Efficient Treatment of Slaughter House Wastewater by Anaerobic Hybrid Reactor Packed with Special Floating Media

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Abstract

Slaughterhouse wastewater is characterized by the presence of high concentration of slaughtered animal's blood and high suspended solids from rumen and stomach content. Hence this wastewater depicts high pollution load in terms of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) , Suspended Solids in the range of 22000-27500 mg/l ; 10800-14600 mg/l and 1280-1500 mg/l respectively. This wastewater is categorized as high strength wastewater and needs treatment prior to its discharge.A laboratory study on a hybrid reactor of 50 liters capacity was initiated. Reactor was packed with light weight floating media. The advantage of this media is its light weight , its shape which provides 100 m^2/m^3 area on which the microorganism are immobilized making it more sustainable to shock loadings. Because the media is always in motion its clogging due excess biomass deposition on surface is prevented. Moreover good contact between the substrate and the microorganism is ensured because of its floating nature.

Studies on different organic loadings ranging between 1.0-6.0 kg COD/m^3/Day and two HRT's of one and two days were studied. Efficiency of the wastewater was very good with COD/BOD reductions in the range of 86.0 % -93.58% and 88.9 % -95.71% respectively obtained at one day HRT . The reduction was observed to increase marginally at two day HRT and organic loading rates between 1.0-6.0 kg COD/ m^3/Day. It was very clear from the results that the special media provided good treatment efficiency. This article discusses in detail the efficiency of the special media at different organic and hydraulic loading rates.

Keywords:-Hybrid, Anaerobic, Floating Media, Slaughter house wastewater.

Introduction

Slaughterhouse wastewater is categorized under strong wastewater . It has high concentrations of suspended solids , soluble and insoluble organics and exhibits high COD and BOD. Moreover the

slaughterhouse wastewater is highly proteinetious and putrefies faster leading to environmental pollution problems. The abattoir wastewater is also characterized by the presence of high degree of blood from slaughtered animals, suspended solids due to rumen contents , undigested food ,feathers, flesh pieces and pieces of bone making it very strong (Bull etal 1982) . Blood contributes a COD of 3,75,000 mg/l (Tritt and Schuehard 1992) . It becomes imperative to recover and reuse blood as it is a value added product , the recovery also reduces the pollution load. Strength of slaughterhouse wastewater varies from slaughter house to slaughterhouse based on the number and types of animals slaughtered , volume of water used and by product recovered .

Slaughterhouse wastewater depicts BOD/COD ratio 0.6 indicating its highly biodegradable nature. This waste water harbours many disease causing microorganism ex- ; tuberculosis , Salmonellosis and Helminthosis and requires proper treatments prior its disposal . The slaughter house wastewater causes de-oxygenation of the water bodies (river) (Quinn JM and McFarlane 1989) and ground water contamination (Sangodoyin and Agbawhe O M 1989).

Anaerobic treatment systems are more suitable options for the slaughter house wastewater treatments. This option has been successfully applied to slaughter house wastewater . Anaerobic treatment provides high COD, BOD and SS removals ,while producing recoverable source of energy in form of methane gas. The anaerobic treatment generates a very low quantity of sludge and also does not require chemical pretreatment.

Literature shows , that fixed film fixed bed reactors have been successfully, used for the slaughterhouse wastewater treatment in late 80's and 90's . An anaerobic filter reactor to treat slaughter house waste water that contained 46% its COD as SS was successfully treated and reported (Tritt1992). Later Upflow Sludge Blanket Reactor system came into being for the different industrial wastewater including slaughterhouse wastewater (Lettinga et al 1989, Mijalova Nacheva P et al 2011) ,subsequently Anaerobic Hybrid Reactor system combining UASB and Filter for the treatment of slaughterhouse was introduced and reported (Borja et al 1995). This was followed by the work of (Ruiiz et al 1997) who successfully treated the slaughterhouse wastewater in a UASB reactor and an anaerobic filter .It was further reported that this system resulted in good reductions in COD and BOD even at high organic loadings.

These studies were followed by many new modifications in reactor configuration . One such reactor system was Anaerobic Hybrid Reactor System packed with pleated polyvinylchloride rings. This new configuration was applied to poultry slaughter house waste water very successfully (Rajkumar et al 2012).In the present article feasibility of a new floating media packed Anaerobic Hybrid Reactor in the treatment of slaughter house wastewater has been studied and discussed

Materials and Methods-

Slaughterhouse wastewater required for the studies was procured from a local municipal corporation operated slaughterhouse .This wastewater was collected on hourly basis for a period of four hours (till slaughtering process was continued) and a combined waste water was prepared to have a properly homogenized wastewater of uniform quality. Slaughterhouse wastewater contains high concentration of solids and hence the waste water was settled for an hour before its use in the experiments. Both raw combined wastewater and half hour settled wastewater were subjected to routine physicochemical parameter as per the standard methods (20^{th} edition 1998). Important parameters needed for an anaerobic reactor system were carried out for the collected wastewater samples. Results are shown in Table 1

Table 1: Physico- chemical characteristics of slaughter house wastewater

Parameter	Raw wastewater	Half an hour settled wastewater
pH	6.9-7.1	6.9-7.2
Alkalinity as $CaCO_3$	3820	3642
Total Solids	9260	8120
Total Volatile Solids	5575	4872
Suspended solids	2562	614
Chemical oxygen demand (COD)	27800	18904
Biochemical oxygen demand (BOD)	16680	11340
Sulphate as SO_4	96	86
Phosphate as PO_4	78	64
Chloride Cl	464	452
Sodium Na	248	242
Potassium K	312	300
Total Ammonia as NH_3^-N	308	296
Total vijeldah as nitrogen asN	920	898
Oil and grease	246	232

*All parameter are expressed as mg/l except pH.

Anaerobic hybrid reactor was fabricated using acrylic pipes . Working volume of the reactor was maintained at 50 liters. Bottom one fourth space was provided for sludge accumulation above which a perforated plate was provided to support the floating media matrix. An inverted cone shaped funnel was held over the top of the water column submerged to some extent inside the water column for collecting gas. Figure 1 shows the reactor details.

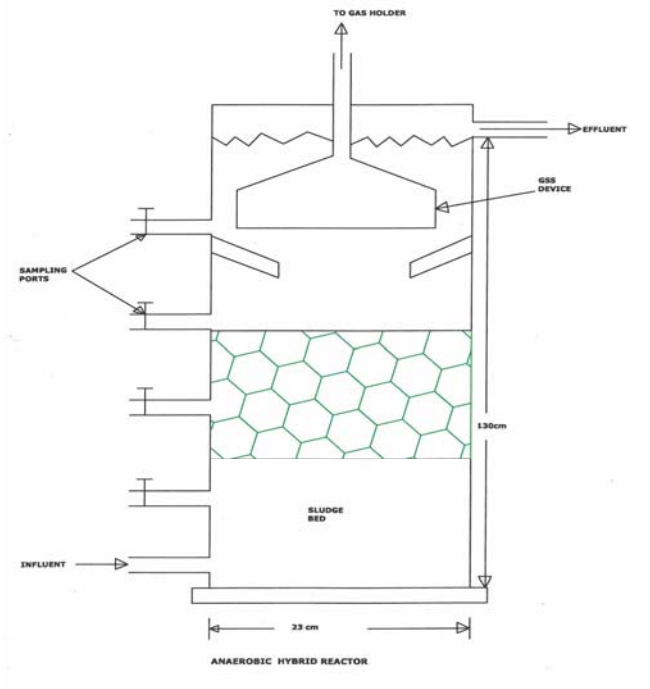

Figure 1 Details of Anaerobic Hybrid Reactor

The cone is connected to the gas collector to collect the biogas produced. Flow rate of the influent was maintained using a flow meter. Details of the floating media are shown in Table 2.

Once the reactor was stabilized as was observed from constant COD value and daily gas production rate, wastewater feeding was initiated. Approximate organic loading rates of 1.0; 2.0 ; 3.0 ; 4.0 ; 5.0 and 6.0 Kg COD/m^3d were studied at hydraulic loadings of one and two days.

Table 2: Details of floating media matrix

s/n	Parameter	Details
1	Structure	Self supporting cylindrical shaped with internal ribs and concentric section.
2	Media	187mm x 51mm
3	Specific gravity	0.95-1.04gms/cm^3
4	Surface area	100 m^2/m^3
5	Void age	> 95%
6	Bulk density	35 kg/m3
7	Colour	Black

Treated effluent from different organic loading rates were collected regularly and analyzed. Result are shown in Table 3 and 4 . Wastewater used in the experiment was settled for half an hour to

reduce the solids to prevent choking and clogging. Gas monitoring was done regularly. Gas was collected in Tedler's bag and was subjected to gas analysis. Methane was analyzed using Unitran handy methane meter and CO2 by Orsat Apparatus.

Table 3 Performance of Anaerobic Hybrid Reactor at various organic loading rates (HRT + 1 day)

Parameter *	**Organic loading Kg COD/m3.d**					
	0.998-1.06	1.9-2.01	3.0-3.26	3.98-4.11	4.99-5.0	6.0-6.02
pH	7.1-7.2	7.2-7.3	7.2-7.3	7.3-7.5	7.5-7.6	7.6-7.7
Alkalinity as CaCO3	356	390	436	466	480	498
Volatile acid as CH3COOH	70	75	86	94	98	120
Total ammonium nitrogen-NH3-N	136	148	160	172	184	196
Suspended solid	126	143	174	188	196	206
Total nitrogen as -N	34	40	45	52	58	68
Total phosphate asPO4	5.0	5.6	6.2	6.6	7.0	7.3
Chemical oxygen demand(COD)	68	150	276	421	591	842
Percent COD reduction	93.58	92.5	91.2	89.6	88.2	86.0
Biochemical oxygen demand(BOD)	22	58	112	176	242	345
Percent BOD reduction	95.71	94.4	93.17	92.0	90.88	88.9
m^3 gas /kg cod added	0.326	0.318	0.298	0.286	0.272	0.268

* All parameter are expressed as mg/l except pH, COD/BOD reductions and Gas Production

During reactor startup the reactor was filled with diluted night soil sample. Domestic sewage was used for diluting the night soil sample . The reactor was filled with this wastewater seed and allowed to stand for a period of 15 days , subsequently wastewater feeding was initiated for a minimum organic loading of 0.5kg COD/m^3/d. Gradually the loading was increased to 1.0 kg COD/m^3.d and the reactor was operated on this loading for some time till the reactor stabilized as was observed from constant COD reduction and constant gas production. Reactor startup took a total of 45 days.

Table 4 Performance of anaerobic hybrid reactor at various organic loading rates (HRT=2days)

Parameter *	**Organic loading Kg COD/m3.d**					
	0.998-1.06	1.9-2.01	3.0-3.26	3.98-4.11	4.99-5.0	6.0-6.02
pH	7.32 - 7.4	7.4 -7.5	7.48-7.56	7.5-7.6	7.62-7.74	7.7-7.8
Alkalinity as CaCO3	426	464	492	520	546	572
Vol. acids as CH3COOH	86	96	106	112	118	128
Total ammonium nitrogen asNH3-N	132	142	154	166	178	210
suspended solid	120	136	166	172	184	196

Total Nitrogen as-N	28	36	40	46	52	60
Total phosphate asPO4	4.2	4.4	4.8	5.2	5.4	5.7
Chemical oxygen demand (COD)	104	264	468	670	918	1425
Present COD reduction	94.8	93.4	92.2	91.6	90.8	88.10
Biochemical oxygen demand (COD)	45	120	216	336	460	636
Present BOD reduction	96.24	95.0	94.0	93.0	92.16	90.4
M3/Kg COD added	0.338	0.324	0.306	0.292	0.288	0.276

* All values are expressed as mg/l except pH, COD/BOD reductions and gas production.

Results and Discussion

Slaughterhouse wastewater used in this study was collected from a municipal corporation operating slaughterhouse where on an average 200 animals are slaughtered. Present treatment facilities is only in the form of fat trap and collection tank, no salvaging of blood is practiced. Hence the wastewater from this slaughter house is very strong and exhibits COD of 27800mg/l and BOD of 16680mg/l respectively. BOD/COD ratio was 0.6 indicating good biodegradable nature. Collected wastewater was settled for half an hour before using it in the Anaerobic Hybrid Reactor.

Anaerobic hybrid reactor was packed with special floating media. Studies were carried out on different organic loading rates(OLR) and hydraulic rates (HRT). Organic loading rates studied were between 1.0 and 6.0 kg COD/m^3.d at two hydraulic loading rates of one and two days.

Settled waste water depicted COD/BOD and SS of 18904 mg/l, 11340mg/l and 614mg/l respectively. Simple setting on an average of 30 minutes resulted in 32% COD reduction and 76% of suspended solids reduction. Settling beyond 30 minutes did not improve the removals significantly.

During energizing the reactor, night soil and sewage were mixed and diluted to required quantity and was filled in the anaerobic hybrid reactor.

Once the reactor was energized, regular feeding of slaughterhouse wastewater was initiated . Initially, 1.0 kg COD/ m^3.d loading was started . Gradually organic loading was increased up to 6.0 kg COD/m^3.d and HRT of one day was studied . Results obtained are depicted in Table 3.

From the results it can be seen that the settled slaughterhouse wastewater used in the experiments had a pH in the range of 6.9 to7.2, total ammonical nitrogen were fairly on a lower side with value of 296 mg/l indicating that no decompositions has set in and wastewater is fresh. In spite of half an hour settling of wastewater suspended solids were around 614mg/l indicating that the wastewater sample contained more finer solids, which escaped settling and only coarse particles must have settled.

Treated effluent from different organic loadings was collected and subjected to routine analysis. It is seen from the results that the effluent pH ranged between7.1 and 7.7 in case of 1day HRT while it

ranged between 7.3-7.8 in case of 2days HRT, indicating efficient performance at both one day and two days retention time.

Generally a UASB reactor comparatively work at low organic loadings while hybrid reactor can work on higher organic loadings due to more surface area available for the microorganism to get immobilized and hence works very efficiently with good removals of COD/BOD.

A hybrid anaerobic reactor packed with PVC rings has been successfully operated up to an organic loading rate of 9.0kg COD/m3.d and achieved good COD removal of 92% (Rajkumar et al 2012) . In the present study even at one day HRT and at 6.0 kgCOD /m^3 .d loading COD reductions of 88.9% was achieved . This may be due to higher strength of slaughterhouse wastewater compared to poultry slaughter house waste water. The reduction increased to 90.4% at same loading but at HRT of two days. Percent BOD reductions varied between 88.9 to 95.71% and 90.4% to 96.24% for the loading rates between 1.0 and 6.0 kg COD/m^3d loading at one day and two days HRT respectively.

During the present study it was observed that at lowest organic loading rate of 1.0 kgCOD/m3 and HRT of 1 day the COD and BOD reduction was 93.58% and 95.71% respectively while at two days HRT and on lowest loading of 1.0 kg COD/m3.d it was 94.8% and 96.24% respectively.

Increase of retention time to two days , increased the removal efficiencies, but it is not worth to increase the HRT further as it will not be economical. Even at the higher loading rate of 6.0kgCOD/m3.d the COD and BOD reductions were very efficient and were more than 85% in both the HRTs of one day and two days. It is very clear that when large quantity of wastewater needs to be disposed /stabilized in shorter duration, then higher loadings, till minimum COD reduction of 75% is achieved can be applied very fruitfully in the hybrid anaerobic reactor system. Literature reports that an organic loading of 8.7kgCOD/m3.d and a hydraulic retention of five days resulted in 79% COD removal. In the present study two days HRT at 6.0 kg COD /m3.d organic loading has resulted in better removal of 88.10%. It is clear from the results that the floating media packed in the hybrid reactor works efficiently.

Volatile acid concentration varied between 70 to 120 mg/l and 86 to 128mg/l in both the retention periods and were well within the limits. Results also indicate proper utilization of volatile acids by the methanogens. It is seen that the system is well buffered. Volatile acid to alkalinity ratio remained around 0.20 to 0.21 indicating efficient working of the system, through out the study period at all loading rates and retention times. Even at higher organic loading rate the system was well balanced, and it never inclined towards imbalance in the reactor.

Total Ammonia nitrogen varied between 136-196mg/l and 132-210 mg/l at one and two days HRT respectively indicating very good buffering in the system.

Daily gas production varied between 0.268 – 0.326 m^3/kg COD added for one day HRT and between 0.276-0.338m^3/kg COD added for two days HRT which lies in the optimal range .It is very clear

that the strong slaughterhouse wastewater can be a potential energy source, if treated anaerobically in an hybrid reactor.Gas analysis indicated 65-68% methane and 32- 38% CO_2 indicating good fuel value.

Conclusion

It can be concluded that anaerobic hybrid reactor systems are more suitable for slaughterhouse wastewater treatment and following benefit can be harvested

- Very efficient treatment in short duration can be achieved.
- It is more suitable than conventional anaerobic fixed film and UASB reactors.
- Higher loading rates can be achieved in short interval of retention time.
- Shock loading can be better handled.
- Efficient substrate utilization is achieved due to good immobilization of microorganisms on the floating media.
- Higher organic loadings with good removals can be achieved efficiently .
- Gas production is a good source of energy and has good calorific value.

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