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DOMESTIC WASTEWATER TREATMENT BY USING POST ANOXIC HYBRID BIOREACTOR.

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Abstract - The study was conducted on Post Anoxic Hybrid Bioreactor (PAHB) for domestic wastewater treatment to provide optimized media filling ratio for carbonaceous and nitrogenous organic matter removal at varying Hydraulic Retention Time (HRT) and Surface Area Loading Rate (SALR). This study focused on the use of a hybrid reactor system in which MBBR carrier media was used but instead of keeping it in suspension; its mobility was restricted and carrier media wasn't allowed to move or settle at the bottom by providing the threads. The maximum organic load applied to the reactor during the study was 23.23 g BOD3/m2/d and 26.11 g COD/m2/d on average. SALR was kept in the range of 5.8 to 23.3 g BOD3/m2/d and 7.5 to 35.6 g COD/m2/d. The media filling ratio was 40% in both aerobic and anoxic bioreactors. The sludge from primary settling tank was used as an external carbon source in anoxic bioreactor for de-nitrification.

Keywords: Post Anoxic bioreactor, Hybrid bioreactor, Grid formation, Uniform spacing, Nutrient removal, Biofilm, Primary sludge, de-nitrification

1.INTRODUCTION

Wastewater treatment and management are one of the major environmental issues the world is facing today. Physical and chemical processes are found uneconomical. Biological processes are a cost-effective and environmentally sound substitute for chemical and physical treatments. The biological wastewater treatment, based on the attached growth mode and suspended growth mode were found to be effective in the removal of organic contaminants and nutrients. The conventional biological wastewater treatment processes show good organic matter and nutrients removal efficiency but it has some disadvantages like settlement of sludge, the large size of reactors, sensitivity towards high organic loads, and recycling of biomass.

Many studies have been carried out on the attached growth system. A Moving Bed Biofilm Reactor (MBBR) is a combination of the suspended growth process and the attached growth process. The biomass is grown on small carrier elements having density less than water and is kept in continuous turbulence inside the reactor. In Moving Bed Biofilm Reactor (MBBR); biofilm gets developed on the media. The biofilm adds the weight of the particle, therefore the weight of media increases with biofilm thickness. So, increasing mixing is required to keep the medipa in suspension. Generally, the efficiency of MBBR for carbonaceous and nitrogenous organic matter removal is more than 90% (Kermani et al., 2008; Javid et al., 2013; Guo et al., 2019). MBBR can be used for carbon as well as nitrogen removal from wastewater. There are some problems associated with MBBR which need to be incorporated.

In the attached growth systems, the carrier material used for the treatment of wastewater either in a fixed or suspended form. Compared to the conventional wastewater treatment system, fixed film bioreactors has an advantage to perform effectively at higher Organic Loading Rates (OLRs), due to retention of

more biomass in the reaction zone, smaller Hydraulic Retention Time (HRT), lesser footprints, and high efficiency. However, one drawback of a fixed-bed bioreactor is that the pores among media are easily gets clogged due to higher biofilm growth (Loupasaki and Diamadopoulos, 2013). The main limitations of packed bed reactors are the cost of the packing material and operational problems and maintenance associated with solids accumulation and possible packing clogging (Metcalf and Eddy, 2003).

However, in MBBR it is quite difficult to keep carrier media in suspension after biofilm is fully developed. MBBR shows better removal efficiency when media will remain in suspension (Christensson and Welander, 2004; Sen et al., 2007; Moga et al., 2014). MBBR system requires optimum aeration because, if less aeration is provided, then initially maximum media will float on the water and further media will start to sink with the development of biomass. If more aeration is provided then, due to shear resistance biofilm gets detached from the media (Eberhard and Peter, 2000; Barwal and Choudhary, 2015). Also, it was seen that many times due to the collision between carrier media detachment of biofilm occurs before its well growth (Eberhard and Peter, 2000). So better arrangement is required to keep media in suspension so that the media doesn't settle down. However, still, no studies have been reported on such kind of media arrangement.

The design of PAHB with restricted mobility of carrier media is helped to keep media in suspension, where the thread was passed through media and fixed at both ends. This configuration helps in both perspectives of keeping media in suspension and overcoming the problem of clogging. The PAHB consists aerobic bioreactor followed by anoxic bioreactor in which primary sludge is used as a external carbon source for de-nitrification

2. EXPERIMENTAL STUDY

2.1 Materials and Methods 2.1.1Source of wastewater

The domestic wastewater was collected from Patil residential house, Kavalapur. The wastewater fed to the system in a continuous mode. In this PAHB system, screened wastewater was fed to a primary settling tank and then it was fed to the secondary treatment unit. For initiation of the biofilm development, the return activated sludge from STP Sangli was fed to the system for the development of an activated sludge.

2.1.2 Characteristics of carrier media

Figure 2.1 shows the photographic view of the carrier media. Commercially available media was used in the study. Media was brought from media manufacturing company OM Environmental solution Pvt. Ltd., Nashik. The name of media used for the study is kaldens K3 which was hollow at middle and cylindrical with external fins of shape. The media has corrugation on it to increase surface area. The characteristics of the media are given in Table 2.1 Further media were inserted in the wire mesh structure as per specified spacing to keep carrier media in suspension.

Fig. 2.1 Photographic view of carrier media

2.1.3 Pilot scale design of Post Anoxic Hybrid Bioreactor

Design guidelines of Moving Bed Biofilm Reactor were referred for the design of this post anoxic hybrid bioreactor. Assumed parameters were inlet flow was 50 KLD, inlet BOD was 150 mg/L and removal efficiency was 90%. The scale factor used for pilot scale model was 100.

Table 2.1: Design parameters for both aerobic and anoxic bioreactor

Parameter	Description
Material	Acrylic
Total depth (cm)	20
Effective Depth (cm)	16.5
Width (cm)	15
Length (cm)	20
Total effective volume (L)	5.6
Diffused aerators (only for aerobic bioreactor)	3
Capacity of each diffused aerator (L/min)	4

2.1.4 Methodology

a) Initiation of the reactor

Active biomass is very important for developing biofilm on media. For this batch, the study sludge is bought from a sewage treatment plant, Sangli. The reactor is operated in batch mode in such a way that its aeration is switched off once after every 6 h cycle for 30min to settle sludge completely. Then, around 50% of wastewater (supernatant of settled wastewater) was replaced with fresh domestic wastewater. Wastewater was replaced thrice a day with an interval of 6 hours .Phosphate buffer, magnesium sulfate, calcium chloride, and ferric chloride (1mg/L each) were added as nutrients each time after the replacement of wastewater. Thus the cycle is run for

10 days, for proper acclimatization and development of an activated sludge. After the development of a sufficient quantity of active sludge, it was filled in Post Anoxic Hybrid Bioreactor system to get the desired MLSS.

Fig: 2.3 Development of an activated sludge

b) Development of biofilm on the media

Biofilm development is the initial stage in MBBR. The sludge in the reactor gets penetrated in the media. This accumulated sludge adheres to the surface of media and starts to grow on the media in the form of biofilm. To set up the reactor for biofilm development following steps are adopted.

The sludge is added in each reactor having mixed liquor count is between 4000-6000 mg/L and the structure of media is placed in respective reactors having media filling ratio of 40%. The remaining volume of the reactor was filled with fresh domestic wastewater. Required aeration was provided and the reactor was operated in continuous mode. Aeration was switched off after decided interval and sludge was allowed to settle completely. Then around 50% of wastewater (supernatant of settled wastewater) was replaced with fresh domestic wastewater. Wastewater was replaced thrice a day with an interval of 6 hrs. This process was continued for the first 15 days. After that fill volume was in This process was continued for the first 15 days. After that fill volume was increased and around 70% of wastewater was replaced with fresh domestic wastewater. Biofilm was visually observed on the media after around 55 days.

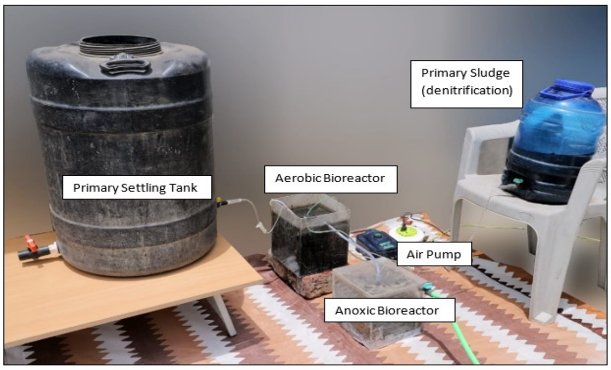

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Fig 2.2 Experimental setup of Post Anoxic Hybrid Bioreactor

The photographic view of the experimental setup is shown in figure 2.2. Aerobic reactor followed by anoxic reactor were made up of glass having media filling ratio is 40% and each reactor having a size of total volume 6.6 L out of which 5.6 L was effective volume. Four diffused aerators were kept at the bottom of aerobic reactor to provide required aeration and sludge recirculation. All diffused aerators were kept equidistant from each other. The filling and decanting were done using siphon action to prevent the leakages through the valves. The primary sludge was used as an external carbon source for de-nitrification in anoxic bioreactor.

2.1.5 Planning of experimental work

Activated sludge was first developed in the pilot scale reactor. This sludge was used to develop adhered biomass on the media introduced in the reactor. Based on the literature review, experimental runs were planned for different values of HRT and OVLR for PAHB. The media filling ratio in both aerobic and anoxic reactor is 40%.

3.RESULTS AND DISCUSSIONS

3.1 Characterization of domestic wastewater

Parameters and their values for domestic wastewater samples collected from combined outlet of grey and black are summarized in Table 3.6. These are the characteristics of feed wastewater after a primary settling tank.

Table 3.1: Characteristics of wastewater (Domestic wastewater of Patil House)

Sr. No.	Parameters	Influent ww
1	pH	6.31-6.44
2	BOD (mg/L)	150-250
3	COD (mg/L)	250-380
4	TKN (mg/L)	45-90

Both the aerobic and anoxic bioreactors are operated in the activated sludge process before adding media in the reactor. In this reactor only suspended biomass was available for biodegradation of organic matter. Table 3.2 shows the results of the batch mode reactors without the attached biomass on the media. MLVSS/MLSS ratio was observed to be 0.70. It should be more than 0.7 (Metcalf and Eddy, 2004). Higher MLVSS/MLSS ratio represents the higher percentage of active micro-organisms.

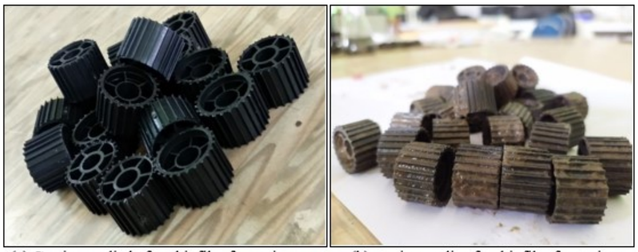
Table 3.2: Performance of batch reactor during ASP cycle

HRT (Hours)	MLSS (mg/L)	MLVSS (mg/L)	OVLR (kg COD/m³/d)	DO (mg/L)	COD Removal Efficiency (%)
6	5070±224	4056±138	1.27±1.98	2.0-2.4	73.88±5.48
12			0.76±0.26		81.54±4.67

The sufficient amount of DO was induced in the wastewater and sludge was sufficiently developed in the bioreactors. Then grids of carrier media were placed in both the aerobic and anoxic bioreactors. The external primary sludge as a carbon source for the de-nitrification in anoxic bioreactor was fed for the achievement of the post anoxic condition.

The fresh domestic wastewater was supplied to the system and efficiency was checked on daily basis. COD removal of domestic wastewater was approximately constant after 50 days. Hence it was concluded that the biofilm formation on the carrier media was almost formed in 50-55 days.

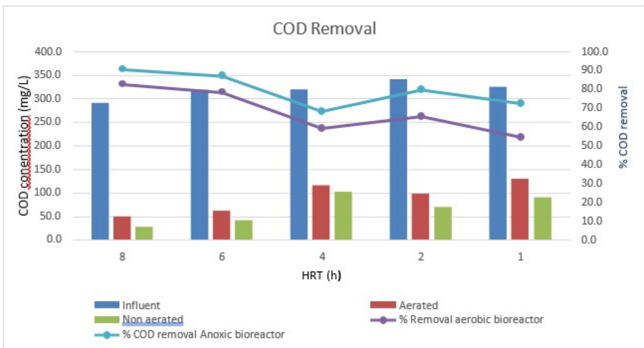
The fig (a) and (b) showed the development of biofilm formation on the carrier media.



(a) Carrier media before biofilm formation (b) carrier media after biofilm formation

(a) Grid formation before biofilm formation (b) Grid formation after biofilm formation

3.3 Effect of OLR and HRT on COD removal



1. The PAHB system was operated in continuous mode for different HRTs (i.e. 1hr to 8hr).
2. For 4 hr HRT the maximum COD removal efficiency was observed as 70% while for 2 hr HRT it was 84%.
3. The removal efficiency for 4hr HRT was less than 2hr HRT was due to incomplete biofilm formation for initial HRT.
4. Removal efficiency got increased when HRT for the system was increased.

5. Removal efficiency got increased when OLR for the system was decreased.
6. For a minimum OLR 0.88 Kg COD/m3.d, maximum COD removal efficiency was observed as 93%.
7. At low HLR of 0.29 m3/m2/d showed average COD removal efficiency of 89.35%

3.4 Effect of OLR and HRT on COD removal
1. Graphs shows the variation in inlet and outlet concentration of BOD3 for different HRT.
2. Influent BOD3 varied between 160 to 230 mg/L during the study. During the biofilm formation phase, the system showed overall BOD3 removal efficiency of about 60% and in the developed phase, it was observed as 72% for 6hr HRT.
3. The removal of organic matter takes place because of decomposition of the organic matter and biofilm formation

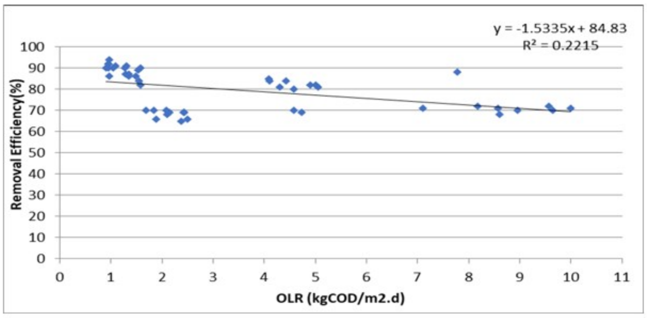


Figure 3.2: Effect of HRT on COD removal for Aerobic and Anoxic reactors

Within the first 2 hours, COD removal efficiency achieved was in the range of 65-75%, The removal efficiency was found to be increased by 10-15% with further increase in HRT up to 4 hours. It was observed that COD removal efficiency increased by 15%. As per CPCB 2015, the COD limit of effluent to discharge into the water resource as well as for land disposal is 50 mg/L. The average COD of domestic wastewater used for this experiment was 250 mg/L. So the COD removal efficiency of 80% is desired for keeping the effluent as per the required standard limits.

3.5 Effect of HRT on TKN removal

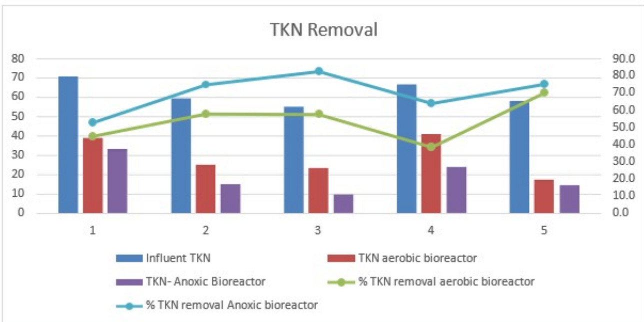


Figure 3.3: Effect of HRT on TKN removal for reactors

Above graph shows TKN removal efficiency for different HRT. For the initial 4hours of HRT TKN removal efficiency achieved was in the range of 50-55%, As HRT was increased by 2 hours with providing a total HRT of 6 hours, the removal efficiency was found to be increased by 20% (85% overall) The disposal standard for discharging the effluent in the water resource as well as land disposal is 5 mg/L (CPCB, 2015). The average TKN of domestic wastewater used for this experiment was 62.5 mg/L. So the TKN removal efficiency of 90% is desired for keeping the effluent as per the required standard limits. So to obtain this much efficiency an HRT of 6 hours is sufficient for the system.

4. CONCLUSION

1.From the results, it is seen that the COD removal efficiency is in the range of 65% to 94%. Similarly, BOD and TKN removal efficiency were 55% to 92% and 50% to 83% respectively.
2.Removal efficiency got increased when HRT for the system was increased.
3.The maximum COD and BOD removal efficiencies were observed 94% and 90% respectively for 8 hr HRT.
4.The maximum TKN removal efficiency was observed 83% for 6hr HRT.
5.The average BOD/COD ratio in the influent wastewater was 0.52 and after treatment, it was 0.47 indicating BOD; was reduced by the biological treatment.
6.The pH value obtained was in the range of 6.5 to 7.5 .The pH remained in the neutral range after treatment.
7.Sometimes the removal efficiency was decreased even after the less OLR and high HRT. The reasons behind the less removal efficiency were
a. Incomplete biofilm development
b. Insufficient air circulation in wastewater
8.Clogging of air diffusers due to increase in sludge
9.The observed effluent COD, BOD3, and TKN values are within the limit to discharge it into marine coastal areas, public sewers, and land for irrigation as per the Environmental (Protection) Rules 1986
10.The observed DO was in the range of 1.3 to 1.5 mg/L. The artificial oxygen with the help of air pump was provided. Hence the DO observed in the effluent was sufficient. Nitrification rate was sufficient because DO was near to the 1.5 mg/L. Hence TKN removal efficiency was more in the PAHB system.

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