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Total Coliforms and Turbidity Removal of Water in the Continuous Sand Filter

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Abstract
The continuous filter is a kind of sand filter, which will operate without any interruptions for backwashing and also it accepts high-suspended solid levels in feed stream. Fouled sand is continuously removed from the filter bed, washed and recycled back without interruption with filtration process. Various samples of water with certain amounts of turbidity enter through a feed pipe and being distributed to the filter. A central column runs from top to bottom of the filter. The water is led through an outer tube in the column by a set of radial, distributor arms. The polluted water flows up ward through the sand bed. The water emerges; clean, in the top section of the tank, and eventually spills over a weir, and then inters into a discharge pipe. In this research, the continuous sand filter was studied to determine its disinfection efficiency in addition to turbidity removal. The results showed that the filtered water had a high quality and the turbidity reduction was 95.5 %. Inspecting the work of the filter had revealed that the removal rates of coliforms and microbial colonies were 99.67 % and 98.99 % respectively. On the other hand, by the use of direct filtration, turbidity reduction was over 97 %. In direct filtration, drinking water with less than 1 NTU turbidity was provided. This continuous sand filter has the advantage of stable operation and more energy saving as compared to the conventional ones.

Keywords: *Drinking water, Continuous sand filter, Filtration, Turbidity reduction, Disinfection.*

Introduction

In filters, backwash process reduces the efficiency of sand filter. The continuous sand filter, also called Dynasand filter or super sand filter, has overcome this problem by eliminating backwashing (1). Fouled sand is continuously removed from the filter bed, washed and recycled without interruption to the filtration process. The sand bed of this continuous sand filter unit is contained in a cylindrical tank with a conical base. At larger plants the continuous sand filter units are housed in concrete vessels (which is the case at most of the German plants). Water to be treated enters through a feed manifold pipe and is distributed in the filter unit. A central column extends from top to bottom of the unit. The water is led through an outer tube in the column by a set of radial, distributor arms. Filtration occurs as the water pressure forces the raw water to flow up ward through the sand bed. The water emerges; clean, in the top section of the tank, and eventually spills over a weir, which guides it into a discharge pipe (2). The most innovative part of the continuous sand filter technique consists of a continuous sand cleaning process. This is located under the distributor arms. At the bottom of the cones and directly under an inner tube in the central column, there is an air-lift pump. Using compressed air, this directs the sand with impurities, up in the central tube, and to a sand cleaner at the top of the unit. This action, in addition to transporting the dirty sand, starts the cleaning process: Turbulence, in this air-lift column, begins to separate out the sand from the dirty particles. The cone shaped base of the tank makes the entire sand bed gradually shift down toward the pump at the bottom. This

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happens because the pump is continually lifting out the deepest sand and transporting it back to the top of the tank. At the top of the central column there is a sand washing unit. This consists of an outer cylinder, with corrugated walls and opens at the bottom. The dirty sand spills out into this cylinder from the top of the central column. The sand cleaning cylinder allows a small proportion of the clean water, rising from the sand bed, to enter (3). The difference in head forces the clean water to flow up the cylinder, while the sand is falling down. The sand (which is heavier than the contaminating particles) continuously moves downward, while the dirt is washed out with the water. The dirty wash water spills out at the top of the central column and is discharged through a second outlet pipe. Thus, the sand is constantly in motion, shifting slowly down through the sand bed, lifted by air pressure to a sand cleaner at the top of the unit, and then returned, cleaned, to the top of the sand bed. In this way the sand filter is being constantly cleaned while simultaneously, filtering raw water (4, 5). This filter is preferable over other filters, because it does not require any equipment for backwashing (Table 1). As pretreatment of raw seawater in the RO (Reverse Osmosis) desalination plant, sand filtration is conventionally applied to maintain the seawater quality within the low SDI (Silt Density Index) level. The conventional fixed bed type has some difficulties because of backwash period. On the contrary, the continuous sand filter does not require the backwash period and also temporary quality deterioration after the backwash never arises (6). Direct filtration is used mainly to produce process water and drinking water from raw water sources, and for wastewater applications (7). Final filtration of biologically treated wastewater is a frequent application for continuous filters. The filtrate meets the highest environmental standards required for wastewaters and the effluents of chemical, food processing and pulp and paper industries (8). Treatment of metal-bearing effluents with pH adjustment and chemical conditioning to precipitate metallic ions, followed by flocculation, sedimentation, and final filtration by a continuous sand filter (8).

Table 1: Comparison of continuous sand filters with a conventional one. (2, 7)

Continuous sand filter	Conventional sand filter
Low power consumption	High power consumption
Average power consumption= 0.077kWh/m3	Power consumption=0.085kWh/m3
Minimum power consumption= 0.019kWh/m3	
Storage tank is not required	Requires storage tank
Control panel is not required	Requires control panel
Automatic valve is not required	Requires automatic valve
Strong air blower is not required	Requires strong air blower
Low capital cost	High capital cost
Less equipments	Many equipments
Simple structure	Complex structure

The continuous sand filter is suitable for many applications

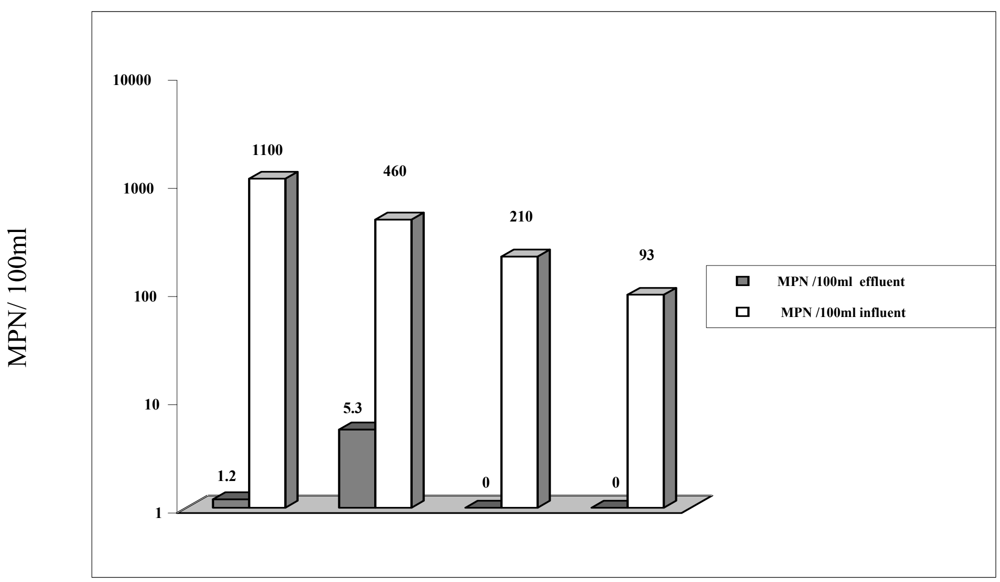
Materials and Methods

In this study, a continuous sand filter unit was designed (Figure1).The major objective was study of the efficiency of continuous sand filter in treatment of raw water. Besides, the capability of this filter in accomplishing water disinfection was studied. The filter is a cylinder unit with 2.0m height and 0.25 m diameter. Total depth of introduced sand bed is specified to be 1.1m.The specifications used for establishing the pilot were selected according to the work of various researchers in this regard

(9, 10).The fine sand was used with effective size of 0.4-0.7mm and uniformity coefficient of 1.57. The samples of water were taken from Tehran tap water and clay was added to prepare certain turbidities in the range of 20 to 160 NTU. After pilot set up, sampling was carried out in 3 phases. In the 1st phase, about 390 samples with various turbidities and loads were analyzed to determine the filter efficiency in turbidity removal. In the first phase, the purpose was to determine turbidity in filter effluent while two different conditions were made as follows: Constant overflow rate and variable influent turbidity. Constant influent turbidity and variable overflow rate. Sampling was carried out from raw, filtrate and wash water. For each phase of the study, when analogous results were obtained from the experiments, sampling was discontinued. In the second phase, it was decided to study the performance of filter in coliform removal through microbiological examination of filtrate water. The above mentioned operational conditions were taken into account in this phase as well. Microbiological examinations were included presumptive and confirmed MPN and plate counting methods. In the third phase, filter performance was evaluated using coagulants. Ferric chloride and aluminum sulphate, which are conventional coagulants in Iran's water treatment plants, were utilized in this phase. First, predetermined turbidities of water were made in laboratory. Optimum dosage for coagulation and flocculation was defined by Jar tests and this dosage was used for water coagulation in the sand filter pilot. In this study, three coagulation and flocculation processes were applied including conventional, direct filtration and in line filtration. Throughout the filter operation, head losses were determined in various overflow rates and turbidities. For influent turbidities in the range of 20 – 60 NTU, head loss was almost constant and determined to be about 0.7m. However, when influent turbidity increased and reached to 70 NTU, head loss in the filter raised and was 1.2m. It should be stated that for a determined turbidity there was not any significant change in head loss because of continuous washing of filter. Continuous sand filter resulted in very low head loss, which in some references it is specified to be as low as 0.5 m (11). For filtration of surface water by use of continuous sand filter, filtration rate should be 6–15 m3/m2/hr (2). In the present study, a filtration rate of 6m3/m2/hr was used to decrease flow rate in this filter. In every 5 minutes, flow rate was measured and it was considered to be constant as it was expected. Flow rate was changing only in cases when turbidity was very high and it was gradually decreased to zero. Flow rate reduction was due to high turbidities applied in the process of determining filter performance. However, and as it was expected, for low and average turbidities, this flow rate was remained constant. In continuous sand filter, the amount of wash-water is reported as 3-5 percent of influent water (11). In this study, volume of wash-water was frequently measured in various turbidities by use of scaled container in the outlet of effluent wash-water, which was determined to be 5 percent of influent raw water fed to the filter. All the analyses were performed according to the procedures outlined in Standard Methods (12).

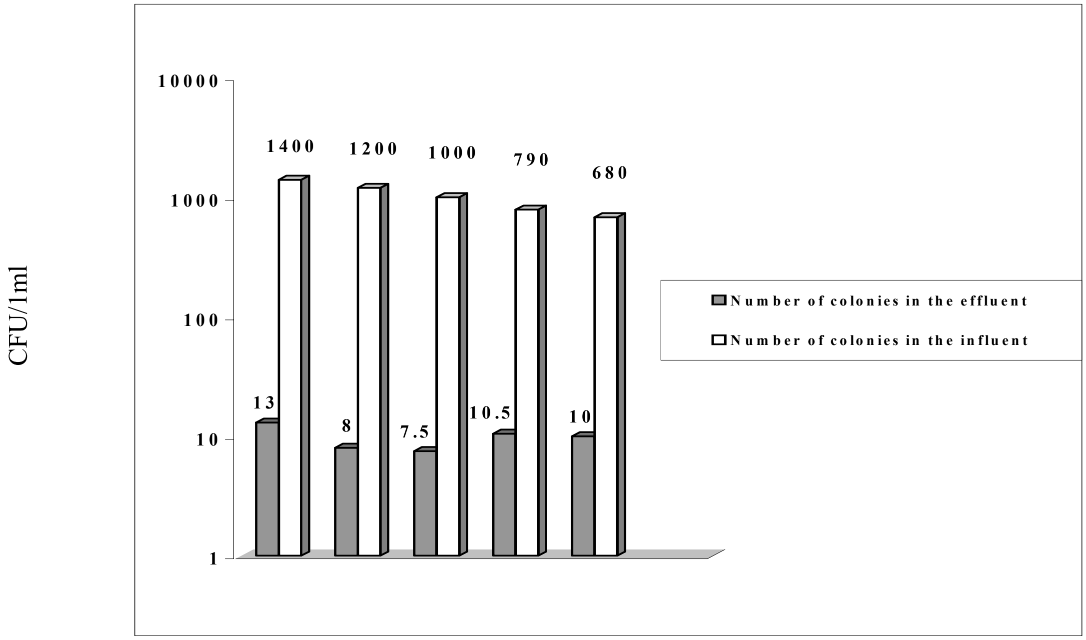
Results

According to Table 2, the highest and lowest turbidity reduction for the influent water ranging 20 – 40 NTU and 140 – 160 NTU turbidities were 95.5 and 92.7 percent respectively. When turbidity reached 160 NTU, the filter nearly clogged and effluent was ceased. Turbidity measurement was carried out while influent turbidity was constant but surface overflow rate varied. Maximum and minimum reduction occurred in 85 m/d and 160 m/d flow rates so that turbidity removal efficiencies were 95.5 and 70.6 percent respectively (Table 3). Increasing overflow rate to more than 160 m/d caused sand column to move in the direction of flow. Therefore, optimum operational conditions in terms of overflow rate and influent turbidity were occurred in 85 m/d and 30 NTU respectively which were taken into account during the filter operation. In the 2nd phase, about 100 samples were tested. According to the results, when overflow rate was 85 m/d with a turbidity of 30 NTU, the highest coliform removal was occurred to be 99 percent. On the other hand, the lowest coliform efficiency for overflow rates greater than 160 m/d was resulted (Figure 2 and 3). In the 3rd phase of the study, and in order to determine the efficiency of coagulants in promoting the performance of continuous sand filter, three filtration methods were studied. These included: conventional filtration using turbidities of 100 and 200 NTU, direct filtration using turbidities of 50 and 60 NTU and in line filtration using turbidities of 20 and 30 NTU. Since direct filtration was only applied for low turbidities, consequently it was decided to use low range of turbidities. Figure 4 shows filter performance with and without using coagulants. As indicated, filter performance was significantly improved by use of coagulants.



MPN/ 100ml

Fig. 2: The comparison of total coliforms in the raw and filtrate water for flow rate of 85 m/d and turbidity of 30 NTU



CFU/1ml

Fig. 3: The comparison of number of microbial colonies in the raw and filtrate water for flowrate of 85 m/d and turbidity of 30 NTU

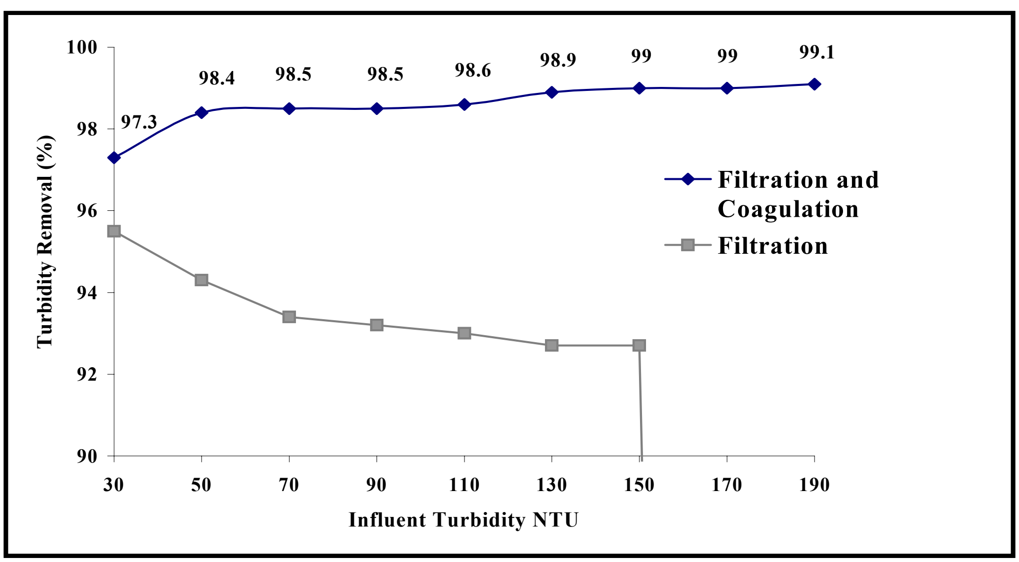


Fig. 4: The comparison of turbidity removal for two treatment processes (Filtration -Filtration and Coagulation)

***Table 2:** The continuous sand filter efficiency in turbidity removal when optimum overflow rate was 85 m/d and influent turbidities were variable

Influent turbidity (NTU) Mean ± δ	Effluent turbidity (NTU) Mean ± δ	Turbidity removal (%)
30 ± 7	1.35 ± 0.4	95.5
50 ±7	2.86 ± 0.6	94.3
70 ±7	4.58 ± 0.44	93.4
90 ±7	6.08 ± 0.49	93.2
110 ± 7	7.66 ± 0.8	93
130 ± 7	9.52 ± 0.35	92.7
150 ± 7	10.96 ± 0.71	92.7
> 160 **		

* Total number of samples = 390
** When turbidity was 160 NTU and more, the filter nearly clogged.

Table 3: The continuous sand filter efficiency in turbidity removal for turbidity of 30 NTU and variable overflow rates *

Overflow rate (m/d)	Effluent turbidity (NTU) Mean ± δ	Turbidity removal (%)
60	1.35 ± 0.4	95.5
85	1.35 ± 0.4	95.5
110	2.60 ± 0.4	91.3
135	4.70 ± 1.30	84.3
160	8.80 ± 1.40	70.6

* Total number of samples = 390

Discussion

This pilot scale, continuous sand filter showed high turbidity removal efficiency in water treatment. As it is indicated in Table 1 and Figure 1 and 2, this filter can accept turbidities about 100 NTU and performs a relatively acceptable disinfection simultaneously. At the same time, the turbidity can be maintained as high as 20 – 60 NTU and head losses as low as 0.7 m .In the some references it is specified to be as low as 0.5 m (11). If coagulants are used in the process of direct filtration it would be expected that 1NTU turbidity for filtered water can easily be achieved as it is indicated by considering the turbidity removal percentages in Figure 4.In the other study by direct filtration , turbidity values of less than 0.5 NTU were obtained(7). Furthermore, turbidities of less than 1 NTU are also expected for the filtrate of this kind of filter in all circumstances with influent turbidities less than 30 NTU (3). The maximum acceptable raw water turbidity was determined to be about 160 NTU. It should be added that the head loss through this filter was almost constant and only a few changes were considered mainly because of the fixed status of sand filter porosity and uninterrupted mode of washing process. Finally, it should be added that some difficulties have been experienced primarily because of some faults in initial designing of the pilot such as not providing enough slope for separator's bottom (13).

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