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Effect of Season and Organic Loading Variation on the Operation of an Indigenously Developed Maize Cobs Trickling Filter (MCTF)

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***Abstract*—** Trickling filters are an attractive wastewater treatment option but the past experience of installing and operating them in Pakistan is not very successful as they have not performed up to the mark. It is, therefore, important to identify the underlying operational problems of trickling filter and resolving them. A pilot scale indigenous maize cobs trickling filter (MCTF) was developed using agricultural waste (Maize cobs) as a biological growth medium to investigate the effect of operational parameters like temperature and organic loadings on the performance of trickling filter operation. The developed MCTF wastewater treatment system was experimented under different organic loadings: 9-21 Kg BOD/m3.d; 9-26 Kg COD/m3.d and a temperature range of 20-43°C during five months of operation. The results indicated that as the organic loadings increased, the removal (%) of BOD and COD decreased for the developed trickling filter. The removal (%) increased with an increase in temperature. The maximum removal (%) was achieved at an organic loading of 12-15 Kg BOD/COD/m3.d and a temperature range of 35-43°C. The main reason of effective BOD and COD removal was rapid development of microbial film (within first two weeks) probably due to the filamentous structure, relatively high specific surface area, and inter-cob voids of the maze cobs. Maize cobs served as an economic, efficient and robust filter media which have better capability to sustain higher organic loadings and temperature fluctuations as compared to other conventional filter media.

Keywords— Trickling filter, Maize cobs, Waste Material, Temperature, Organic loadings

I. INTRODUCTION

The wastewater treatment condition of the country is unsatisfactory as only 5-8 % of the generated wastewater receives treatment [1], [2]. The domestic wastewater containing household effluent and human waste is either discharged directly to a sewer system, a natural drain or water body, a nearby field or an internal septic tank without any prior treatment. About 962,335 million gallons of wastewater is generated in Pakistan including 674,009 million gallons from municipal and 288,326 million gallons from industrial use. Municipal wastewater is normally not treated and none of the cities have any biological treatment process except Islamabad and Karachi, and even these cities treat only a small proportion of their wastewater before disposal [3]. Assuming that all the installed treatment plants are working at their full installed capacity, it is estimated that about 5-8% of urban wastewater is probably treated in municipal treatment plants. The treated wastewater generally flows into open drains, and there are no provisions for safe and checked reuse of the treated wastewater for agriculture or other uses [4], [5]. There is no prevailing concept of treatment at secondary and tertiary level in the country.

Some efforts have been made to treat the municipal wastewaters, for instance, trickling filters were installed in Karachi, but they did not perform up to the mark [4] Therefore, it is important to investigate the underlying problems and resolve the issues in existing wastewater treatment systems in Pakistan. Limited information is available in the literature on the improper running of trickling filter system and their corresponding solutions [6], [7]. In view of this, a pilot scaled trickling filter treatment system was developed to investigate the effects of variable organic loadings and seasonal variation on the performance of trickling filter using agricultural waste (Maize cobs) as its media. Media selection is an important factor to improve the performance efficiency of trickling filter. The effective media play a key role in the development of microbial community/biofilm. Several biofilm support media have been used to increase the performance of trickling filter such as rocks, plastic [6] nylon pot scrubber [7] group the commercial rings (such as crushed leca, kaldnes and Norton), calcitic gravel [7], [9] luffa cylindrica [10] geotextile [11] pall rings [12] polyurethane foam pores [13] Coal cinder [14] etc. The performance of trickling filter is affected by many variables. It includes media size, depth of the media, ventilation, hydraulic rate of application, organic loading rate, pH and temperature of both wastewater and ambient air [9], [15]. Wastewater temperature and ambient air temperature both influence directly and indirectly on the rate of biological degradation (oxidation) and Biofilm/ slime layer growth [16], [17]. Some studies stress that effluent organic concentration increase markedly as flow rare is increased because the substrate in the liquid layer immediately adjacent to the slime layer is depleted rapidly. It follows reverse relation between hydraulic loading rate and concentration penetration depth [15], [18], [19], [20].

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The present work is also an effort to resolve the operational and performance issues regarding trickling filter system using Maize cobs as support medium for Biofilm. The experiments were conducted for varied BOD and COD loadings and temperature variation and the corresponding effects on the performance of the trickling filter system were investigated for the determination of optimized operation conditions.

II. Material And Method

A. *Wastewater Characteristics*

All experiments were conducted using real wastewater collected from sewage collection stations located at the disposal unit of Bahauddin Zakariya University, Multan. The wastewater samples were collected and analyzed for one month before starting the experiment for knowing the influent composition (Table 1). The average wastewater composition indicates that it could be classified as medium type municipal sewage [6]. The average value of influent BOD5/COD was > 0.80 which indicated that the wastewater did not require pretreatment or acclimate biomass [21]. Similarly, Symons, 1960 recommended that the ratio of BOD5 and COD of the wastewater should be >0.6 for biological treatment.

TABLE:1 Characteristics of Raw Wastewater

Parameter	Range	Average
BOD (mg/L)	103-276	214
COD (mg/L)	124-300	250
Temperature (°C)	20-43	34

B. *Experimental Set up and Treatment System Startup*

The MCTF wastewater treatment system body was fabricated locally using (guage 22=0.64mm Zn alloy) metallic sheet in a circular shape with diameter of 76.2 cm and height of 152.4 cm (Fig. 1). The drainage layer having depth of 30.48 cm was laid on the bottom of the reactor body. The drainage layer was designed with rocks having slotted tops to admit the wastewater and support the media. The drainage layer in developed TF also served three functions: i) to transmit the wastewater passing through the filter ii) to sloughed solids from the filter to the settling tank iii) to maintain aerobic condition by supplying ventilation to the filter. Over the drainage layer, the TF system was packed with maize cobs (filter media) for biofilm support. The media was dried before installing in TF and it was installed gently to make sure that there were no breakages during installation. The media was supported by a circular steel grid, which rested at 30.48 cm above the bottom of the filter. The grid was constructed in circular section using steel strips. The utilized media (maize cobs) have length of 7.97 cm and diameter in the range of 1.905-2.54 cm as many authors recommended the size of media (Christoulas, 1990). The depth of the media in TF was of 137.16 cm with effective volume of 0.62 m3 [6]. The Voidage of the filter media (maize cobs) was of 86% which was measured using water replacement method.

The reactor was packed with Maize cobs media. The

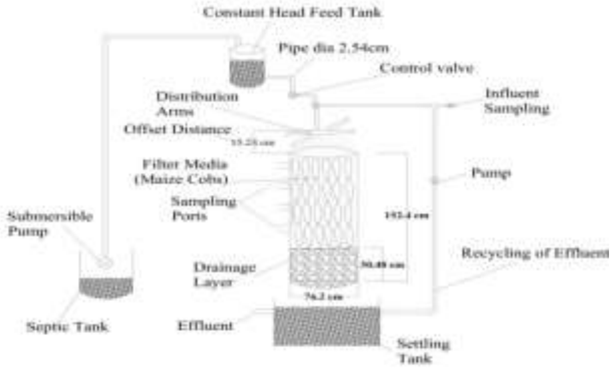

Figure 1. Schematic of the developed MCTF wastewater treatment system

characteristics of media are 1.91-2.54 cm diameter, 7.98 cm length and 86% void ratio. The pilot scale filter was fed with real wastewater using a feed tank by proper gravity head. After the media packing, the developed MCTF treatment system was run for three weeks as a start up period to develop the biofilm. After the development of biofilm/slime layer, the developed trickling filter was operated at constant hydraulic loading rate of 113.28 m3/m2/d for five months with variable organic loadings 9-20 kg BOD/m3.d (Fig. 2). Hydraulic loading rate was increased twice a week up-to 151.68 m3/m2/d for 20 min in order to flush the possible solid accumulation in the media.

C. *Physico-Chemical Analyses*

During the study, the influent and effluent samples were taken at regular intervals. The COD and BOD were tested according to the standard methods described in APHA, 2012. The temperature and dissolved oxygen of the samples were measured at regular intervals using DO meter [DO+6 EuTech (Sr. NO. 662684)

A.Before Biofilm Development

B.During Biofilm Developmen

Fig.ure 2. Filter Media (Maize Cobs)

III. Results and Discussions

A. *Effect of BOD and COD Loadings on the MCTF Operation*

The two main parameters affect the performance of the trickling filter (oxygen transport and organic material transport). These must be sufficiently high so that they do not

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impose a limit on the biochemical reactions). Figure 3 shows the relation between BOD loading and BOD removal (%) for the developed MCTF treatment system. As the BOD loading increased, the BOD percent removal decreased. The BOD loading of the influent was varied from 9 to 21 kg BOD /m3.d and the corresponding BOD removal efficiency decreased from 96% to 48%. The maximum BOD removal efficiency was achieved at a BOD loading rate of 12 to 15 kg BOD /m3.d. This might be due to the varying loading in the influent that caused an increase in average effluent concentration because of the decrease in retention time to contact with slime layer to oxidize the organic matters as well as the non uniform development of Biofilm in the internal structure [13], [21], [23], [11]. In general, the results were in agreement with Richards and Reinhart.

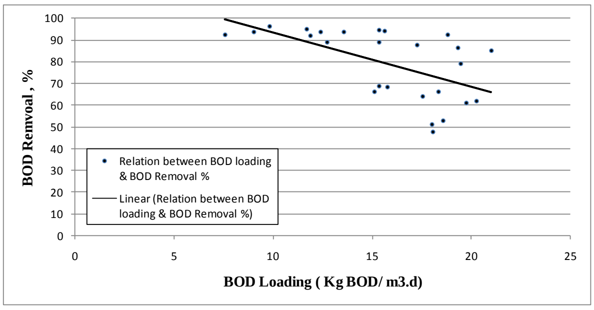

Fig. 3. Effect of BOD loading on the MCTF operation

Similar trend can be seen in Fig. 4. As COD loading increased, the COD removal efficiency dropped from 96% to 43%. The influent COD loading was varied from 9 to 26 Kg COD/m3.d. The maximum COD removal efficiency was achieved when COD loading was 14-18 Kg COD/m3.d. In general, the obtained results were in agreement with [24], [25] reported that the impact of using sunken media and floating media on the performance of biological aerated filters is that the COD removal ratio of the sunken media filter decreased from 68.3% to 30% when the COD loading rate increased from 0.568 (Kg/m3.d) to 1.403 (Kg/m3.d) and the COD of the floating media filter also decreased from 75.3% to 40% under the same COD loading rates.

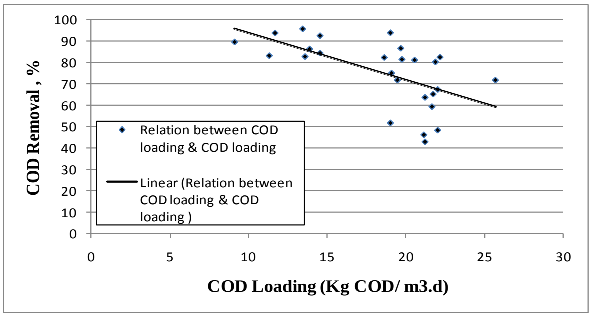

Fig. 4. Effect of COD loading on the MCTF operation

The main reason of effective BOD and COD removal might be due to rapid development of microbial film (within first two weeks) probably due to the filamentous structure, relatively high specific surface area, and inter-cob voids of the maze cobs.

B. Effect of Temperature on MCTF Operation

The developed MCTF treatment system showed considerable variation in BOD and COD removal efficiency with the variation in temperature (Fig. 5). As the air temperature increased, the removal efficiency also increased.

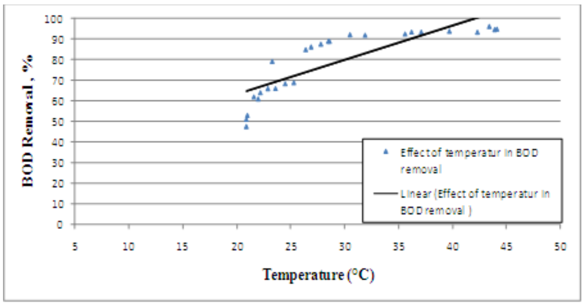

Fig. 5. Effect of temperature on the MCTF operation

The maximum treatment efficiency was achieved when air temperature ranged 32°C to 42°C or in summer season. This might be due to increase in biodegradation processes due to increase in thermal currents and more availability of the oxygen for maintaining aerobic conditions in the reactor [16], 17]. Figure 5 and Figure 6 show that the BOD and COD removal efficiencies increased up to 96% in summer season. The lowest removal efficiency was 48% of the developed trickling filter in winter months when temperature range was 20-24°C. The obtained results were in agreement with [26] in general. Temperature does influence the rate at which biological oxidation occurs. Cold weather generally slows down biological reaction rates of the treatment process and warm weather generally favors biological reactions. It has been known that the amount of biofilm accumulating in the filter fluctuates seasonally and the amount of film increases in winter and decreases in summer [24]. Similarly air temperature also affects the performance of trickling filter in bearing the variation of thermal currents [21], [17], [27], [28], [29].

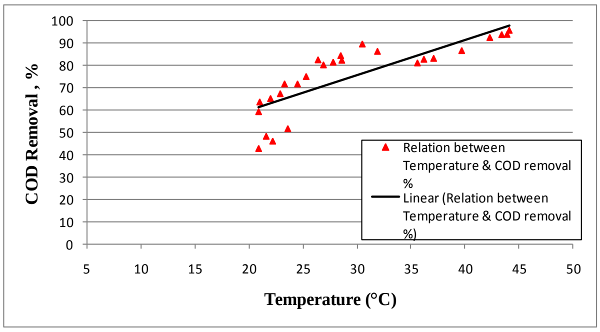

Figure. 6. Effect of temperature on the MCTF operation

IV. Conclusions

A pilot scale Maize Cobs Tricking Filter (MCTF) Treatment System was developed at Bahauddin Zakariya University Multan Disposal Station using indigenous materials for municipal wastewater treatment. The MCTF system body was fabricated locally using (guage 22=0.64mm Zn alloy) metallic sheet. The MCTF was packed with maize cobs,

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obtained from agricultural waste martial. The maize cobs were used innovatively as support media for biofilm growth in the developed treatment system. The results showed that as the organic loading increased, the COD and BOD percent removal decreased. This may be due to reduction in the retention times and non-uniform development of slime layer/biofilm. As the temperature increased, the percent removal increased as well. This might be due to increased thermal currents across the reactor which increases the oxygen availability and maintains aerobic conditions in the treatment system. The results indicate that the Maize cobs are more effective in the treatment processes as compared to plastic and rock media under same organic loadings. This might be due the filamentous structure, relatively high specific surface area, and inter-cob voids of the maze cobs for better biological growth. Maize cobs serve as an efficient and economic trickling filter media as they are indigenously and easily available at no or nominal price.

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