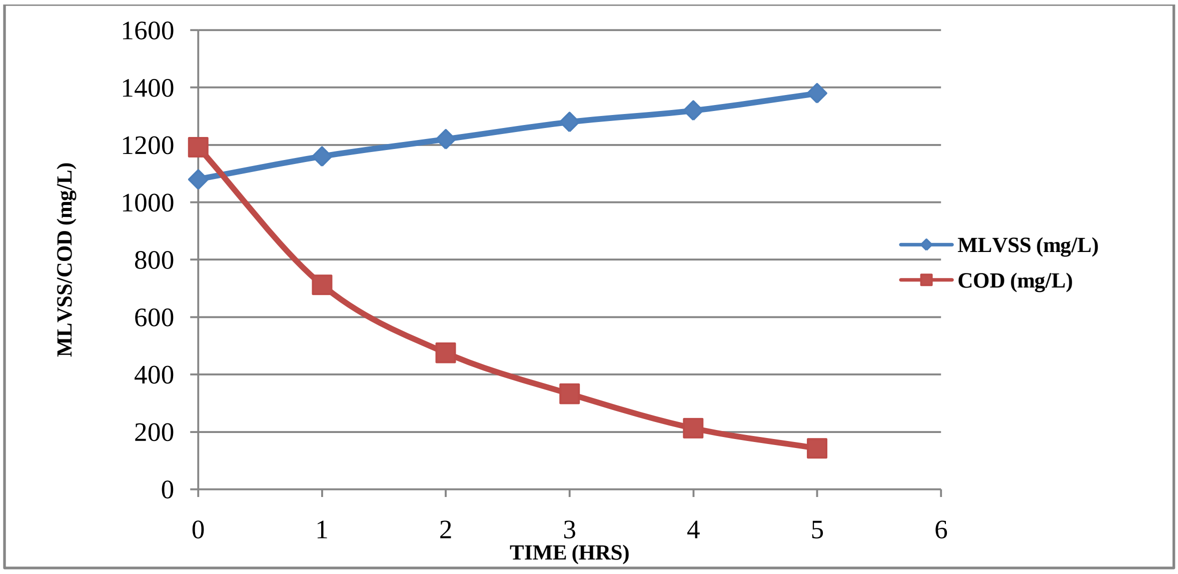

Figure2:- Time Vs. COD/MLVSS when Hydraulic Retention Time = 60 minutes & MLVSS = 1000mg/L

Table 2:- Determination of COD When Synthetic Waste Water Concentration: 1 GPL, MLVSS = 2000 mg/L and Hydraulic Retention Time = 60 minutes

Time (hr.)	0	1	2	3	4	5
MLVSS (mg/L)	1960	2050	2160	2220	2260	2280
COD (mg/L)	1056	580	370	254	165	102
%COD Reduction	0	45.08	64.96	75.95	84.38	90.34

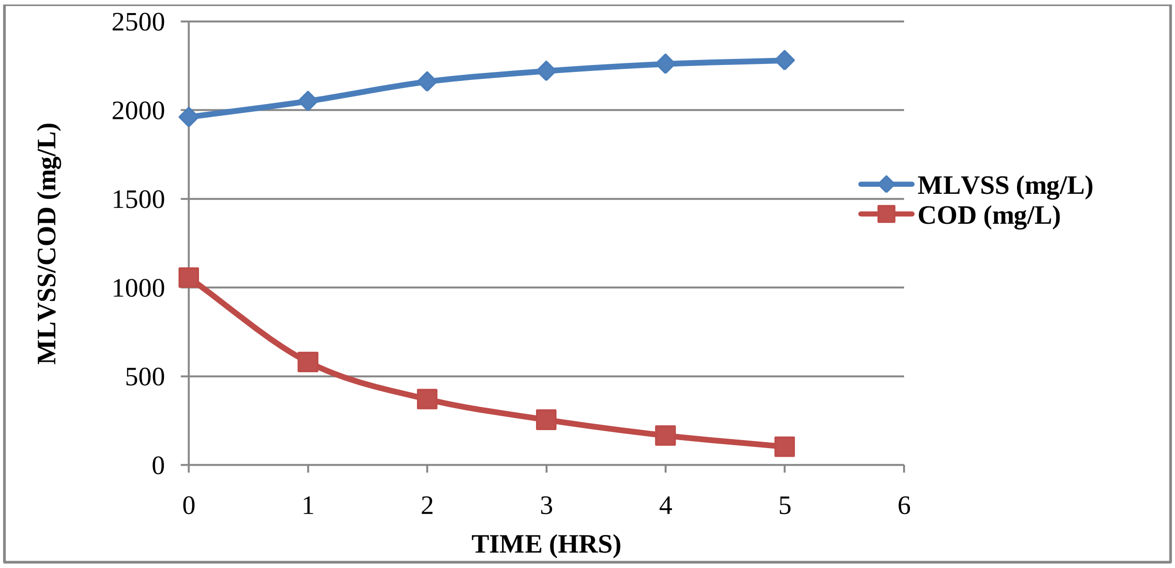

Figure 3:-Time Vs. COD/MLVSS when Hydraulic Retention Time = 60 minutes & MLVSS = 2000mg/L

Table 3:-Determination of COD When Synthetic Waste Water Concentration: 1 GPL, MLVSS = 3000 mg/L When Hydraulic Retention Time = 60 minutes

Time (hr.)	0	1	2	3	4	5
MLVSS (mg/L)	2960	3140	3260	3340	3380	3420
COD (mg/L)	1024	554	340	210	112	48
%COD Reduction	0	45.90	66.80	79.49	89.06	95.31

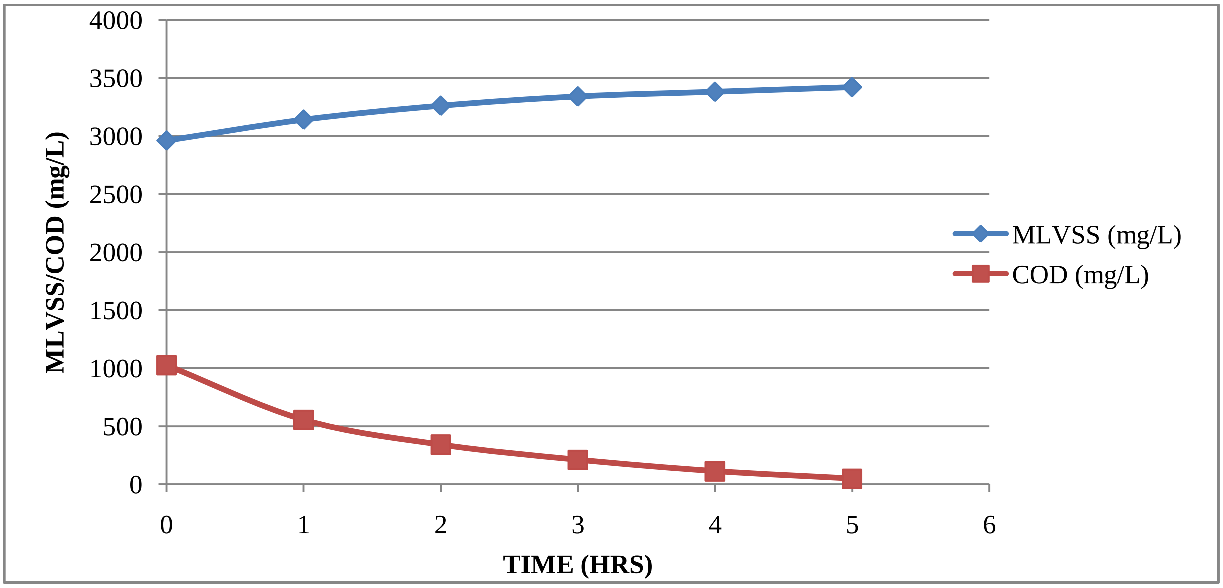

Figure 4:-Time Vs. COD/MLVSS when Hydraulic Retention Time = 60 minutes & MLVSS = 3000mg/L

Table 4:- COD Removal Efficiency Vs. Time for Synthetic Waste Water Concentration: 1 GPL,MLVSS=1000,2000 & 3000mg/L & Hydraulic Retention Time = 60minutes

Time (HRS.)	% COD Removal		
	1000 mg/L	2000 mg/L	3000 mg/L
0	0.00	0.00	0.00
1	40.27	45.08	45.90
2	60.15	64.96	66.80
3	72.15	75.95	79.49
4	82.21	84.38	89.06
5	88.09	90.34	95.31

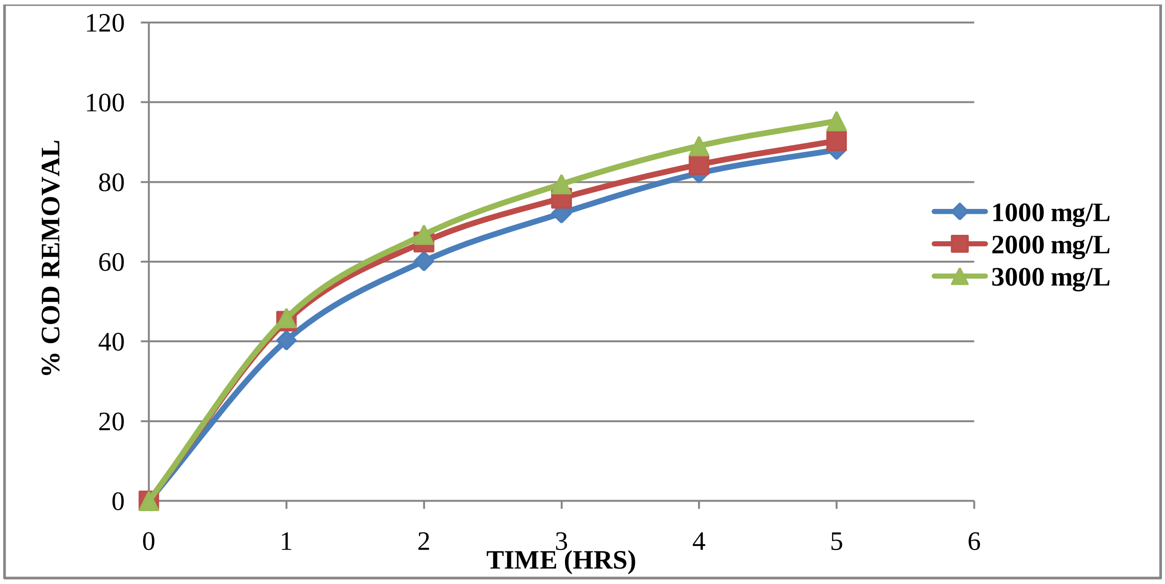

Figure (5):- Time Vs. COD/MLVSS Removal Efficiency when MLVSS = 1000, 2000, 3000 mg/L &60 minutes Hydraulic Retention Time.

The experimental data was collected by using Compact jet loop reactor. Compact jet loop reactor was operated under steady state, by varying the MLVSS concentration as 1000 mg/L, 2000 mg/L and 3000 mg/L for 1 GPL synthetic waste water concentration and at hydraulic retention time of 60 minutes.

The values of COD obtained for 1GPL synthetic waste water concentration at MLVSS concentration 1000 mg/L, 2000 mg/L, 3000 mg/L and hydraulic retention time of 60 minutes are depicted in table 1, 2 and 3. The relationships between hydraulic retention time and COD/MLVSS for above results are shown in figure 2, 3 and 4. It was noted that the COD value decreases with increase in MLVSS concentration and time.

The treatment efficiency of reactor in terms of COD removals was studied for concentrations of 1000, 2000, 3000 mg/L at time interval of 60 minutes and the result is depicted in table 4. The relationship between hydraulic retention time and the overall efficiency of the removals indicated by % reduction of COD for above result is shown in figure 5.

Thus the results indicate that as the MLVSS concentration increases, COD removal efficiency also increases; for e.g. the observed COD removal efficiencies are 88.09, 90.34, 95.31 % for MLVSS concentrations of 1000, 2000 & 3000 mg/L at hydraulic retention time of 60 minutes respectively.

As per our previous experimental study and results for bubble column reactor (7), it was observe that all calculated values of COD in Bubble column reactor were around the permissible limit and for Compact jet loop reactor it is observed that all values are under permissible limit i.e. 250 mg/L given by the general standards for discharge of environmental pollutants decided by Central Pollution Control Board, ministry of environment and forests, Government of India.

From above results it is concluded that maximum COD removal efficiency was obtained at MLVSS concentration of 3000 mg/L and time value of 60 minutes. It is also concluded that maximum COD removal efficiency is found in Compact jet loop reactor as compared to Bubble column reactor. This is due to the fact that in jet loop reactor, very finely dispersed air bubbles produce high turbulence and efficient mass transfer. Moreover the biomass also works very efficiently due to constant inertia when they are projected into the core of the reactor through the two fluid nozzles.

VI. CONCLUSION

In growing industrialization era the water purity is the main problem. Water is needed everywhere for process, utilities, household purpose etc. so for waste water, treatment has become more and more important. For the treatment of waste water activated sludge process is environmentally useful.

The Compact Jet Loop Reactor is found most effective and economical for the treatment of industrial waste water by using activated sludge process and widely used for removing organic components from waste water. The pollution load was estimated by Chemical Oxygen Demand (COD). Results obtained in this study has indicated that percentage reduction of COD reached up to 95% in treated effluent at MLVSS concentration of 3000 mg/L and an aeration time of 1hour.

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