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Preparing Secondary Effluent for Urban Non- Potable Applications by Floating Media Filtration

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Abstract
Conventional sand filtration which has become a common wastewater treatment technology to satisfy regulations appointed for effluent reuse, suffers from the disadvantage of high energy for backwashing. The subject of this study is application of downflow floating media prior to coarse sand filtration, which requires less water for backwash. Two pilots have been employed in two stages. For the first stage, a pilot of two columns was used, one was packed with plastic beads and the other with coarse sand. For the second, floating medium was placed on the sand in a unique column. The effluent of Ghods Treatment Plant was selected as the influent for the both pilots and a turbidity of 2NTU for the filter effluent has been specified as the breakthrough. Final results showed the good efficiency of the system in removing pollutants even in the case of using a unique column. Moreover, this system was determined to be able to meet the non potable reuse standards of water recycling in cities. The performance of the system in reducing chlorine demand was also drastic and results indicated a maximum of 66% and a minimum of 50% decrease in this regard.

Keywords: *Wastewater reuse, Urban non-potable uses, Tertiary treatment, Floating media filtration, (DFF), Coarse Sand Filtration (CSF)*

Introduction

Numerous areas in the world are facing drastic water shortages. This has resulted in evaluation of wastewater reuse as a means of supplementing or replacing existing water sources (1, 2). In this case, the quality of the reclaimed water must be assured. Indeed, wastewater can reduce the demand of freshwater, when it is properly treated or recycled. Wastewater in a conventional treatment- plant is generally required to be treated to the secondary level. Only few uses are recommended at this level and for many common uses, further treatment is always required (3, 4). For most non-potable uses in cities freshwater is not needed and as every densely populated area is short of water, an attractive use of reclaimed water is for urban non-potable applications (1, 4). In Figure 1 various urban applications of wastewaters and recommended guidelines are summarized. In order to reuse effluents while complying with these recommendations, wastewater filtration often becomes necessary. Advances in water and wastewater filtration technology have made use of direct and contact filters as two viable designs in a number of treatment plants. A new type of coarse media flocculator, using buoyant media instead of the heavier sand has been employed in order to facilitate cleaning and providing water savings. Besides, in some industrialized countries this method is preferred over other types of flocculation- filtration because of its greater flexibility (1, 5). Also, cost savings versus conventional filtration could be gained by less land requirements and less cost of building tanks (6). When addressing concerns for direct filtration by fine sand, we should refer to: shorter filter runs, sensivity to influent turbidity and much water required for backwashing. But, down flow floating medium/coarse sand filter (DFF.CSF) dose not

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suffer from these disadvantages and overcomes the shortcomings such as limited retention capacity and high energy for washing (3, 4). In this system the floating medium is used as a flocculator/pre filter while the coarse sand serves as a subsequent polishing filter (7, 8). Secondary effluent treatment by using DFF-CSF has been performed in laboratory and field studies since 1990 in some countries (1). In Iran, only the use of conventional filteration has been studied and reported (9).

Materials and Methods

In this study a pilot of 2 columns made of plexyglass was used in 2 stages (Figure 2). For the first stage each column was consisted of one medium. One was packed with floating media of PVC material (beads with about 4mm diameter and 0.84 g/cm^3 density) and the other with coarse sand (effective size = 2mm and uniformity coefficient = 1.5). The specified depths of these media were 40 and 50 cm and the total height of their columns were 120 and 150 cm respectively. In the second stage, the floating medium was placed on the coarse sand filter in a unique column of 250 cm height. Again, the depths of both media were adjusted to be 40 and 50 cm. The effluent of Ghods Treatment Plant (in Tehran) was selected as the influent for the designed pilots (Table 1). The samples were first analysed for qualitative characteristics and then coagulated by an optimum dose of $Al_2(SO_4)_3$ (about 30 mg/l determined in jar tests). After treatment by downflow floating coarse sand filters, the effluent of each filter run was analysed for determining the treatment efficiency. Three different filtration rates have been used: 5- 7.5 and 10 meters per hour 12 samples have been tested for each rate. The operation times were adjusted to: 67, 56 and 46 hours at 5, 7.5 and 10 mh^{-1}, respectively. At the first rate, 4 samples were treated according to the first stage of this study and the others according to the second stage. As the results of these preliminary treatments were quite similar, it was decided to continue the evaluation only by the use of the singular column pilot (i.e., 2nd stage of the study).

Fig. 1: Recommended guidelines, monitoring and wastewater treatment operations for nonpotable urban reuse applications (4, 6)

Nonpotable Applications:
Landscape and recreational irrigation, cleansing and construction, Industry, fire fighting, toilet flushing, commercial air conditioning, environmental enhancement

Required Treatment:
Secondary treatment, filtration and disinfection

Quality:
$BOD_5 \leq$ 10 mg/L
Turbidity $\leq$ 2 NTU (24 hour average sample)
$\leq$ 5 NTU (at all times)
Fecal coliforms should not be detected
MPN $\leq$ 14 to 200 / 100 mL (7 day average sample)
Residual chlorine $\leq$ 1mg/L after 30 minutes in distribution system.

Monitoring:
pH and BOD_5 : weekly
Turbidity : continuous
Fecal coliforms : daily
Residual chlorine: continuous

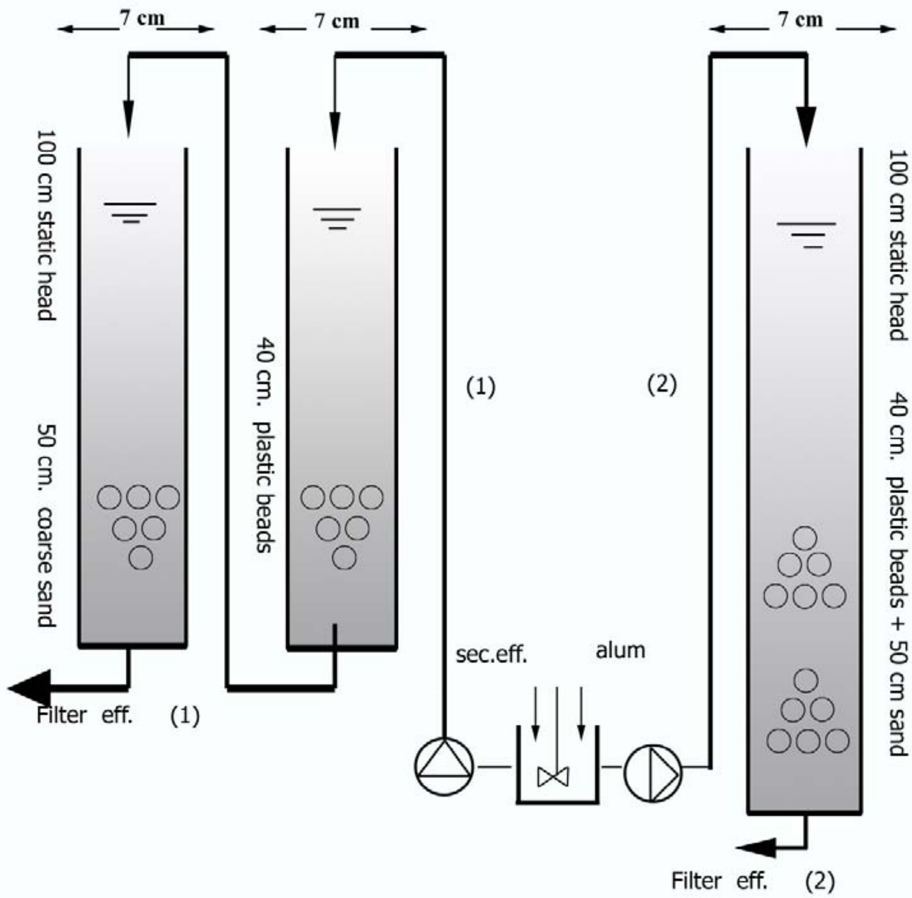

Fig. 2: Schematic view of the pilots Route (1) – effluent filtration by flocculation in a separate column having floatable media. Route (2) – effluent filtration by using floating media as a prefilter

Results

Table 2 summarizes the results of determining the performance of floating medium filtration in reducing the remained pollutants of the secondary effluent in 3 different rates. Also, in Figures 3 to 5, the effects of the filtration system in removal of the most important contaminants could be considered for the rate of 5m/h. Figure 6 shows the effect of filtration in reducing the chlorine demand of the secondary effluent again at the filtration rate of 5m/h. The effect of increasing filtration rate in changing the content of solids load that can penetrate into the filtration system and thereby in changing the time required for each filter run can be seen in figure 7. Finally, Figure 8 shows the required rates of water for filter backwash.

Table 1: Characteristics of the secondary effluent from Ghods Treatment Plant*

Parameters	Filtration Rate (m/h)								
	5			7.5			10		
	Range	Average	Standard deviation	Range	Average	Standard deviation	Range	Average	Standard deviation
pH	7.2 – 7.5	7.3	0.09	7.2- 7.5	7.3	0.09	7.2 – 7.5	7.36	0.1
Turbidity (NTU)	6.3 – 7.5	7.06	0.33	6.4–7.8	7.13	0.36	6.2 – 7.3	7.00	0.28
Total BOD_5 (mg/L)	16.9 – 22.8	19.65	1.54	17.2–19.9	18.52	0.8	17.5 – 19.6	18.65	0.67
Soluble BOD_5 (mg/L)	3.1 – 3.7	3.35	0.17	3.3 – 3.9	3.56	0.16	3.4 – 3.9	3.66	0.17
Total COD (mg/L)	32- 42	35.5	3.3	30 – 38	34.33	2.5	36 – 42	38.66	1.5
Soluble COD (mg/L)	8 – 12	10.66	1.2	10 -12	11.16	0.98	10 – 12	10.83	0.98
Total Solids (mg/L)	556.0 –	627.5	44.5	608.3–	640.2	29.5	560.0–	618.8	37.2
Total suspended Solids (mg/L)	704.6	18.14	1.2	692.0	18.40	0.93	688.6	17.75	0.56
Conductivity (μmohs/cm)	16.6 – 20.2	828	52.6	17.3- 20.6	873.7	41.6	17.0 – 18.6	728.7	49.2
Total Coliforms (MPN/100ml)	730 – 890	75	24.49	795 – 935	58	34.06	750 – 882	57	23.61
$\times 10^{-3}$	22- 110	29	11.97	27 – 140	31.25	20	33 – 110	29.16	13.48
Fecal Coliforms (MPN/100ml)	14- 50	19.8	1.1	14 – 80	19.8	0.61	17- 60	19.2	0.93
$\times 10^{-3}$	18.3 – 21.0			18.9 – 20.4			17.8 – 20.7		
Chlorine Demand (mg/L)									

*The period of sampling was from January 2001 to May 2002. 12 samples were tested for each filtration rate (a total of 36 samples).

Table 2: Performance of floating media filtration in removing residual pollutants of secondary effluent samples (DFF = 40 cm and CSF – 50cm)

Parameters	Average Removal Efficiency (%)			Pollutant Remained in Filter Effluent
	5	7.5	10	
Turbidity (NTU)	83.7	77.9	74.0	1 – 2
Total BOD5 (mg/L)	80.1	70.6	62.0	4.4 – 8.6
Soluble BOD5 (mg/L)	41.4	35.6	29.5	1.8 – 2.7
Total COD (mg/L)	69.3	62.8	56.0	9.2 – 18.4
Soluble COD (mg/L)	32.9	29.4	27.0	5.3 – 8.7
Total Suspended Solids (mg/L)	82.8	73.5	64.4	2.8 – 7.3
Total Coliforms (MPN/100ml)*	57.0	52	48.2	$9.4 \times 10^3 – 72.5 \times 10^3$
Fecal Coliforms (MPN/100ml)*	54.8	47.7	43.4	$9.3 \times 10^3 – 45.2 \times 10^3$
Chlorine Demand (mg/L)	66.6	59.5	50.5	5.9 – 10.3

*After disinfection of filter effleuent by chlorine (1 mg/l residual and 30 minutes contact time), no coliforms were remained.

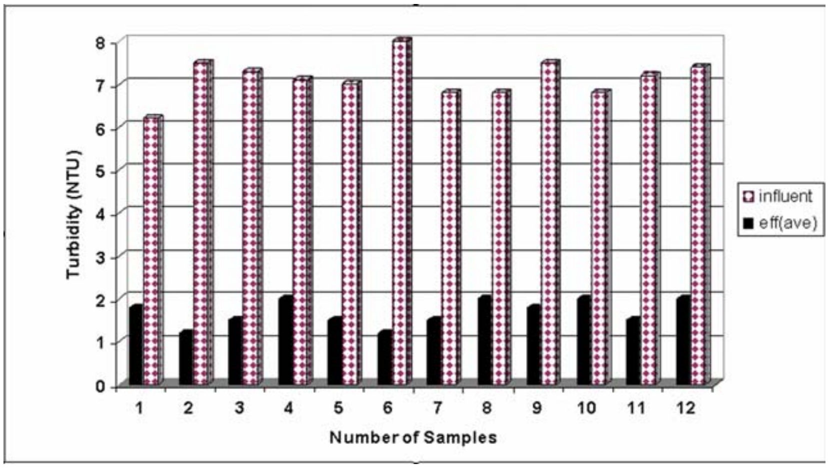

Fig. 3: Effect of filtration on turbidity removal at 5m/h

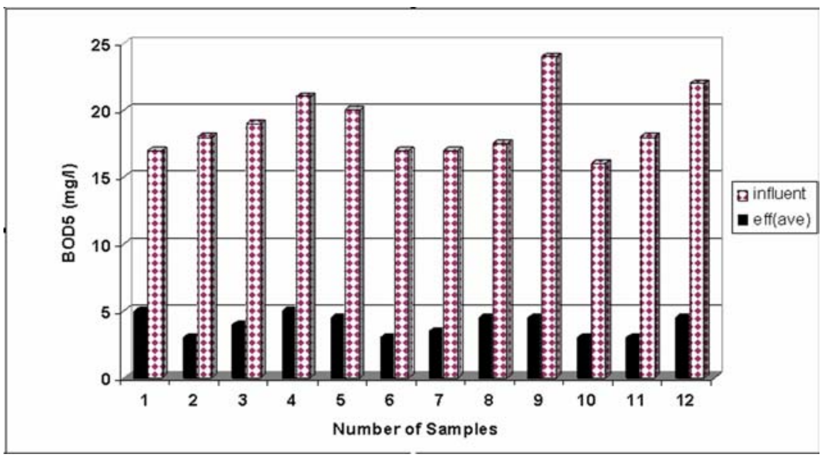

Fig. 4: Effect of filtration on total BOD_5 removal at 5m/h

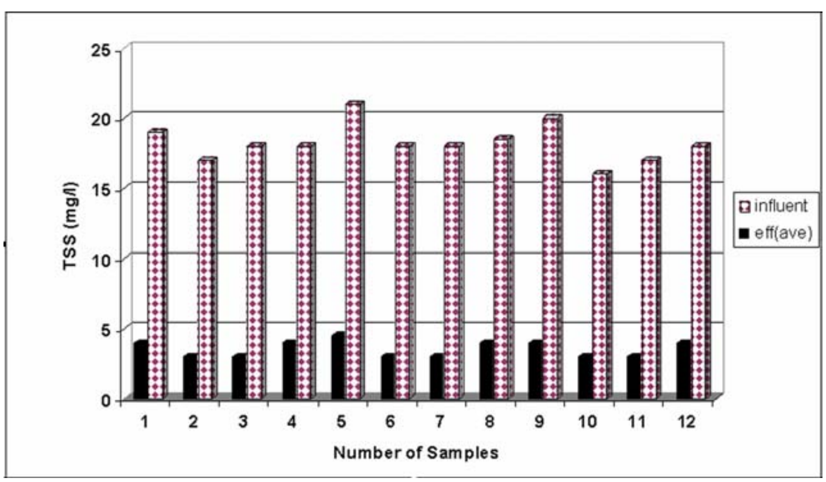

Fig. 5: Effect of filtration on TSS removal at 5m/h

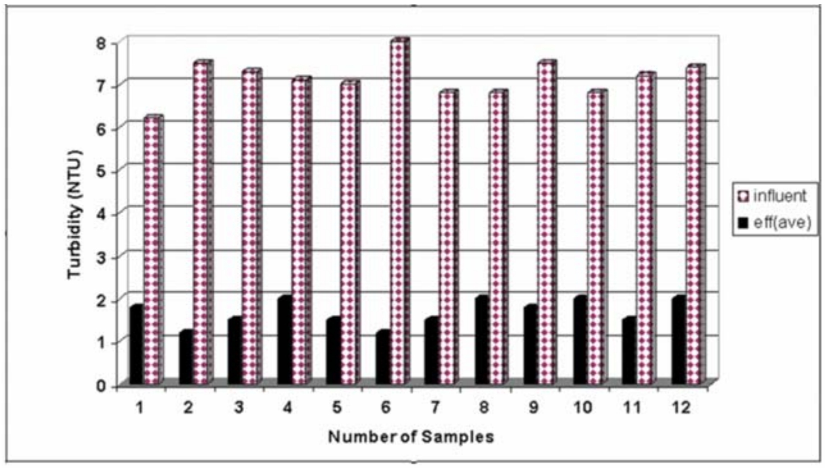

Fig. 6: Influence of filtration on chlorine demand of wastewater

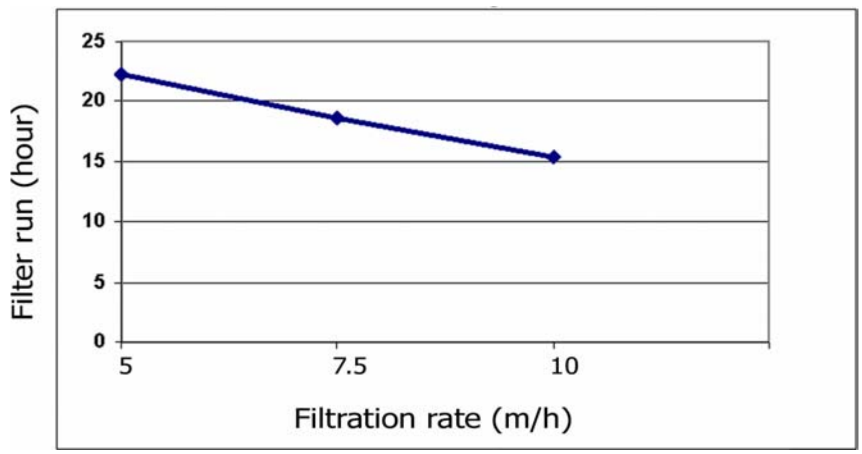

Fig. 7: Filter run changes at various filtration rates

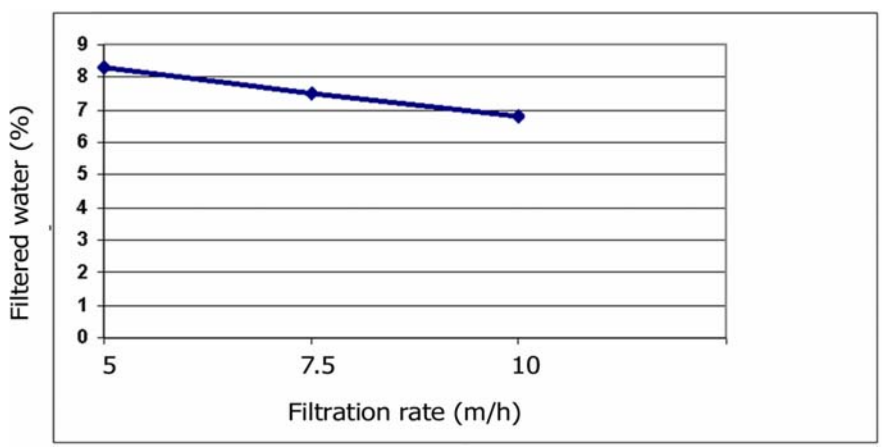

Fig. 8: Required water for filter backwash at various rates

Discussion

In this study, the applicability of DFF-CSF in preparing a suitable effluent for urban uses has been examined. By comparing the concentrations of pollutants remained in filter effluent reported in Table 2 with recommended guidelines presented in Figure 1, it could be concluded that all pollutants (except coliforms) have been reduced significantly ($P<0.001$) by effluent treatment in any of the 3 specified rates and thereby ensuring the requirements of non-potable reuse standards of wastewater. Of course, the maximum efficiencies of pollutants removal belonged to the least velocity. Besides, the longest filter run belonged to the velocity of 5m/h (Figure 7). Pointing to the necessity of having a free- of – pathogen effluent for urban non-potable uses it should be noted that the goal cannot be achieved by mere filtration, although, we experienced more than 40% reduction in total and fecal coliforms density even without performing terminal disinfection. Nevertheless, one of the most important effects of secondary effluent filtration was on disinfection. Figure 6 illustrates this effect for total coliform inactivation in filtered and nonfiltered effluents the effect of filtration before disinfection was drastic and the chlorine dose required for a given log inactivation could be lessened to one half. It is obvious that the treated effluent with less chlorine demand has some advantages over groundwater for irrigation of landscape and recreational areas in a city. This is because of the fact that recharging of groundwater reservoirs is a timely and expensive process and from economical point of view, the treated effluents are often much cheaper than the groundwater sources. The expenses for pumping and withdrawl of water from groundwater sources would be much more if the water table is lower than the usual depths. In case the water is being pumped from the depth of 60 meters or so, the power of the pump can be calculated as below:

$$P = \frac{wQH}{75\eta_p\eta_m}$$

Where P = power (horse power)
Q = flow (m^3/s)
H = total dynamic head (m)
w= water specific weight (kgf/m^3)
ηp = pump efficiency (usually around 0.7) and ηm = motor efficiency (around 0.7)

For a water demand of 0.5 m3/s and total dynamic head of 75 meters, the result would be:

$$P = \frac{1000x0.5x75}{75x0.7x0.7} = 1020hp = 736kW$$

Then by considering the price of electricity for a period of 30 years, 6 months a year and 10 hours a day, the cost of energy will roughly be equal to about10^9 Rials ($ 125000 assuming 400 Rials per kW). This amount by itself is much more than the cost of irrigation by similar flow supplied from treated effluent. The detailed calculation of a case study in this regard can lead to a difference in cost to as much as 3 to 5 folds. In any event, the treated effluents are more available for municipalities to satisfy the growing urban water demand. As figure 8 indicates the water demand for filter backwash was more than 5% of the reproduced water at all the specified filtration rates, whereas it should be at least 2% when utilizing media lighter than fine sand. It should be explained that in this research only water has been used for backwashing, certainly, this criterion for water consumption which is expected for DFF-CSC could be easily achieved by arranging the system with water plus air washing equipment and so gaining an extra advantage over conventional filtration. The final conclusion is that reclamation for urban use will promise water and cost recovery only by considering all the required steps in designing the filtration process and this begins with attention to the filter media.

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