IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 14, Issue 3 Ser. II (March. 2020), PP 35-40
www.iosrjournals.org

Influences of Organic & Hydraulic Loading Disturbances on a Lab-Scale Upflow Anaerobic Filter

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Abstract: *Anaerobic process has been widely used for stabilization of municipal waste sludge as well as industrial waste. A lab scale upflow anaerobic filter was operated for the treatment of synthetic wastewater, and the influence of various organic loading rates and hydraulic loading rates on the performance of reactor were studied. Whole investigations were carried out in two different phases over about 12 month's operation. During first phase, organic loading rates from 0.5 to 4.5 kg-COD/m^3 were applied to reactor by keeping constant hydraulic loading rate as 0.2m^3/m^2/day whereas in the second phase, hydraulic loading rates from 0.2 to 0.5 m^3/m^2/day were kept by applying constant organic loading rate of 2.5 kg-COD/m^3. The COD removal efficiency was obtained at 92% under the organic loading rate of 2.5 kg-COD/m^3 and 84% under the hydraulic loading rate of 0.3m^3/m^2/day and the hydraulic retention time of 60 h. Interestingly, gas production rate was observed 0.2m^3/kg-COD and 0.04 to 0.1 m^3/kg-COD at organic loading rate of 2.5 kg-COD/$m^3$and hydraulic loading rate of 0.5 m^3/m^2/day respectively.*

Key Word*: Anaerobic, COD, Organic loading rate, hydraulic loading.*

Date of Submission: 12-03-2020 Date of Acceptance: 27-03-2020

I. Introduction

Industrial wastewater especially from food processing industries, soft drink and beverage industries contains high organic matter**.** So, it has become necessary to treat industrial effluent and sewage waste before discharging it into a water body to avoid environmental related problems. It can be treated by using aerobic processes such as activated sludge process, trickling filter, aerated lagoons etc. but these methods involve high power consumption, capital and maintenance cost.

In anaerobic treatment, oxygen is not required. Hence anaerobic treatments such as anaerobic digestion, anaerobic filter can be carried out economically as no aeration is required. Anaerobic treatment has many advantages due to low production of waste biological solids. **(Rangaraj Ganesh, Rajgopal Rajinikanth,2010)** Anaerobic process has been widely used for stabilization of municipal waste sludge and many industrial wastes such as sugar industry waste, tannery waste, distillery waste etc. Hence, in the present study it is intended to explore if the anaerobic filter process can be efficiently used in synthetic wastewater treatment under various loadings and operating conditions.

Up flow anaerobic filters (UAFs) have been effectively used for the treatment of a variety of industrial wastewater, especially for high strength wastewaters. Media size, media height, upflow velocity plays an important role on performance efficiency of UAFs **(Tin Sang Kwong & Herbert H. P. Fang, 1996)**. Hydraulic retention rate also play a vital role on efficiency of UAF and it is necessary to study that under particular Organic loading rate, the variation in HLR can affect the system.

So, the study was carried out to find out maximum OLR and HLR at which Up-flow Anaerobic Filter works satisfactorily while treating synthetic wastewater sample.

II. Material And Methods

2.1 Experimental Set up

A lab scale model of Up-flow Anaerobic Filter (UAF) reactor was made up having square shape in cross section. The inner dimensions were 10 cm x 10 cm and height 1.4 m. Outlet for effluent collection was located at 1.3m from the bottom of the filter. Three sampling ports were provided at a distance 30 cm apart. The gas outlet was also provided at the top 10 cm above the effluent port. The gas collection device consists of two gas aspirator bottles connected to each other one long tube connecting one of the aspirator bottles with gas outlet.

Table 2.1- The Specifications of UAF Reactor

Sr No.	Characteristics	Unit	Values
1	Operation mode	-	Continuous
2	Flow Mode	-	Up flow
3	Flow Type	-	Plug Flow
4	Total Height	cm	140
5	Effective/Media Height	cm	115
6	Inner Dimensions	cm	10 x 10
7	Total volume	m^3	0.014
8	Total Void Volume	m^3	0.0085
9	Total Effective Area	m^2	5
10	Body Material	-	Acrylic
11	Inlet Port	-	1 no., 5mmØ, rubber tube
12	Effluent Port	-	1 no., 5mmØ, rubber tube
13	Gas Outlet Port	-	1 no., 5mmØ, rubber tube
14	Drain Port	-	1 no., 5mmØ, rubber tube
15	Sampling Port	-	3 no., 5mmØ, rubber tube
16	c/c distance between sampling ports	cm	30
17	Volume of Aspirator Bottle(Gas Collection Bottle)	m^3	0.005

The glass bottle holds 5 liters of acidified brine solution. The anaerobic filter reactor had an empty volume of 14litres (10cms x 10cms x 140cms) and void volume (with an installed support filter materials) of about 9.5litres. The influents were fed from same feed tank to the bottom of the column by the help of gravitational force.

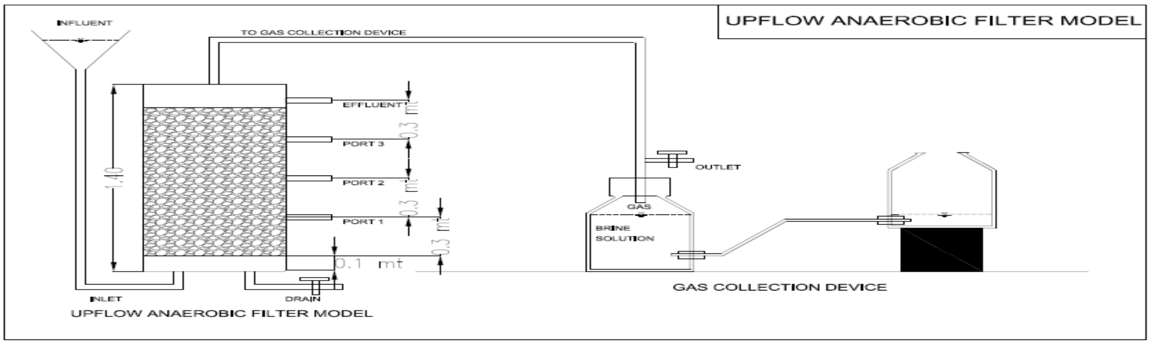


Fig No.1: Upflow Anaerobic Filter Setup

Table 2.2 - Filter Material Specifications

Sr No.	Characteristics	Unit	Values
1	Type of Material	-	Plastic
2	Height	cm	1.5
3	Diameter	cm	2.2
4	Bulk Density	Kg/m^3	0.96 – 0.98
5	Void Fraction	%	74
6	Fill Fraction	%	26
7	No. of pieces of filter material in model reactor	No.	1014
8	No. of pieces of filter material/m^3	No.	10^5
9	Specific surface area	m^2/m^3	500
10	Volume occupied by filter material	m^3	0.01
11	Total effective area of filter material	m^2	5

Fig No.2: Upflow Anaerobic Filter Experimental Setup & Covered with tarpaulin sheet.

2.2 Procedure methodology

Phase I :-Effect of Organic loading rate

Initial 20 days period was given for seeding purpose to develop anaerobic conditions and initial built up of microorganisms. Settled sewage and cow-dung slurry was used for seeding purpose .After preparing sewage-cow dung slurry, filter was then seeded by feeding slurry up to effluent port level and model was kept undisturbed for next 20days to develop anaerobic conditions were developed in the reactor. 3 weeks of seeding, model was fed with synthetic wastewater keeping influent COD loading of 0.5, 0.1 and 0.15 Kg COD/m^3 etc till failure to acclimatize bacteria to synthetic wastewater for time being of 43 days. For each organic loading, influent and effluent were analyzed at inlet and outlet for parameters such as pH, volatile acids, alkalinity, COD and gas production to find out the maximum organic loading at which reactor works satisfactorily. **(s.kumbhar & j.main,2013)**

Table no.2.3– Operating Schedules and Applied Organic Loading Rates (Phase-I)

Test phase	OLRs,(Kg COD/m^3)	Influent COD concentration (mg/l)	HLR, ($m^3/m^2/d$)	HRT (days)
1	0.5	500	0.2	5
2	1.0	1000	0.2	5
3	1.5	1500	0.2	5
4	2.5	2500	0.2	5
5	4.5	4500	0.2	5

Phase II:- Effect of Hydraulic Loading Rate:-

Filter reactor was loaded with varying Hydraulic Loading Rates (HLRs) by keeping constant organic loading at which model gave higher efficiency and then hydraulic loading was increased to check the performance of the reactor till failure.

Table no.2.4 – Operating Schedules and Applied Hydraulic Loading Rates (Phase-II)

Test Phase	OLR, (Kg COD/m^3)	Influent COD conc. (mg/l)	HLR, ($m^3/m^2/d$)	HRT (days)
1	2.5	1800.50	0.2	5
2	2.5	1583.33	0.3	5
3	2.5	1187.5	0.4	5
4	2.5	950	0.5	5

From phase-I experiment, it was observed that, reactor gave better efficiency as well as higher gas production rate for organic loading of 2.5KgCOD/m^3 [efficiency = 92.3%; gas production = 0.2m^3/Kg COD destroyed] and

HLR of $0.2m^3/m^2/d$. Therefore, organic loading of $2.5KgCOD/m^3$ was kept constant and efficiency of reactor was evaluated for varying HLRs to find maximum HLR at which reactor works satisfactorily

III. Result

3.1. Observation and Result of Phase 1:-

When the Organic Loading of $0.5KgCOD/m^3$ was maintained initially COD reduction efficiency of 68% was obtained and it went on increasing to 78%. When the loading was changed accordingly to $1Kg\ COD/m^3$ efficiency came down to 57% and from the next day, it went on increasing up to 89% and remained constant.

At the loading rate of 1.5 and $2.5Kg\ COD/m^3$, efficiency obtained was within 89-92% which was more than that obtained for loadings of 0.5 and $1.0KgCOD/m^3$. The reason for this may be that, at the lower loading rates of 0.5 and $1.0KgCOD/m^3$, the microbial yield was also low. So, even though bacteria developed and got acclimatized to synthetic wastewater, the reduction efficiency was only within 68-78% and as soon as loading increased, there was a built of microorganism with sufficient availability of more food and COD removal efficiency rose up to 92% for increased loading of 1.5 and 2.5Kg.

Table 3.1 - Results of COD Removal efficiencies for Phase-I

OLR ($KgCOD/m^3$)	Influent COD conc. (mg/l)	Effluent COD conc. (mg/l)	COD removal Efficiencies (%)
0.5	500	160	68
0.5	500	160	68
0.5	500	157.44	68.51
0.5	500	111.84	77.63
0.5	500	110	78
1	1000	431	57
1	1000	398.4	60.15
1	1000	320	68
1	1000	280	72
1	1000	240	76
1	1000	154.88	84.5
1	1000	116.16	88.38
1	1000	113	89
1.5	1500	165.76	89
1.5	1500	161.28	89.24
1.5	1500	122.4	91.84
1.5	1500	122	92
2.5	2579	384	84
2.5	2579	234.3	90.62
2.5	2579	200	92
2.5	2579	192	92.3
4.5	4500	1858	57
4.5	4500	1607	64
4.5	4500	1459	68
4.5	4500	1382	69
3.5	3500	777.2	77.78
3.5	3500	542	84.51
3.5	3500	509.6	85.44
3.5	3500	542.08	84.51

As soon as loading increased from 2.5 to $4.5KgCOD/m^3$, efficiency came down to 57% and then it rose up to 68% within next 3-4 days. This happened because of sudden increase in loading, the performance of the reactor was affected as its parameters were not found within the required limit. So it was decided to decrease the loading. Feed was given with loading of $3.5KgCOD/m^3$ to check the reactor's performance. Efficiency obtained was 85%. From this experimentation work, it was observed that, the reactor gave better efficiency at organic loading rate of $2.5KgCOD/m^3$. So the phase-I experimentation was stopped to go ahead for effect of HLR on reactor keeping constant Organic loading rate of $2.5KgCOD/m^3$.

3.2. Observation and Result of Phase II:-

During the phase-I experimentation, reactor gave better efficiency of 92% for Organic Loading of $2.5KgCOD/m^3$ at constant HLR of $0.2m^3/m^2/d$ throughout. In phase-II, model was tested for hydraulic loadings by keeping constant organic loading of $2.5KgCOD/m^3$.

When hydraulic loading of $0.2m^3/m^2/d$ was maintained by keeping organic loading of $2.5KgCOD/m^3$ constant throughout, initially efficiency observed was 81% which further went on increasing up to 84% and remained constant.

As soon as hydraulic loading increased to $0.3m^3/m^2/d$ efficiency suddenly dropped to 57% and for next 3days, it remained constant within the range of 56-58%.

For hydraulic loading of $0.4m^3/m^2/d$ & $0.5m^3/m^2/d$, initially efficiency observed was 58%. Efficiency again dropped to 54% .For gradual increase in Hydraulic Loading Rate, efficiency continuously went on decreasing and at higher loading of $0.5m^3/m^2/d$; efficiency dropped to 50% even though all the parameters were found to be within the required limits.

Table 3.2 – Results of COD Removal Efficiencies for Phase-II

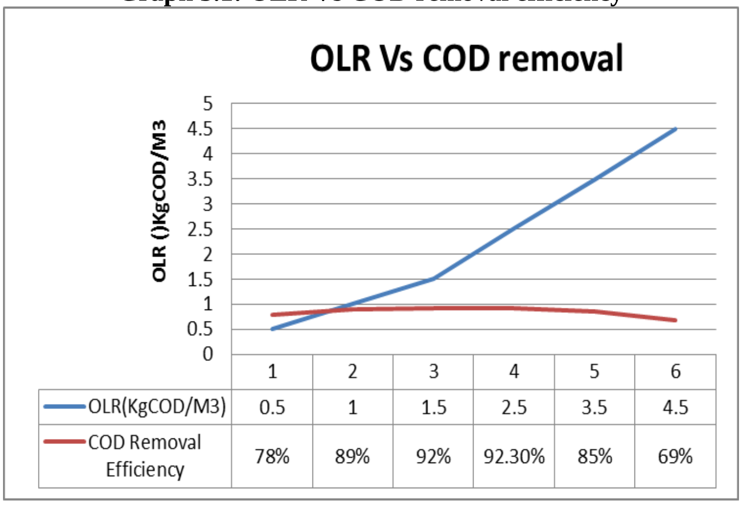
HLR ($m^3/m^2/d$)	Influent COD conc.(mg/l)	Effluent COD conc.(mg/l)	COD removal efficiencies (%)
0.2	1520	280	81.57
0.3	1520	243	84
0.3	1547.2	238	84.60
0.3	1547.2	275.52	82.19
0.4	1230.15	517.92	57.89
0.4	1230.15	595.23	51.61
0.4	1230.15	513.76	58.23
0.4	1230.15	537.6	56.29
0.5	960	398.4	58.50
0.5	960	434.72	54.71
0.5	960	481.92	49.8
0.5	960	480	50

Throughout experimentation, pH was maintained within 7.5-8.0, alkalinity was around 800mg/l, volatile acids were within the range of 100-300mg/l. Gas production observed was also very low about $0.04m^3$/Kg COD destroyed for higher hydraulic loading.

IV. Discussion

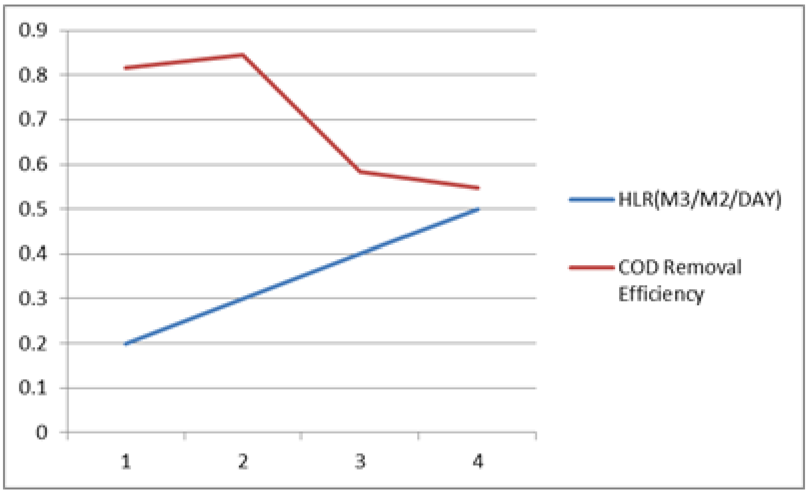
During the phase-I experimentation, model gave better performance at loading rate of $2.5KgCOD/m^3$ with efficiency of 92% and its performance was deteriorated at loading rate of $4.5KgCOD/m^3$. Throughout this experimentation, hydraulic loading rate was $0.2m^3/m^2/d$ which was constant for all loading rates. But before starting phase-II experimentation, model was again tested for organic loading of $2.5KgCOD/m^3$. Therefore from initial date, feed was given with loading rate of 2.5Kg with hydraulic retention time of 5days and loading was continued till last date. Efficiency obtained was 92% on last date.

Graph 3.1: OLR Vs COD removal efficiency



During the phase-II, hydraulic loading of $0.2m^3/m^2/d$ was maintained from first date, by keeping organic loading of $2.5KgCOD/m^3$ constant throughout, initially efficiency observed was 81% which further went on increasing up to 84% and remained constant for next 3 days. As soon as hydraulic loading increased to $0.3m^3/m^2/d$ from 04/09/19, efficiency suddenly dropped to 57% and for next 3days, it remained constant within the range of 56-58%.For hydraulic loading of 0.4 & 0.5 $m^3/m^2/d$, initially efficiency observed was 58%. On 19/09/19, efficiency again dropped to 54% and on 20/09/19 and 21/09/19, efficiency observed was 50%. For gradual increase in Hydraulic Loading Rate, efficiency continuously went on decreasing and at higher loading of $0.5m^3/m^2/d$; efficiency dropped to 50% even though all the parameters were found to be within the required limits.

Graph 3.1: HLR Vs COD removal efficiency



Throughout experimentation, pH was maintained within 7.5-8.0, alkalinity was around 800mg/l, volatile acids were within the range of 100-300mg/l. Gas production observed was also very low about $0.04m^3$/Kg COD destroyed for higher hydraulic loading.

V. Conclusion

UAF model reactor gave better performance at organic loading rate of $2.5KgCOD/m^3$ and hydraulic loading rate of $0.3m^3/m^2/d$ with COD removal efficiency of 92% as well as higher gas production rate of 0.2m3/Kg COD destroyed. But its performance gets affected for higher OLR of $4.5KgCOD/m^3$. Hence, it can be concluded that Up-Flow Anaerobic filter can treat synthetic wastewater effectively up to organic loading rate of $2.5KgCOD/m^3$ and hydraulic loading rate of $0.3m^3/m^2/d$ and it cannot tolerate higher organic loads and hydraulic loads due to lower biomass concentration. Hence, UAF plant can be operated effectively up to Organic Loading Rate of 2.5Kg COD/m^3 and Hydraulic Loading Rate of $0.3m^3/m^2/d$ with Hydraulic Retention Time of 5days.

References

[1]. Puñal, Méndez, R., and Lema (1998) -"Multi-Fed Upflow Anaerobic Filter: Development and Features", Journal of Environmental Eng., Vol.124(12), pages 1188–1192.
[2]. Franco A., Roca E. and Lema, J. (2007) -"Enhanced Start-Up of Upflow Anaerobic Filters by Pulsation", J. Environ. Eng., Vol. 133(2), pages 186–190.
[3]. Seunghwan Lee, Hongshin Lee, Seongeok Lee (2007) – "Media configuration and recirculation of UAFF for piggery wastewater treatment", Korean J. Chem. Eng., Vol.24(6), pages 980-988.
[4]. Jea Youl Joung, Hae Woo Lee, Hyeoksun Choi, Min Woo Lee, Jong Moon Park (2009) – "Influences of organic loading disturbances on performance of anaerobic filter to treat purified terepthalic acid wastewater", J. Bioresource Technology, Vol. 100, pages 2457–2461.
[5]. Stall, T.R. and Sherrard, J.H., "Effect of wastewater Composition and Cell Residence Time on Phosphorus Removal in Activated Sludge, Journal", Water Pollution Control Federation, Vol. 48, No. 2, (1976) [for Synthetic wastewater composition]
[6]. Rangaraj Ganesh, Rajgopal Rajinikanth, Joseph V. Thanikal, Ramamoorty Alwar Ramanujam, Michel Torrijos, "Anaerobic Treatment of winery wastewater in fixed bed reactors", Bioprocess Biosyst Eng (2010), Vol. 33, pages 619-628.
[7]. Tin Sang Kwong and Herbert H. P. Fang, "Anaerobic degradation of cornstarch in wastewater in two up-flow reactors" , Journal of of Environmental Engineering (1996), Vol. 122, pages 9-17.
[8]. S.Kumbhar, J.Main (2013), "Reuse potential of treated sewage from sequencing batch reactor", International Journal of Applied Engineering Research ,8(17),2011-2015, January 2013

Snehjit Kumbhar, etal. "Influences of Organic & Hydraulic Loading Disturbances on a Lab-Scale Upflow Anaerobic Filter." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 13(3), (2020): pp 35-40.