Evaluating the effects of the flow direction on the performance of the rapid sand filter

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Abstract
The rapid sand downflow filter is widely used in water treatment plants. On the other hand, this filter has some drawbacks included the significant development of the head loss via the filter media because most of the rejected particles are removed by the upper layers. As well, the filter particles are redistributed during the backwash process causing the settling of fine particles on the upper part of the filter media, and this needs to increase the number of backwash processes. For these reasons, the cost of the produced water increases. The aim of the present study is to explore the possibility of using the upflow sand filter (UF-Filter) as a good alternative to the downflow sand filter (DF-Filter). To achieve the aims of the present study, a comparison was made between the performance of both filters through simultaneous experiments under different operating conditions. These conditions included changing of the filtering velocity from 5 m/h to 10 m/h and the initial water turbidity with a range of (10 – 200) NTU. The sand media with sizes of (0.6 - 1mm) and with 63 cm of depth was used. Experimental results show that the turbidity removal efficiency of the DF-Filter is of about 1.1 times that of the UF-Filter. On the other hand, the UF-Filter has higher turbidity removal efficiency than the DF-Filter by about 1.1 times when the initial turbidity of the influent water is greater than 150 NTU and the filtration velocity is equal to 10 m/hr. These differences in the removal efficiency between both filters can be considered as few values. The average filtration efficiency of the UF-Filter operated with the filtration velocity of 5 and 7.5 m/h is higher than that of the DF-Filter operated with the filtration velocity of 7.5 and 10 m/h, respectively under the same operating conditions. The filtration efficiency of both filters increases when the backwash was carried out before each experimental process instead of replacing the filter media. Also, the head loss of the DF-Filter is significantly increased due to redistribution of the sand media taking place during the backwash cycle, while the head loss of the UF-Filter is not affected. The head loss of the UF-filter at the end of each experimental run is less than that of the DF-Filter by about (18.18 % - 45.31 %) when the filter medium is replaced and this range is increased to about (53.31 % -
62.34 %) when the backwash is performed prior to the start of the experimental work. Thus, the decrease in head loss leads to an increase in the filter running time and decrease the number of backwash process.

Keywords: upflow filter, rapid sand filter, head loss, filtration rate, water turbidity treatment

1. Introduction

A lot of the water turbidity is removed by a sequence of processes which are coagulation, flocculation, and sedimentation. As well as, further removal of the suspended particles is obtained by the filtration process to get pure waters within the standard specifications of the public health [1, 2].

Rapid downflow sand filter extensively used in the treatment of water. The range of its effective sizes (ES) and its uniformity coefficients (UC) are of (0.45 - 0.7) mm and (1.3 - 1.7) mm, respectively [3]. As the water flows through a granular filter bed, the suspended particles attach to the granules of the filtering media causing clogging of some pores, reducing the size of pores channels, and rising the head loss of the filter. If the head loss exceeds the critical value or the filtration quality reaches below the permitted value during filtration, the filter stops serving and the backwashing process begins. Backwashing basically involves reversing and raising the water flow through the filter to clean the filter from the contaminants that accumulate in the filter media, and this requires a substantial volume of washing water up to 10% of the filtered water amount [4]. This type of filter has some drawbacks. The major drawback is the reduction of the operating duration of the filter, thereby increase the number of washing processes. As most of the water impurities are removed close to the upper part of the sand layer leaving most of the filter thickness unused, the filter pores are early clogged, especially at the high water turbidity levels [5, 6]. Also, the stratification that occurs in the sand layer during the backwash process, makes the fine particles of sand settled on the upper face of the sand layer and reducing the size of pores of this face. Accordingly, the head loss dramatically increases during the operation of the filter, which leads to the need for further repeated backwash processes [7, 8].

The common solution to overcome this problem is of using a dual-media rapid filter that consists of an anthracite layer settled over a sand layer [9, 10]. So, the direction of flow moves from a coarse layer to a fine layer. Hence, the head loss development is delayed and the duration of filter run is increased if the suitable sizes are chosen for both media layers. However, anthracite is not always readily available, it is not the most economical option in certain cases. This is particularly right in the many of developing states, and in the rural regions around the world.
Most of the global and local studies focus on the rapid downflow filters (DF-Filters), but there is still some lack of studies of the rapid upflow filters. Furthermore, there are no local studies of rapid upflow filters (UF-Filters). So, further researchs on the granular upflow filter is important to solve particular problems in the water treatment.

The use of UF-filters which can be considered as a better alternative to DF-Filters to improve the performance of the filtration processes in terms of the development of head loss and filter operating time that is a goal of the study as well as saving energy, and reducing effort and cost in the water treatment. Unlike DF-Filter, the important feature of filtering water flowing from coarser to finer gradient is guaranteed in the UF-Filter even after the backwash, which it can achieve a consistent distribution of captured particles over the entire depth of filter, a significant storage capacity of solids in the coarse gradient, a longer run period and a lower head loss [11]. The authors [12] showed that the effect of gravity on the direct filtering process gave higher initial efficiency for the DF-Filter than the UF-Filter. [13] improved the ripening process using ETSFW (Extended Terminal Sub-Fluidized Wash) technique with cationic polymer in washing water for the DF-Filter and the UF-Filter. Nevertheless, the head loss increases during the ripening of the DF-Filter and this leads to increase the removal of the prevailing surface resulting in shorter run ultimately. On the contrary, the UF filter has a less head loss development and a long filter run. This idea helps to make the up-flow filter more acceptable. Therefore, this study is conducted to compare the performance of both the upward and downward filters. Since the filtration rate and the initial water turbidity mainly affect the granular filtration process [10], their effects on the two filters are investigated in the present study.

2. Materials and Methods

In the present study, a pilot plant that consists of two columns of filters, the upflow and the downflow filters, was designed and constructed to study simultaneously the filtration efficiency of each filter type under different operating conditions. The schematic diagram of the pilot plant used is shown in Figure 1.

2.1 Pilot plant components

1. Feeding tank of Synthetic Turbid Water: Two polyethylene plastic tanks are installed in the experimental running unit, the volume of the first and second tanks are 1000 L and 500 L, respectively. The first tank is placed on the ground as shown in Figure 1, while the second tank is
placed 4 m above the ground level to achieve the constant head required for water flow. Tanks are filled with turbid water and they are used as storage and feed tanks of the turbid water for the pilot units. A submersible pump was used inside each tank to recirculate turbid water to keep it homogeneous along the tank. In addition, water is supplied from the first feeding tank to the second one via a feed pump. Thereafter, the turbid water is supplied from elevated tank to the pilot plant by gravity.

![Schematic diagram of the pilot filtration units used](image)

**Figure 1.** Schematic diagram of the pilot filtration units used

2. **Flow meters:** The flow meters are installed on the feeding pipes of each filter to measure the flow rate of turbid water.

3. **Pipes and valves of the pilot plant:** The polypropylene type pipes (PPR) of 12mm diameter are used to deliver synthetic turbid water between tanks and the pilot plant filters. Valves have been utilized in the pilot plant to perform various services including maintaining and controlling the flow rate passing through the flow meters towards filtration columns and collecting samples of filtered water.

4. **Columns of filtration:** Two columns were designed and installed to run in two parallel patterns which are downflow and upflow directions as shown in the Figure 1. The filtration
columns were made of PVC material of 150 cm high and 10 cm in diameter. A perforated disc made of stainless steel placed at the bottom of filtration columns to support the media of the filter, and distribute the backwash water and the influent turbid water. The perforated disc that is of 0.1 cm thickness has holes of 0.2 cm diameter uniformly distributed over its entire area. In order to measure the head loss that occurs due to filtration of turbid water throughout the filter media, two-transparencies plastic tube each of 10 mm diameter are installed on the inlet and outlet of each filter column.

2.2 Filter Media

The materials of the filter media used in the current study is of uniform sand with size gradations of (0.6 – 1) mm, effective size of 0.63 mm, and uniformity coefficient of 1.29. The sand is placed on the top of the gravel layer. The filtration media layer is of 63 cm height for all filters utilized. The sand is carefully washed with water to remove impurities, dirt, and salts before placing it in the filter columns. The gravel layer is of 10 cm depth, and its particles size ranges between 2.5 mm and 6.5 mm. The gravel is used as a support layer located directly under the filter media to prevent particles of the filter media from clogging the underdrain orifice. Also, the gravel layer permits the turbid water to easily flow from the underdrain orifice during upflow and backwash processes [14].

3. Results and Discussion

Twenty-one experimental runs were carried out to study in removing of the water turbidity and reducing of the head loss. In the present study, the average efficiency of water treatment was assessed for turbidity in each filtration cycle. The effluent turbidity of the DF-Filter and the UF-Filter were measured each hour during running of the pilot plant. The running time of each filter was about 11 hours of every run. Synthetic raw water was used instead than river water in order to carry out a wide range of water turbidity which had been required in experimental tests with more controlled method. The overall range of the turbidity of synthetic raw water varies between 10 NTU and 200 NTU. Filtration velocities that have been studied were 5, 7.5, and 10 m / h. The pressure drop (head loss) was recorded for both filters by the piezometers at the first hour and the end time of each run. The filtering media is replaced before each operation to maintain the same conditions and get an accurate comparison of the results for different cases of each run. Except of
the runs NO.9 and NO. 16, the backwashing of the filtration media was carried out before filters run to observe the changes taking place.

3.1 Experimental Study Results

Both filters were tested under the same operational conditions which are the influent water turbidity, the running time, and the filtration rate. Average initial turbidities of (10, 20, 40, 70, 100, 150 and 200 NTU) were used in the runs Nos. (1, 2, 3, 4, 5, 6, and 7), in the runs Nos. (8, 9,10, 11, 12, 13, and 14), and in the runs Nos. (15, 16, 17, 18, 19, 20, and 21) respectively. The experimental operations were divided into three groups as follows:

3.1.1 First group (Run NO. 1 – Run NO. 7)

The results of the first group of experiments under the filtration velocity of 5 m/h show that the DF-Filter gives slightly higher removal efficiency rate than that of the UF-Filter for each run as presented in Figure 2. The reason of this is due to gravity effect on the removal efficiency of particles for downflow direction via sedimentation mechanism which leads to increase the capture of particles by the DF-Filter and this is in a good agreement with the study of [15]. The highest turbidity removal rate of the DF-Filter and the UF-Filter are 87.37 % and 83.07 %, respectively for run NO. 4 and the lowest turbidity removal rate are 77.43 % and 69.98 %, respectively for run NO. 1. The values of turbidity removal of the DF-Filter are of about (1.11, 1.19, 1.08, 1.05, 1.09, 1.1, and 1.07) times that of the UF-Filter for run Nos. 1, 2, 3, 4, 5, 6, and 7, respectively by an average value of 1.1 times. Thus, these differences in the removal efficiency of water turbidity of both filters can be considered as few values.

3.1.2 Second group (Run NO. 8 – Run NO. 14)

In this runs, the filtration velocity of 7.5 m/h is utilized. It is found that the average removal efficiency of the DF-Filter is higher than that of the UF-Filter under the same conditions, except under the initial turbidity level of 200 NTU, the average removal efficiency of water turbidity of both filters is significantly close to each other as shown in Figure 2. The maximum average removal efficiency of water turbidity of the DF-Filter and the UF-Filter is 77.69 % and 72.88 %, respectively for the run NO. 11, and the minimum average removal efficiency is 58.27 % and 56.5 %, respectively for the run NO. 14. The removal efficiency rate of turbidity of the DF-Filter is about (1.1, 1.1, 1.1, 1.07, 1.1, 1.07, and 1.03) times that of the UF-Filter for runs Nos. 8, 9, 10, 11, 12, 13, and 14, respectively by an average value of 1.08 times, and they can be considered as few values.
3.1.3 Third group (Run NO. 15 – Run NO. 21)

The filtration velocity of 10 m/h is used in each run. It is found that the DF-Filter has higher removal efficiency rate of water turbidity than the UF-Filter when the average values of the initial turbidity are 10, 20, 40, 70 NTU. Also, the results show that the removal efficiency rate of water turbidity of the DF-Filter is approximately close to the UF-Filter under the initial turbidity of 100 NTU, but the UF-Filter has a removal efficiency rate of turbidity greater than that of the DF-Filter when the values of water turbidity are 150 and 200 NTU as presented in Figure 2. It is also found that the maximum average filtration efficiency of the DF-Filter and the UF-Filter is 68.97 % and 62.22 %, respectively for run NO.16 and the minimum average filtration efficiency of the DF-Filter is 44.82 % for run NO. 21, whereas the minimum average filtration efficiency of the UF-Filter is 46.72 % for run NO.15. Also, the average removal efficiency of water turbidity of the DF-Filter is about (1.23, 1.11, 1.11, 1.14, and 1.04) times that of the UF-Filter of runs Nos. 15, 16, 17, 18, and 19, respectively by an average of 1.13 times. On the other hand, the average removal efficiency of water turbidity of the UF-Filter is about (1.09, 1.08) times that of the DF-Filter of runs Nos. 20 and 21, respectively by an average of 1.1 times. This may be due to the high filtration rate and the increase of influent turbidity that leads to an increase in the amount of suspended particles that flow into the two filtration columns and reduce the retention time of each filter, So the chances of the particles capture reduce in the granule bed by the mechanism of particles removal especially the sedimentation mechanism that differs between the DF-Filter and the UF-Filter and this is in a good agreement with the study of [16]. Consequently, the filtration efficiency of the DF-Filter decreases due to the decreasing of the effect of the particle’s removal mechanism by the gravitational sedimentation, while the filtration efficiency of the UF-Filter increases due to the increasing of the effect of the filtration depth, and this is in a good agreement with the study of [13]. Thus, the removal efficiency of water turbidity of the UF-Filter is greater than that of the DF-Filter for runs Nos. 20 and 21.
Figure 2. The relation between the average turbidity removal efficiency and the average initial turbidity of both filters of groups Nos. 1, 2 and 3 at under three filtration rates and a running time of 11 h.

3.2 Effects of the Filtration Rate

The effect of filtration velocity on the average filtration efficiency and the total head loss for DF-Filter and UF-Filter is presented in Figure 2 and Figure 3, respectively. Average removal efficiency and total head loss are usually calculated at the end of each experimental run. Generally, it is found that the increasing of the filtration rate leads to decrease the efficiency of filtration process (i.e. effluent turbidity increased) and increase the head loss of both types of filters. At the higher filtration velocities, the more amount of suspended particles flow to the filtration bed, and the contact time of suspended particles with the media grains decreases. Hence, some of these particles get out with the effluent water without any filtration mechanism such as interception, collision, and sedimentation. Therefore, the quality of the effluent water decreases and this result meets the data reported by [16]. On the other hand, increasing of the flow rate increases the collision between the suspended particles and the filter grains, it also increases fluid shearing force on captured particles, so particulate detachment can occur when the adhesive force between the suspended particles and the filter grains is less than the shear force. Thus, the effluent turbidity increases, and this is in a good agreement with the study of [13].
In the second group, the average removal efficiency of turbidity is less than that of the first group by (7.49, 10.88, 11.85, 9.67, 9.74, 16.07 and 20.75) % with an average of 12.35 % for the DF-Filter and by (6.23, 3.72, 12.71, 10.19, 9.99, 12.82 and 17.41) % with an average of 10.44 % for the UF-Filter in runs Nos. 8, 9, 10, 11, 12, 13, and 14, respectively. In the third group, the average removal efficiency of turbidity is also less than that of the second group by (12.25, 5.11, 10.38, 9.48, 12.68, 17.03 and 13.45) % with an average of 11.48 % for the DF-Filter and by (17.04, 5.32, 9.53, 13.09, 8.22, 7.94 and 7.82) % with an average of 9.85 % for the UF-Filter in runs Nos. 15, 16, 17, 18, 19, 20, and 21, respectively. Therefore, the removal efficiency of turbidity of the DF-Filter is affected by the increasing of the filtration rate more than that of the UF-Filter.

Under the same influent turbidity, it is also found that the average filtration efficiency of water turbidity of the UF-Filter under the filtration velocity of 5 and 7.5 m/h is higher than that of the DF-Filter under the filtration velocity of 7.5 and 10 m/h, respectively. On the other hand, the average removal efficiency of water turbidity of the UF-Filter of runs Nos. 9 and 16 under initial turbidity of 20 NTU is slightly less than that of the DF-Filter because the filter media was not replaced in both filters before starting a new run. As well as the backwash process redistributes the particles of the filter media and makes the settling of fine particles on the top zone of the filter media layer. Thus, the average removal efficiency of water turbidity of both filters increases as presented in Figure 2.

The results shown in Figure 3 reveals that the increasing of the filtration rate leads to increase the head loss of both filters and this in turns leads to decrease the running time of each filter. In the second group, the head loss is greater than that of the first group by (42.9, 58.4, 38.3, 37.1, 34.9, 32.3, and 31.0) % with an average of 39.3 % for the DF-Filter and by (18.5, 20.7, 28.6, 31.0, 29.8, 28.0, and 29.6) % with an average of 26.6 % for the UF-Filter in runs Nos. 8, 9, 10, 11, 12, 13, and, 14, respectively. In the third group, the head loss is also greater than that of the second group by (23.4, 15.4, 13.0, 17.3, 20.3, 21.7, and 19.3) % with an average of 18.6 % for the DF-Filter and by (22.9, 31.0, 31.4, 23.6, 19.0, 19.4, and 16.9) % with an average of 23.4 % for the UF-Filter in runs Nos. 15, 16, 17, 18, 19, 20, and 21, respectively.

It can also be seen that the head loss of the DF-Filter increased significantly when the backwash was performed before the starting of the experimental run in runs Nos. 9, 16 due to stratification of the sand media that takes place during the backwash cycle. The fine sand grains
settle on the top zone of the filter media layer, so the porosity of the top zone of the filter media layer reduces and this leads to get a high removal efficiency of turbidity in top layer of the DF-Filter. Hence, the head loss of the DF-Filter increases and this is agreed with the conclusion found by [17]. On the other hand, it is found that there is no noticeable effect of the head loss of the UF-Filter because this filter maintains the gradient of the media grains from coarse to fine even after backwashing and this is consistent with the study results of [13]. It can be concluded that if the backwash is carried out before each filtration process in the present study, the values of the filtration efficiency of both filters and the head loss of the DF-Filter increase while the head loss of the UF-Filter is not affected.

Figure 3 The relation between the total head loss and the average initial turbidity of both filters of groups Nos. 1, 2 and 3 under three filtration rates and the running time of 11 h.

3.3 The effect of the flow direction on the head loss

Based on the data collected from experimental work it can be concluded that the development of head loss of the UF-filter (i.e. pressure drop through filter media) is slower than that of the DF-Filter as shown in Table 1, 2, and Table 3. In particular, the head loss of the DF-Filter significantly occurs because most of the suspended particles of the turbid water do not penetrate the filter media deeply, while the head loss of the UF-Filter slowly occurs due to the efficient diffusion of these
particles within the depth of the filter media. Hence, the decrease of the head loss leads to an increase in the running time of the filter and this is compatible with the results obtained by [18].

Table 1. The head loss development of both filters for the first group under the filtration rate of 5 m/h and the running time of 11 h.

| Run NO. | initial Turbidity average (NTU) | time (h) | DF-Filter development head loss (cm) | UF-Filter development head loss (cm) | The difference at the end of the run % |
|---------|---------------------------------|----------|--------------------------------------|--------------------------------------|----------------------------------------|
| 1       | 10                              | (1 - 11) | 28 - 28                              | 21 - 22                              | 21.43                                  |
| 2       | 20                              | (1 - 11) | 29 - 32                              | 21 - 23                              | 28.13                                  |
| 3       | 40                              | (1 - 11) | 31 - 37                              | 22 - 25                              | 32.43                                  |
| 4       | 70                              | (1 - 11) | 33 - 39                              | 23 - 29                              | 25.64                                  |
| 5       | 100                             | (1 - 11) | 34 - 41                              | 26 - 33                              | 19.51                                  |
| 6       | 150                             | (1 - 11) | 36 - 44                              | 27 - 36                              | 18.18                                  |
| 7       | 200                             | (1 - 11) | 37 - 49                              | 28 - 38                              | 22.45                                  |

Table 2. The head loss development of both filters for the second group under the filtration rate of 7.5 m/h and the running time of 11 h.

| Run NO. | initial Turbidity average (NTU) | time (h) | DF-Filter development head loss (cm) | UF-Filter development head loss (cm) | The difference at the end of the run % |
|---------|---------------------------------|----------|--------------------------------------|--------------------------------------|----------------------------------------|
| 8       | 10                              | (1 - 11) | 41 - 49                              | 26 - 27                              | 44.90                                  |
| 9       | 20                              | (1 - 11) | 48 - 77                              | 27 - 29                              | 62.34                                  |
| 10      | 40                              | (1 - 11) | 42 - 60                              | 27 - 35                              | 41.67                                  |
| 11      | 70                              | (1 - 11) | 47 - 62                              | 32 - 42                              | 32.26                                  |
| 12      | 100                             | (1 - 11) | 48 - 63                              | 34 - 47                              | 25.40                                  |
Table 3. The head loss development of both filters for the third group under the filtration rate of 10 m/h and the running time of 11 h.

| Run NO. | Initial Turbidity average (NTU) | time (h) | DF-Filter Development head loss (cm) | UF-Filter Development head loss (cm) | The difference at the end of the run % |
|---------|---------------------------------|----------|--------------------------------------|--------------------------------------|----------------------------------------|
| 15      | 10                              | (1 - 11) | 52 - 64                              | 33 - 35                              | 45.31                                  |
| 16      | 20                              | (1 - 11) | 65 - 91                              | 37 - 42                              | 53.85                                  |
| 17      | 40                              | (1 - 11) | 54 - 69                              | 36 - 51                              | 26.09                                  |
| 18      | 70                              | (1 - 11) | 58 - 75                              | 43 - 55                              | 26.67                                  |
| 19      | 100                             | (1 - 11) | 60 - 79                              | 45 - 58                              | 26.58                                  |
| 20      | 150                             | (1 - 11) | 63 - 83                              | 47 - 62                              | 25.30                                  |
| 21      | 200                             | (1 - 11) | 65 - 88                              | 51 - 65                              | 26.14                                  |

3.4 Effect of Influent Turbidity Concentration

The analysis of results show that the increasing of an average initial turbidity leads to increase the turbidity of effluent water. On the other hand, it is also found that the average filtration efficiency increases with increasing of the turbidity of influent water up to 70 NTU, but it decreases under the turbidity of influent water of 100, 150, and 200 NTU. This may be attributed to the aggravation of the detachment of the accumulated deposits on the surface of the media grains, and this detachment considerably depends on the increase of the amount of influent turbidity. Therefore, the average filtration efficiency reduces at a high initial turbidity as shown in Figure 2. When the initial turbidity was increased, the head loss increased for both filters at the same operating conditions in all groups as shown in Figure 3. Thus, the high turbidity of the effluent water or the high head loss of the filter will decrease the filter runtime. These conclusions are in a well agreement with the results concluded by [19, 20].
Conclusions

The conclusions of the present study are drawn below:

1. Under the filtration velocities, 5, 7.5, and 10 m/ hr, the maximum average efficiency of turbidity removal of the DF-Filter is 87.37%, 77.69%, and 68.97%, respectively, and of the UF-Filter is 83.07%, 72.88%, and 62.22%, respectively.

2. It was concluded that the removal efficiency of water turbidity of the DF-Filter is about 1.1 times that of the UF-Filter. On the other hand, the UF-Filter has the turbidity removal efficiency greater than the DF-Filter by 1.1 times under the values of the initial turbidity greater than 150 NTU and the filtration velocity of 10 m/h. these differences in the removal efficiency of water turbidity of both filters can be considered as few values.

3. Under the filtration velocity of 7.5 m/h, the filtration efficiency value of turbidity of the DF-Filter and the UF-Filter decreases by about 12.35% and 10.44 %, respectively than their values under the filtration velocity of 5 m/h. Also, under the filtration velocity of 10 m/h, the filtration efficiency value of turbidity of the DF-Filter and the UF-Filter decreases by about 11.48 % and 9.85 %, respectively than their values under the filtration velocity of 7.5 m/h. This indicates that the DF-Filter was more affected by increasing the velocity of filtration.

4. Under the same operating conditions, the average filtration efficiency of turbidity of the UF-Filter under the filtration velocity of 5 and 7.5 m/h is higher than that of the DF-Filter under the filtration velocity of 7.5 and 10 m/h, respectively.

5. It could be concluded that under the same operational conditions, if the backwash is carried out before each filtration process in the present study, the values of the filtration efficiency of both filters and the head loss of the DF-Filter increase, while the head loss of the UF-Filter is not affected.

6. The head loss of the UF-filter at the end of each experimental run is less than that of the DF-Filter by about (18.18 % - 45.31 %) when the filter media is replaced and this range is increased to about (53.31 % - 62.34 %) when the backwash is performed prior to the start
of the experimental work. Thus, the decrease in head loss leads to an increase in the filter running time and decrease the number of backwash process.

7. It is found that the average filtration efficiency increases with the increasing of the turbidity of influent water up to 70 NTU, but it decreases under the turbidity of influent water of 100, 150, and 200 NTU.

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