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Enhancing Efficiency of Anaerobic Digestion by Sand Filtration of Effluent

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Abstract The effluent of an anaerobic digester is rich in terms of solid concentration, particularly the suspended solids [1]. It may be rich in terms of nutrients also depending upon the source from where it has been generated. These solids in the effluent are reflected in terms of high COD. The effluent of the anaerobic digester can be used for irrigation purpose or may be discharged into some receiving water-body or on land. It can be further treated also to enhance its recyclability. In each case, it is desirable that the effluent is of high quality or in other words it is having less solid content. The solid content of the effluent can be reduced either by effluent settling or by effluent filtration. The settling of effluent is also a growing technology yet it is in its primitive stage. The present work has experimentally explored the second option that is the effluent filtration. It is found that the effluent can be effectively filtered to reduce the COD and solid content of itself, thus making the disposal easier. The experimental study has been done for the campus of an engineering college, SSBT's College of Engineering and Technology, Bambhori, Jalgaon, MS.

Keywords Anaerobic digestion, Effluent filtration, Wastewater recycling

1. Introduction

Traditionally aerobic treatment of wastewaters has been the preferred option over anaerobic treatment for environmental engineers owing to the speed of treatment basically. The anaerobic biomass has a very poor yield. Hence in effect its speed of decomposition becomes poor. The effective speed of decomposition can be increased by increasing the biomass concentration. Conventionally the biomass is concentrated by settling. However the anaerobic biomass has very poor settling characteristic. Hence filtration of the biomass is considered to be a better option. Here is a review of studies done of sewage filtration by some investigators: Graja and Wilderer [2] investigated soil biotechnology treatment of wastewater and found soluble COD removal efficiencies between 40 and 60% and nitrogen removal efficiencies around 96%. Munch and Barr [3] used controlled struvite crystallization for side stream filtration coming from sludge concentration units in order to remove phosphorus from. A magnesium, ammonium and phosphate crystal occurring naturally was used. Jeison *et al* [4] investigate the feasibility of filtration of sludge using membrane filtration. They found that the effluent can be effectively filtered and the digester efficiency can be significantly increased.

Design of filter needs organic loading rate. Researchers have proposed organic loading rates also. Organic loading rates between 0.976 and 24.4 g/m^2 BOD_5 per day is used for many facilities [5, 6].

Matejcek *et al* [7] did studies using high strength wastewater also. Their long term studies were based considered the effluents obtained from restaurants. The significant finding in this work is the determination of upper limit for organic loading. The results suggested that the maximum organic loading should be between 7.32 and 11.71 g BOD_5 per m^2 per day.

The rural development committee of Washington State Department of Health in 2002 has done regressive assessment of research on sewage filtration. Nakada *et al* [8] has studied the filtration of sewage from pharmaceutical industry. Daniel *et al* [9] studied the filtration of domestic sewage. Liang *et al* [10] investigated the ultra pressure filtration of domestic sewage.

The present work has used sand filtration technique for the filtration of slurry of anaerobic digester digesting kitchen waste. It is observed that the sand filtration can effectively reduce the COD of the digester effluent significantly. It can operate for long run and is viable in size. The case study is done for the residential campus of an engineering college, SSBT's Colelge of Engineering and Technology, Bambhori, Jalgaon, MS.

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2. Experimental Study

The first part of this study is to design an anaerobic digester using kitchen waste and to obtain effluent. In the next part the effluent of digester has been filtered using a sand filter. The COD of effluent with and without filtration are compared.

A small size digester is designed using plastic material. A cylindrical can of size 54 cm diameter and 90 cm height is used as shown in figure 1.

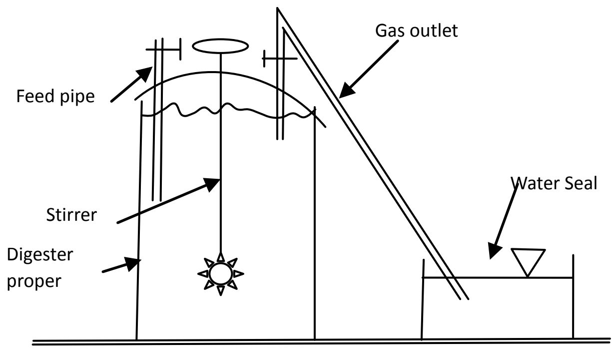

Figure 1. Experimental set up of an anaerobic digester

Capacity of the reactor is 230 L. It is has a mechanical stirrer system. Its gas vent is submerged in water so that the gasses generated in the digester may get an escape but oxygen may not enter into it. The digester is fed with the kitchen waste in slurry form. The waste is pulverized well. Initial feed slurry of 10% solid concentration is prepared with trial. It had a COD of around 5000 mg/L. The digester is fed with 5 L slurry daily, mixed well and the equivalent amount of discharge is collected from the effluent pipe. This amount of slurry is equivalent to an organic loading rate of 10 kg/m^3 day. This is the optimum loading rate suggested for pilot scale anaerobic digesters by Chen *et al* [11]. The digester is allowed to get stabilized for around six months. Its performance is monitored over the period.

Once the digester got stabilized, its effluent is filtered out through a sand filter. The design of sand filter is done as follows:

The effluent of experimental digester is having BOD_5 @ 20°C as ~600 mg/L. Considering the effluent volume to be 5 L per day (as per design of digester), the organic load can be estimated as follows:

BOD = 600 mg/L, Flow = 50 L/day, Total organic content = 600 * 50 = 30 000 mg/day

= 30 000 * 2.20462 * 10^{-6} = 30.01 g/day

Considering organic loading rate to be 0.273 g/cm^2/day

Area of filter required = 0.066/0.56 = 0.178 ft^2

Thus, an area of 11 cm x 11 cm will well sufficient for sand filter. Thus a sand bed is prepared using a plastic box having sizes 11 x 11 x 30 cm. The depth is taken as 30 cm as suggested by Matejcek *et al* [7].

The characteristics of effluent before and after filtration are determined.

3. Results and Discussion

The slurry fed to the digester has been characterized for some important parameters as presented in table 1. They are determined using relevant standard methods for characterization of waters and wastewater.

Table 1. Feed slurry characteristics

S. N.	Parameters	Unit	Values
1	Total suspended solids	mg/L	10674
2	Total dissolved solids	mg/L	5980
3	Total Volatile solids	mg/L	7850
4	COD	mg/L	5280
5	BOD_5 @ 20°C	mg/L	2970
6	TKN	mg/L	206
7	Phosphorous	mg/L	41
8	Chlorides	mg/L	542
9	Sulfates	mg/L	70
10	pH	mg/L	7.8

These are average characteristics of feed slurry. The solid waste was collected once in a month and stored in a deep freezer. The slurry was characterized every time when the new solid waste was collected. The characteristics were found to be reasonably constant.

The effluent from the digester has been monitored every week. The digester got was stabilized after some initial transitions. However it did not acquire a true steady state owing to wide seasonal changes during the experimentation. The variation of COD is shown in fig 2.

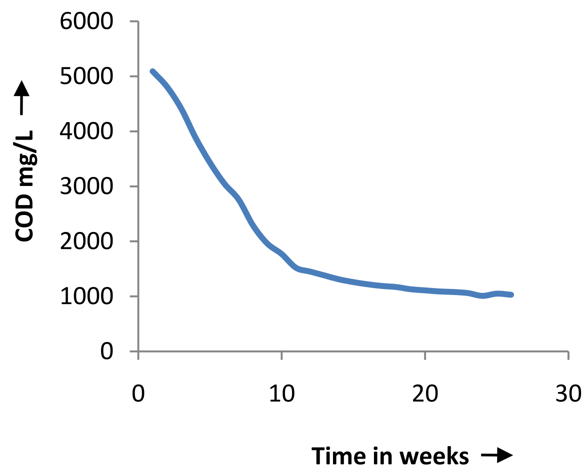

Figure 2. Effluent COD variation with time

It is seen that the COD reduction rate is high in the initial stage. Later COD gets almost stabilized with mild reduction rate. The initial high reduction rate indicate that the biomass inoculation used was well acclimatized with the waste.

The variation of BOD_5@ 20°C is shown in figure 3.

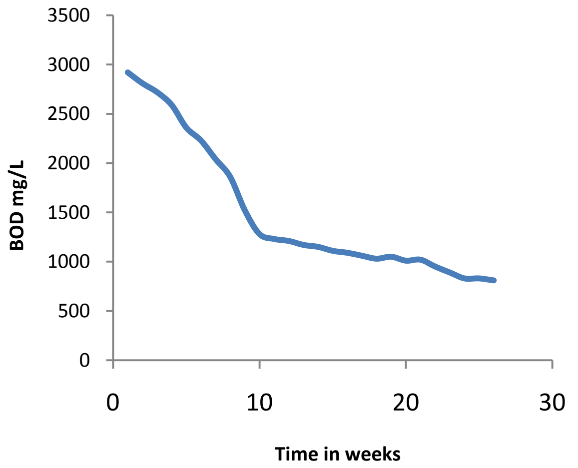

Figure 3. Effluent BOD reduction with time

BOD_5 @ 20°C reduction is rapid initially. Later the it is slow. Most of the reduction rate is acquired in the first 10 weeks. Later it is stabilized.

The Total Solid content of the digester is also monitored. Its variation is as shown in figure 4.

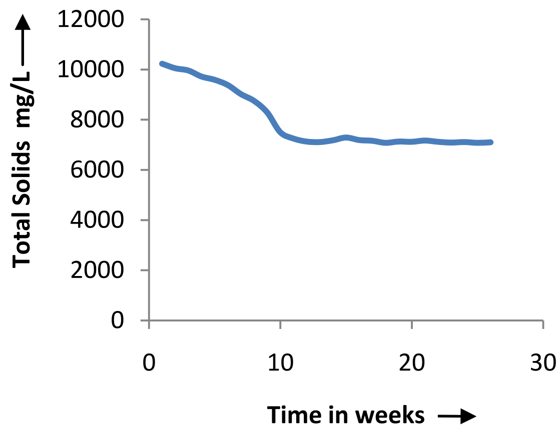

Figure 4. Variation of total solids in the experimental anaerobic digester with time

It is visible that the Total Solid content has reduced initially the high rate of reduction and finally it is stabilized within 12 weeks. The digester is working finally at around 7% solid content.

The effluent of the anaerobic digester is filtered through the sand filter. The characteristics of unfiltered and filtered effluent are monitored for a period of 10 weeks. It was started from 16TH week of the start of the anaerobic digester and was continued till 26TH week. Till 16TH week the digester had got almost stabilized. This is evident from the results shown vide figure 5 – 7.

Fig 5 compares the COD of filtered and unfiltered effluents.

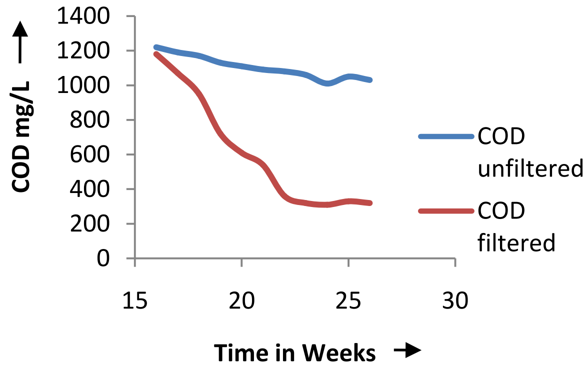

Figure 5. Comparison of COD of filtered and unfiltered effluent

It can be seen that the filtration is able to bring down the COD around 300 mg/L while the unfiltered COD has remained around 1000 mg/L. The filtration process does not show the efficiency immediately. In fact it requires some time to get stabilized. It may be attributed to the development of zooglial film around the sand particles. The filter is able to bring down the COD to the permissible limit of discharge on land or sewage farming.

The figure 6 shows the comparison of filtered and unfiltered effluent BOD. It can be seen that the filtration is very effective in bringing down the BOD to well up to the permissible level of discharge on land.

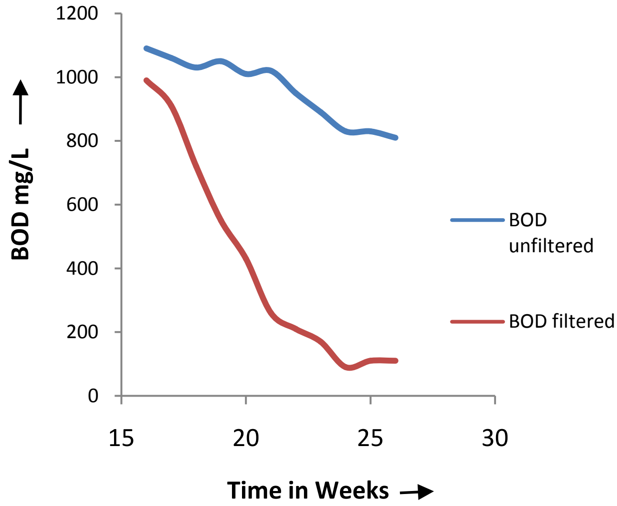

Figure 6. Comparison of BOD of filtered and unfiltered effluent

BOD and COD are the important parameters which decide the feasibility of the liquid waste for disposal.

The TSS content of the effluent is also monitored. It is presented in figure 7.

It can be seen that TSS reduce significantly with filtration. In fact the pattern of reduction in the figure shows that the TSS could have been even reduced in the prolonged experimentations.

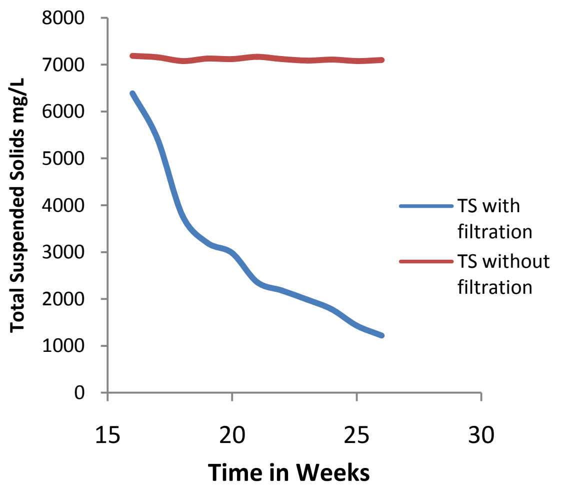

Figure 7. Effect of filtration on Total Suspended Solids

The summarized characteristics of filtered effluent can be described in table 2.

Table 2. Characteristics of filtered effluent

SN	Parameters	Unit	Value for unfiltered effluent	Value for filtered effluent
1	Total solids	mg/L	10674	1210
2	Total dissolved solids	mg/L	5980	3710
3	Total Volatile solids	mg/L	7850	2620
4	COD	mg/L	5280	320
5	BOD_5 @ 20°C	mg/L	2970	110
6	TKN	mg/L	206	176
7	Phosphorous	mg/L	41	37
8	Chlorides	mg/L	542	542
9	Sulfates	mg/L	70	25
10	pH	mg/L	7.8	7.6

It can be seen that the filtration works very well in bringing down the pollution parameters of the digester effluent. The reduction in BOD and COD is significant. The nitrogen and phosphorus content of the effluent suits to irrigation requirements.

4. Conclusions

The anaerobic digestion effluent is rich in terms of BOD, COD and other parameters of concerns. Its disposal is a problem. It cannot be used directly for irrigation purpose. However filtration by sand media is an effective method process of removal of organic content from the effluent. It brings down the COD and TS in effluent effectively and makes it fit for irrigation. The filter has uninterruptedly worked for six months. Hence its endurance can be assured. The filter size is quite small compare to the digester. Hence it can be put in practice. It is hoped that the findings of the present research will provide useful database for the designers of the filters for anaerobic digester effluent.

List of Abbreviates

i	**BOD**	**Biochemical Oxygen Demand**
ii	**COD**	**Chemical Oxygen Demand**
iii	**TSS**	**Total Suspended Solids**
iv	**TKN**	**Total Kjeldahl Nitrogen**

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