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# Experimental Investigations of Performance of Lateral Flow Sand-Bed Filters for Wastewater Treatment

Anoop Nr. Singh[1], Akshit Mittal[2]
[1] Dept. of Civil Engineering, Rajkiya Engineering College, Azamgarh-276201 (U.P.), India
[2]Undergraduate, Department of Environmental Engineering, Delhi Technological University, Delhi-110042 India
[1]anoopnarain1407@gmail.com, [2] akshit97mittal@gmail.com

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***Abstract:***

Experimental investigations were done to analyze the effect of temperature, loading rate and filtration length on the filtration efficiency of lateral flow sand-bed filter (LFSF) model. In the present study a lateral sand bed filter model (LFSF) has constructed to simulate river sand bed and the effect of temperature, loading rate and filtration length on the filtration efficiency of the model has been analyzed.LFSF was quite efficient in organicmatter(BOD)removalwithmeanremovalefficiency90.6%andwithmeanin creaseefficiency of 48.9 % in DO. Mean removal efficiency in total coliform removal was 34.9 %. The sand filter model has shown lesser removal in EC, TDS and Salinity (4-6%). pH of wastewater shows it slightly changed from acidic to alkaline due to filtration. Mean pH value of wastewater increased from 6.72 (before filtration) to 7.5 (after filtration). Temperature of sand shows positive effect on BOD removal. As temperature of sand bed increases from 28.4 to 35.8$^0$C, BOD removal % increases from 80.3 to 91.5. Loading rate has significant effect on pollutant removal, as loading rate was increased from 0.30 $m^3/m^2/hr$ (35.8 l/hr) to 0.33 $m^3/m^2/hr$ (54 l/hr), mean removal efficiencies for BOD, EC, TDS and Salinity reduced from 94.54, 6.10, 6.06 and 6.10 to 86.77, 2.85, 2.92 and 5.88 respectively. As filtration length has increased in the LFSF, BOD removal has alsoincreased.This paper clearly show that the naturally formed river sand-bed at convex side of river which is a waste land can be effectively utilized on the sustainable basis for further treatment of the secondary wastewater in a city like Varanasi, India, situated on the concave bank of theriver Ganga.

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## 1. INTRODUCTION

River in plains form sand bed on the convex side (Alekseevskiyet al. 2008; Choudhary et al. 1998). The present study investigates the idea of disposing secondary treated wastewater into the river sand bed for its further purification before it get mixed with river water. Due to the slope of river sand bed

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which is towards river, the disposed waste water will get filtered through sand bed and then mix with river water as non point source (Choudhary et al. 1998; Choudhary 2008). Depending upon the discharge & quality of wastewater, size of sand particles, height of ground water table & location of waste water discharge, some part of it will mix with ground water and then will reach to river water & some part will reach to river water without mixing with groundwater. Some study on the utilization of sand bed filters for treatment of wastewater has also been conducted by a few researchers. (Rolland et al., 2009) conducted a study to analyze the effect of media implementation on the efficiency of treatment of wastewater. The study showed that however the compaction of the sand might have a detrimental impact on the performance of a fine grained sand bed, but it will be beneficial for coarse grained sand bed. (Elbana et al., 2012) conducted a study to analyze the effect of sand media filter for removing turbidity from an effluent which is being used for micro-irrigation. The study showed that the media accomplished a turbidity removal rate for between 59.6% to 85.4%, depending on the size of sand size.

In the present study a lateral sand bed filter model (LFSF) has constructed to simulate river sand bed and the effect of temperature, loading rate and filtration length on the filtration efficiency of the model has been analyzed. The objectives of this study are: (i) To find out the affect of temperature on the filtration efficiency of lateral sand bed on the basis its ability to vary the parameters: D.O., B.O.D., E.C., T.D.S., Salinity, pH and Total Coliform Bacteria of wastewater. (ii) To find out the affect of influent loading rate on the filtration efficiency of lateral sand bed on the basis its ability to vary the parameters: D.O., B.O.D., E.C., T.D.S., Salinity and pH of wastewater. (iii) To find out the affect of filtration length on filtration efficiency of the lateral sand bed on the basis its ability to vary the B.O.D. of wastewater.

## 2. MATERIAL ANDMETHODS

For the qualitative study of filtration through natural exposed sand bed at the convex side of river, lateral flow sand filter was constructed using the sand of sand-bed of river Ganga at Varanasi.Effectivedia. (D10), Coefficient of permeability (K) and Coefficient of uniformity (Cu) of sand were measured and their values are 0.097mm, 12.725 X $10^{-3}$ cm/sec and 2.11 which indicates it is fine sand of uniform nature. The experimental model was a rectangular tank of size 244 cm x 180 cm x 46 cm shown in Fig. 1(a). The model was divided into three parts. The part is of 15 cm x 58 cm x 45 cm and serves as influent inlet tank. The second compartment made to serve the purpose of filter & porous media. Sand ofriver Ganga's sand-bed was filled in this compartment for filtering the secondary treated waste water. Depth of sand bed was 27 cm at upstream side & 18 cm at downstream side so it is having a slope. Observation wells were immersed within the porous media to collect filtered waste water from different points in the sand bed and to get the effect of seepage length on filtration. Twelve wells, four in each row were provided in three rows. Distance between each well in a row is 40cm.

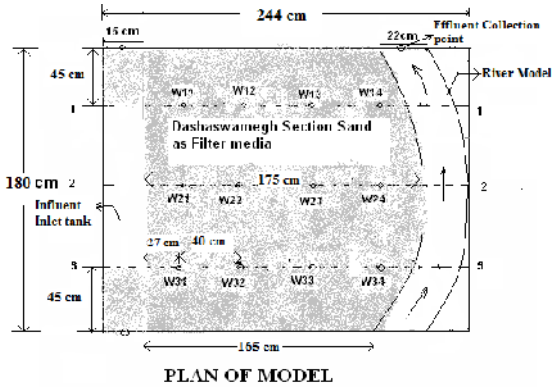


**Figure 1(a).** Top View of the Model

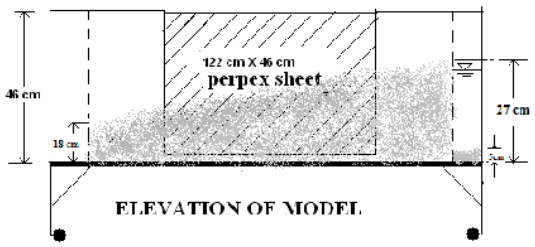


**Figure 1(b)**. Sectional Side View of the Model

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The third part i.e. the downstream of the sand bed is the curve of width 22 cm at the both ends with non uniform width & cross-sectional area. Experiments were performed in the summer season (lean period for river) to simulate the low flow conditions in river & high temperature of sand bed. Data were collected at different temperatures and loading rates to assess the effect of temperature and loading rate on filtration. 250 liters of Secondary treate deffluent was brought from Bhagwanpur STP daily for 15days & dose dintermittently3
for 6 hrs in a day to lateral sand bed at the rate of 0.30 m /m /hr to mature the sand bed, after filtrationof
wastewater, The time for the filters to stabilize and reach a constant performance (maturation) was found to be approximately 10 days, but progression to maturity up to 40 days was also observed (Bauer et al. 2011). After 15 days, sampling of secondary treated wastewater before filtration & after filtration was started. Samples were collected for 75 days in the interval of 5 days from observation wells (with the help of hand operating suction pump) as well as from outlet point. Experiments were done for two loading rates of 0.30 and0.33
3 2

**m /m /hr** and at different sand temperatures. Constant loading rate of 0.30 and0.33 m /m /hr was maintained by maintaining constant depth of 20 & 25 cm respectively in the inlet tank with the help of sluice valve. D.O., B.O.D., E.C., T.D.S., Salinity, pH, Temperature & Total Coliform were measured before filtration & after filtration. Except B.O.D.andtotal Coliform the other parameters were measured with digital probe of HACH, USA. B.O.D and Total Coliforms were measured by standard method and standard total Coliform fermentation Technique (Clesceri et al. 1998)2 respectively. Temperature of sand bed was measured in the intervals of 30 minutes during filtration by platinum thermocouple digital sensor at the depth of 15 cm from the surface of sand bed near to well no W22 to find the effect of temperature of sand bed on pollutantsremoval.

## 3. RESULTS ANDDISCUSSIONS

Performance of filter is evaluated on the basis of mean removal efficiencies of parameters and effect of temperature and loading rates on filtration.

### 3.1. *Effect of Temperature on Filtration at Loading Rateof 0.33m$^3$/m$^2$/hr(54l/hr)*3 2

#### 3.1.1. *Effect of Temperature on BODRemoval*

**Table 1.***Temperature wise Treatment Performance (% Reduction in B.O.D.) at Loading Rate of 54 l./hr or 0.33 m$^3$/m$^2$/hr*

| Atmos. Temp. Range($^0$C) | Av. Sand Bed Temp.($^o$C) | % Removal in B.O.D. |
|---|---|---|
| 24-30 | 28.4 | 80.3 |
| 37.5-40.5 | 29.4 | 85.0 |
| 30.5-28.5 | 30.5 | 90.5 |
| 46-44 | 34.8 | 89.5 |
| 45.5-44 | 35.8 | 91.5 |

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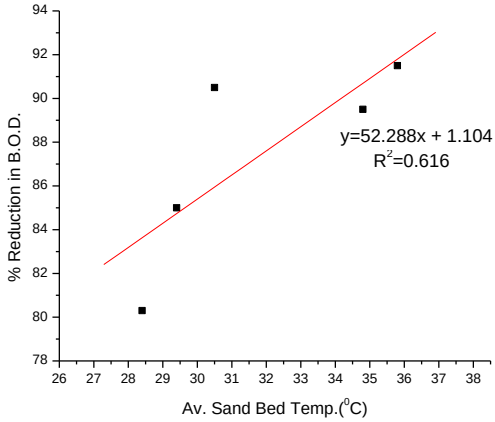


**Figure 2.**Temperature wise Treatment Performance (% Reduction in B.O.D.) at Loading Rate of 54 l/hr or 0.33 $m^3/m^2/hr$

Table 1 & Fig. 2 are showing effect of temperature of filtering medium (sand) on B.O.D. removal ofwastewater. The graph shows the linear fit of the data obtained by experimentation. The valueof Coefficient of regression(r) is 0.78. Data shows that increasing temperature has positive effect on BOD removal.As
temperature of sand bed increases from 28.4 to 35.8$^0$C BOD removal % increases from 80.3 to 91.5. The reason for increase in BOD removal with increase in sand temperature is the increase in biological reaction-rate constant with temperature (Metcalf & Eddy, 1996). The effect of temperature on the reaction rate of a biological process is usually expressed in the following form:

$$r_T = r_{20}\theta^{(T-20)}$$

Where, $r_T$ = reaction rate at T℃

$r_{20}$ = reaction rate at 20℃

$\theta$ = temperature-activity coefficient

T = temperature, $^o$C

This shows that in summer season (lean period for river) utility of sand bed increases for pollution management. Similar experiments on lateral sand bed were done by (Check et al. 1994; Havard et al. 2008). A positive relationship between temperature and treatment performance was noted for BOD (linear) and NH4-N (quadratic) (Havard et al. 2008). These results show, in summer season (lean period for river utility of sand bed increases for pollution management.

### 3.1.2. *Effect of Temperature on Total ColiformRemoval*

**Table 2**.*Mean values, standard deviation, range (Log10X) of Total Coliform Bacteria, MPN/100ml before and after filtration & %Reduction*

| Av. Atmospheric Temp. | Av. Sand Bed Temp. | Before Filtration | | | After Filtration | | | % Reduction |
|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Range | Mean | SD | Range | |
| 34.8 | 30 | 6.32 | 0.077 | 6.23-6.38 | 6.16 | 0.06 | 6.11-6.23 | 30 |
| 45.3 | 36 | 4.88 | 0.25 | 4.60-5.07 | 4.64 | 0.29 | 4.3-4.8 | 39.8 |

Table 2. shows the data of total coliform removal at loading rate of 0.30 $m^3$ /$m^2$ /hr at different averagesand bed temperatures.

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This table clearly shows that as the averagetemperature of sand bed increases from 30 to 36$^{o}$C removal efficiency of sand bed increases from 30% to 39.8%.

Data of (Olson et al. 2005) shows that the sand filter reduced the Fecal Coliform by 2.9 log in summer (av. temperature=15.48C) and 2.0 log in winter (av. temperature=8.88 C). These results indicate that potential of sand bed increases in terms of total coliform& fecal coliform removal in the summer which is the lean period for the river.

### 3.1.3. *Effect of Loading Rate on PollutantsRemoval*

**Table 3.***Comparative Treatment Performance at Two Different Loading Rates*

| Parameter | Influent Concentration | | Filter Outlet Concentration | | % Change | |
|---|---|---|---|---|---|---|
| | Loading Rateof 0.30 $m^3/m^2/hr$ | Loading Rateof 0.33 $m^3/m^2/hr$ | Loading Rate of 0.30 $m^3/m^2/hr$ | Loading Rate of 0.33 $m^3/m^2/hr$ | Loading Rateof 0.30 $m^3/m^2/hr$ | Loading Rateof 0.33 $m^3/m^2/hr$ |
| D.O (mg/l) | 3.67 | 4.2 | 5.51 | 6.2 | +50.12 | +47.62 |
| B.O.D. (mg/l) | 17.76 | 17.54 | 0.97 | 2.32 | -94.54 | -86.77 |
| E.C. (µs/cm) | 688.5 | 687.2 | 646.5 | 667.6 | -6.10 | -2.85 |
| T.D.S (mg/l) | 334.8 | 335.2 | 314.5 | 325.4 | -6.06 | -2.92 |
| Salinity | 0.33 | 0.34 | 0.31 | 0.32 | -6.10 | -5.88 |
| pH | 6.72 | 6.72 | 7.5 | 7.5 | +11.61 | +11.61 |

From the table, it can be observed that the % change obtained, with the change in the loading rate for D.O. is 50.12% to 47.62%, for BOD is -94.54% to -86.77%, for E.C. is -6.10% to -2.85%, for TDS is -6.06% to -2.92%, for salinity is -6.10% to -5.88% and for pH, it remains constant. The maximum change has been obtained for B.O.D. These results are due to the increase in wastewater residence time in filter at lower loading rate. The reason for more % increase in D.O. at lower loading rate can be the higher removal in BOD. Also, The bacteria have a higher amount of time to react with the organic matter, thus increasing the removal rate of BOD at lower loading rates.

### 3.1.4. *Effect of Length ofFiltration*

**Table 4**.*Effect of Filtration Length on Percentage Reduction in B.O.D.*

| Well No. | % B.O.D. Removal | | | | | Average % B.O.D. Removal |
|---|---|---|---|---|---|---|
| | 12/05/11 | 17/05/11 | 20/05/11 | 21/05/11 | 25/05/11 | |
| W21 | 92.6 | 92.4 | 94.7 | 87.2 | 85.8 | 90.54 |
| W22 | 92.6 | 97.9 | 94.8 | 92.3 | 86.6 | 92.84 |
| W23 | 94.6 | 98.9 | 98.9 | 86.5 | 89.9 | 93.76 |
| W24 | 98.9 | 99.1 | 95.6 | 97.6 | 90.9 | 96.42 |

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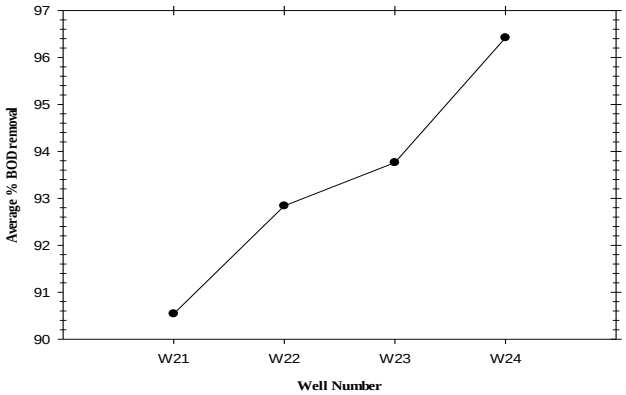


**Fig 3. Average % BOD removal with the Well number**

From the data of Table 4 and Fig 3., it is clear that as the distance of travel of wastewater in the sand bed increases, its BOD reduces.

## 4. CONCLUSIONS

Lateral flow sand filter (LFSF) constructed as river sand-bed of lean period has been proofed to be quite efficient in organic matter (BOD) removal with mean removal efficiency 90.6 % and with mean increase efficiency of 48.9 % in DO. Results show that as temperature of sand bed increases from 28.4 to 35.8$^{0}$C BOD removal % increases from 80.3 to 91.5 which clearly indicate that in the most critical period of river pollution i.e. in summers (lean period) utility of river sand-bed enhances for pollution management. Loading rate has significant effect on pollutant removal, as loading rate was increased from 0.30 $^{3}$/ $^{2}$/hr (35.8 l/hr) to 0.33 $^{3}$ $^{2}$/hr (54 l/hr), mean removal efficiencies for BOD, EC, TDS and Salinity reduced from 94.54, 6.10, 6.06 and 6.10 to 86.77, 2.85, 2.92 and 5.88. As filtration length was increased in the LFSF, BOD removal has increased. This paper clearly show that the naturally formed river sand-bed which is a waste land can be effectively utilized on the sustainable basis for further treatment of the secondary wastewater in a city like Varanasi, India, situated on the concave bank of theriver Ganga.

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