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# Modelling of the Fabrics Filtration to Remove the Turbidity from the Extracted Groundwater

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**Abstract**

Fabrics filtration through capillary action is an effective tool for treating water at the site of use. It is applied in reducing the turbidity of the extracted groundwater to below the permissible limit in accordance with international standards, provided that the other parameters are met. The present study intends to evaluate the treated water quality after filtration using fabric capillary action in viewpoints of the turbidity removal and the filter run length using non-woven fabrics. In addition to deriving the design equation of the model and ensure its validity. The obtained results revealed that the optimum range of the filtration rate is between 5-10 m/d to guarantee that the filtered water turbidity to be consistent with the international standards of potable water. Furthermore, the filter unit was mathematically modelled to derive its design equation as well as estimating the filter run length by indicating values of the other parameters in the recommended range of the filtration rate.

***Keywords:*** Fabric capillary action; filtration; turbidity removal; water treatment.

## 1. Introduction

Residents of the unplanned residential areas suffer from lack of access to safe potable water from public water distribution networks. In Egypt, this problem is usually solved by extracting groundwater to serve limited residential communities. In this manner, El-Sayed [1] reported that about 78.79% of groundwater is safe for potable uses in Egypt. However, the groundwater quality needs to be monitored and sometimes the extracted groundwater needs specified treatment at the site of use [1, 2-7]. In situ treatment principally intends to reduce the extracted groundwater turbidity to less than the permissible limit according to the international standards [8]. However, many treatment technologies have failed in the site of use because of the relatively high running costs as well as the need for proficient operators.

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Therefore, the potable water supply to the unplanned residential areas is a major challenge [4, 6].

There are various uses of fabrics in water filtration applications, e.g. house filter and membranes. For a period of time ranging from five to ten years, the authors in [4, 5, 9] created a novel water filtration technique based on fabric capillary action. The idea of capillary action is that the liquid transfers throughout the permeable spaces in a solid, attributable to the forces of adhesion, cohesion, and surface tension [10].

The authors in [4, 5] achieved the perception of the filter employing the fabric capillary action after conducting field and laboratory investigations.  This observation accomplished by conveying the water from a channel to another through non-woven fabrics on the basis of capillary action concept, leaving the turbidity, suspended solids, in addition to other pollutants at the inlet channel while the rest of pollutants retained across the fabrics. This system has been applied by Ayoub [11] for removing the iron and manganese from the groundwater to reach acceptable values for use in potable purposes.

The authors in [4,5] used synthetic turbid water to simulate the raw water influent to the filtration system and the influent turbidity was up to 21 NTU while the filtered water turbidity was less than 0.9 NTU. Moreover, the removal efficiencies of algae and bacteria reached up to 98% and 97% respectively. Fadel [5] reported that the proposed water filtration system using fabrics is more advantageous than the slow sand filters in viewpoints of the net water production, the fixed and operating costs with the same occupied area. Hence, the fabric capillary action is a promising technique for water filtration. On the other hand, El-Gamal and his colleagues [4] recommended further work to create the adequate design criteria for the filtration system using fabric capillary action.

This work intends to evaluate the treated water quality after filtration using fabric capillary action in viewpoints of the turbidity removal and the filter run length. In the present study, the non-woven fabrics were selected as filter media. In this manner, the inlet water to the filter was extracted from a private groundwater well in El-Mahalla El-Koubra City, Egypt. Moreover, the practical results were compiled and analyzed with a view to investigate the adequate design criteria and deriving the design equations for the filtration system using fabric capillary action and applying it for the mentioned case study.

## 2. Methodology

The experimental work was conducted in light of the water treatment system created by the authors in [4, 5] to control the quality and quantity of treated water after filtration using the fabric capillary action. Furthermore, the filtration system was mathematically modelled to facilitate its design.

### *2.1. Study area*

The experimental work was conducted in the location of a private groundwater well located in an unplanned residential area located in Abu-Rady District, El-Mahalla El-Koubra City, El-Gharbia Governorate, about 130 km north Cairo, Egypt. The water entering the filtration system was collected from the groundwater extracted from the previously mentioned groundwater well.

### *2.2. Water quality and sampling*

The extracted groundwater samples were collected before conducting the experimental program during April-July 2017 for analyzing the different groundwater characteristics.

Additionally, the various results were statistically treated as shown in table (1). However, the turbidity was the selected parameter to evaluate the filtration using fabric capillary action via portable turbidimeter HACH® 2100Q to measure the inlet and filtered water quality.

These analyses were completed according to the Standard Methods for the Examination of Water and Wastewater [12].

**Table 1:** Descriptive statistics of the extracted groundwater parameters and the standard values according to [8]

| Parameter | Results of the statistical analysis | | | | Standards [8] |
|---|---|---|---|---|---|
| | Max. | Min. | Mean | Standard deviation | |
| pH | 8.5 | 7.7 | 8.2 | 0.35 | 8.0 |
| Turbidity, NTU | 4.8 | 3.1 | 4.2 | 0.44 | 1.0 |
| Total hardness (TH), mg/L | 233 | 108 | 175 | 21.2 | 300 |
| Total dissolved solids (TDS), mg/L | 325 | 234 | 266 | 26.8 | 500 |
| Calcium ($Ca^{+2}$), mg/L | 73 | 40 | 54 | 12.8 | 75 |
| Magnesium ($Mg^{+2}$), mg/L | 43 | 26 | 32 | 7.4 | 30 |
| Chlorides ($Cl^{-}$), mg/L | 91 | 73 | 57 | 14.4 | 250 |
| Sulfates ($SO_4^{-2}$), mg/L | 112 | 84 | 96 | 13.6 | 200 |
| Nitrates ($NO_3^{-}$), mg/L | 8.3 | 4.8 | 5.4 | 1.5 | 45 |

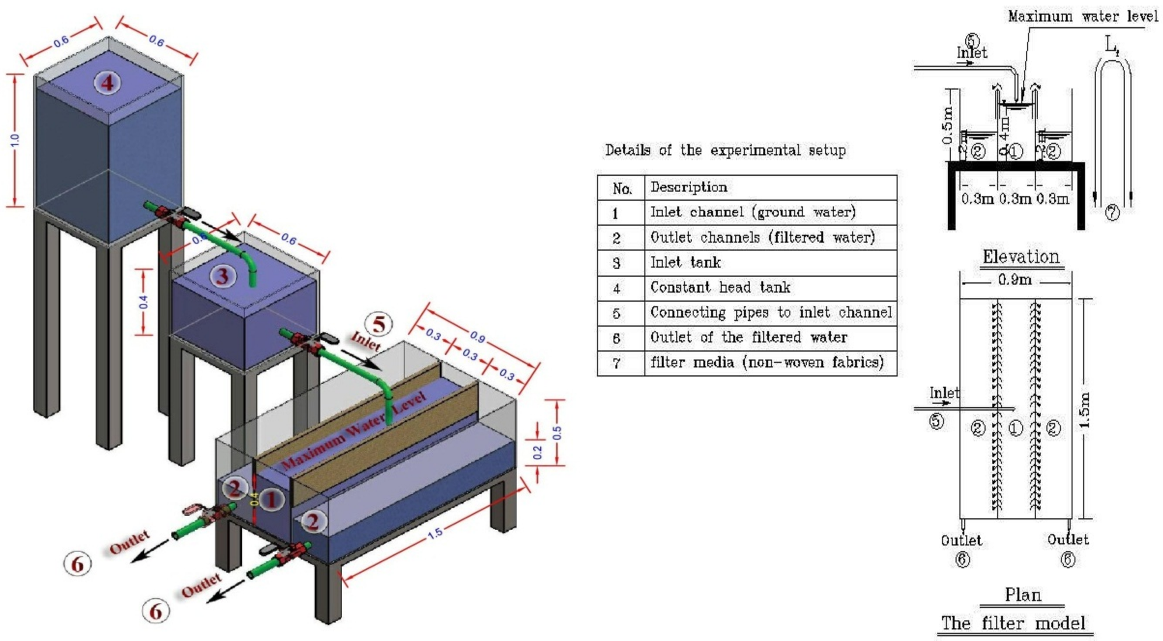
### *2.3. The filter model*

In the present study, the filter model was designed to conform to the innovative design of the water filtration framework created by the authors in [4, 5].

This model was designed to filter 6-24 $m^3$/d of the extracted groundwater where the filtration rate (ROF) ranges between 5-20 m/d to evaluate the effect of ascending filtration rate on the turbidity removal efficiency as well as running length of the filter, which is terminated when the effluent flow declines to less than 85% of the flow at beginning of the filtration runtime according to El-Gamal and his colleagues [4].

The filter unit was fabricated from metal sheets with a thickness of 0.7 mm.

Components of the experimental setup are shown in figure (1-a), whereas figure (1-b) appears the filter model and description of the whole components of the filtration system.




(a) (b)

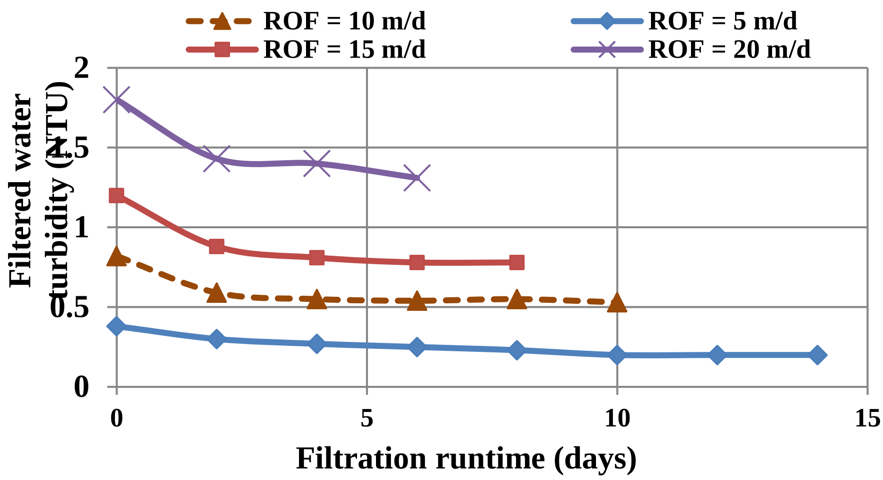
**Figure 1:** A schematic diagram of the experimental setup of filtration system using the fabric capillary action in (a) an isometric view, (b) a projection of the filter model with a tabulated description of the whole system [11]

The experimental setup mainly consists of a constant head tank, inlet tank, and the filter model tank divided into an inlet channel in the middle of the filter and two adjacent outlet channels, which gather the filtered water. Dimensions of the filter model are 1.5 m of length, 0.9 m of width, and 0.5 m of depth. The fabrics were placed above the inlet channel to absorb the inlet water, then filtering it via capillary action. Moreover, the fabric specifications are new-nonwoven polyester (100% polyester), with a thickness of 1.65 mm, dimensions of 0.8m*1.5m, weight per area of 480 gm/m$^2$, and 98% of the surface porosity that conformed with the fabric specifications recommended by the authors in [4,5].

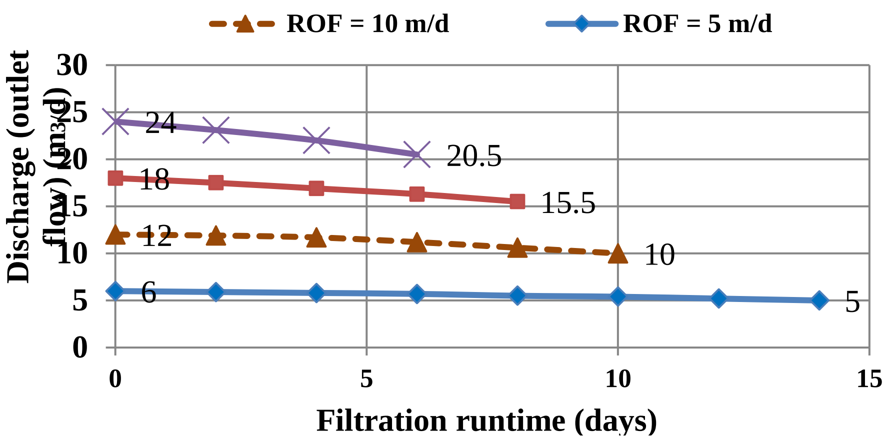
## 3. Results and discussion

### *3.1. The filtered water turbidity*

The filtered water turbidity was measured through the experimental program as indicated by different filtration rates ranged between 5-20 m/d as shown in figure (2-a). The filter run length ($t_f$) was experimentally determined when the effluent flow declines to 85% of the flow at the initial runtime of the filter as appeared in figure (2-b) by terminating the filtration process promptly. On the other hand, it is noticed that the filtered water turbidity values were ranged between 0.21-0.38 NTU at a filtration rate of 5 m/d, 0.53-0.82 NTU at a filtration rate of 10 m/d, 0.78-1.2 NTU at a filtration rate of 15 m/d, and finally 1.31-1.8 NTU at a filtration rate of 20 m/d. It is observed that the turbidity values are relatively improved when the filtration rate is lower due to a slowing of the water transfer throughout the permeable spaces in a solid, attributable to the forces of adhesion, cohesion, and surface tension as mentioned before in [10]. Therefore, the optimum range of the filtration rate is between 5-10 m/d to guarantee that the filtered water turbidity to be consistent with the international standards of potable water [8]. Hence, the recommended filtration rate using fabric capillary action is compatible with that detailed in [4, 5, 11].




(a)




(b)

**Figure 2:** Observed values of (a) the filtered water turbidity (NTU), and (b) the effluent flow through the experimental program

### *3.2. Model development and deriving the design equation*

The deriving of the design equation depends mainly on the dimensional analysis [13] by creating a mathematical relationship that links the effluent flow from the filter (Q) on the one hand while, the filtration time (t) and the length of the filtration path ($L_f$) are dependent variables on the other as follows:

$$Q = f(t, L_f) = kt^a L_f^{\ b} \rightarrow (1)$$

Where:

- Q = the effluent flow from the filter ($m^3$/d),
- t= the filtration time observed from the beginning (d),
- $L_f$= Length of the filter path (m), and
- k= an empirical coefficient deduced below.

The equation (1) should be dimensionally homogeneous [13]. Thus, the exponent of each quantity must be the equal on each side of the equation as follows:

$$\therefore L^3T^{-1} = T^aL^b$$

$$\therefore a = -1, b = 3$$

$$\therefore Q = k\frac{{L_f}^3}{t} \rightarrow (2)$$

By applying the boundary conditions, at the effluent flow at the initial runtime of the filter of $Q_0$, and beginning of the filtration runtime of $t_0$, substituting in equation (2):

$$\therefore Q_0 = k\frac{{L_f}^3}{t_0} \rightarrow (3)$$

Similarly, by applying the boundary conditions, at the effluent flow at the end of the filter run length of $Q_f$ , and the filter run length of $t_f$, substituting in equation (2):

$$\therefore Q_f = k\frac{{L_f}^3}{t_f} \rightarrow (4)$$

From the equations (3), and (4)

$$\therefore Q_0 - Q_f = k{L_f}^3(\frac{1}{t_0} - \frac{1}{t_f}) \rightarrow (5)$$

Assume that the allowable reduction in the effluent flow does not exceed than 15% of the effluent flow at the beginning of the filtration runtime [4]:

$$\therefore Q_f = 0.85Q_0 \rightarrow (6)$$

From the equations (5), and (6)

$$\therefore Q_0 = \frac{kL_f^{\ 3}}{0.15}\left(\frac{1}{t_0} - \frac{1}{t_f}\right) \rightarrow (7)$$

The empirical coefficient (k) resulted from the dimensional analysis as explained in equation (7) can be deduced using a linear regression from the sketched relationship between the empirical coefficient (k) and the filtration rate as appeared in figure (3), where their values were attained after operating the filter with different filtration rates.

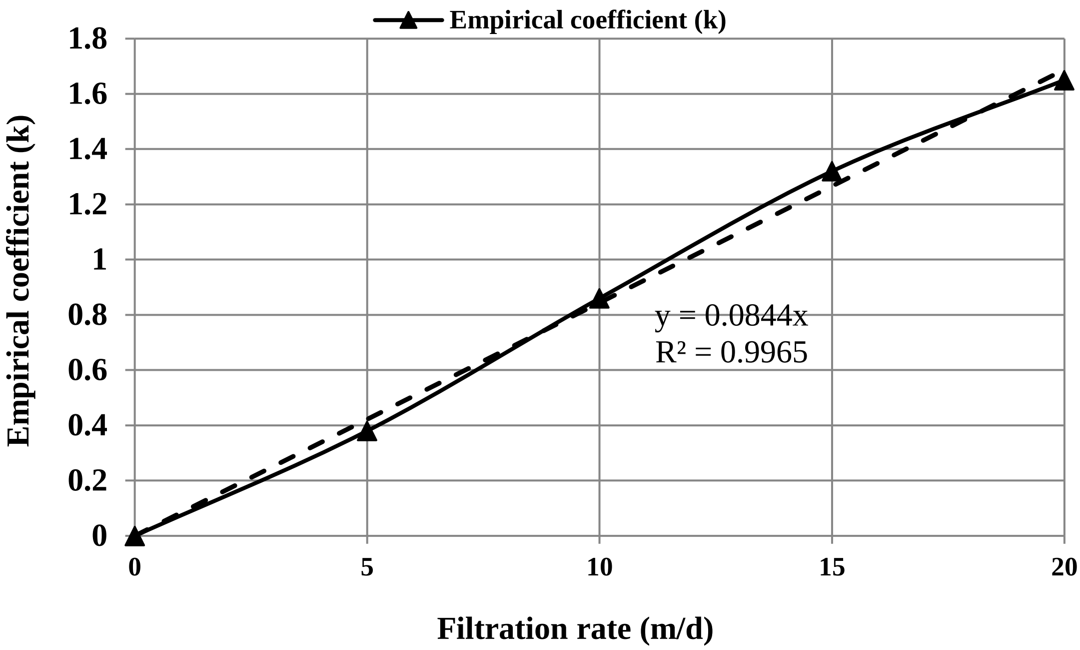



**Figure 3:** The empirical coefficient versus the filtration rate

Figure (3) shows the strong correlation between the empirical coefficient (k) and the filtration rate where the value of $R^2$ is 0.996 for the linear regression equation of y = 0.084 x. Therefore, the best fit equation can be used to complete deriving of the design equation as follows:

$$\therefore k = 0.084ROF \rightarrow (8)$$

Substituting in equation (7)

$$\therefore Q_0 = 0.56(ROF)L_f^{\ 3}\left(\frac{t_f - t_0}{t_f t_0}\right) \rightarrow (9)$$

Figure (4) represents the relationship between the filter run length ($t_f$) and the filtration rate (ROF), where the regression analysis was conducted to attain the best fit equation accompanied by the $R^2$ value of 0.975. Furthermore, figure (4) appears values of the initial runtime of the filter ($t_0$) in minutes. Therefore, the best fit equation can be used to complete deriving of the design equation.

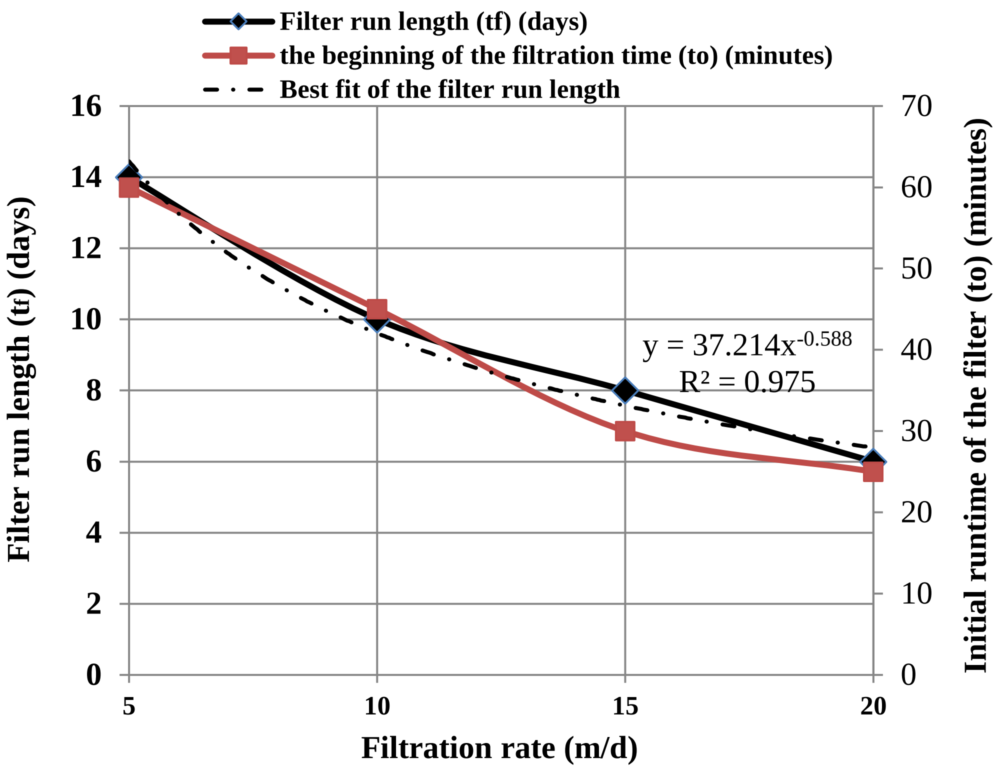



**Figure 4:** The filter run length and the initial runtime of the filter versus the filtration rate

$$\therefore t_f = 37.21(ROF)^{-0.58} \rightarrow (10)$$

$$\therefore ROF = \frac{510.54}{t_f^{1.72}} \rightarrow (11)$$

Substituting in equation (9) to find the final design equation as follow:

$$\therefore Q_0 = 286 L_f^{3} \left(\frac{t_f - t_0}{t_f^{2.72} t_0}\right) \rightarrow (12)$$

Where:

- $Q_0$ = the effluent flow at the initial runtime of the filter ($m^3$/d),
- $L_f$ = Length of the filter path (m),
- $t_f$= the filter run length (d), and
- $t_0$ = the initial runtime of the filter (d),

### *3.3. Model validation*

The validity of the derived equation (12) is evaluated by using it to calculate the filter run length by informing the remaining components of the equation as explained before and then comparing the results with the values of filter run length obtained from the experimental program. Figure (5) shows a comparison between the values of the filter run length calculated by the derived equation (12) and their corresponding values obtained experimentally. It is noticed that the difference between the two corresponding values ranges from 3% to 13.6% at the filtration rate between 5-10 m / day to, while the maximum difference is 48.3% at a filtration rate of 20 m/d. Therefore, the design equation is valid for estimating the filter run length by indicating values of the other parameters in the recommended range of the filtration rate (i.e. 5-10 m/d).

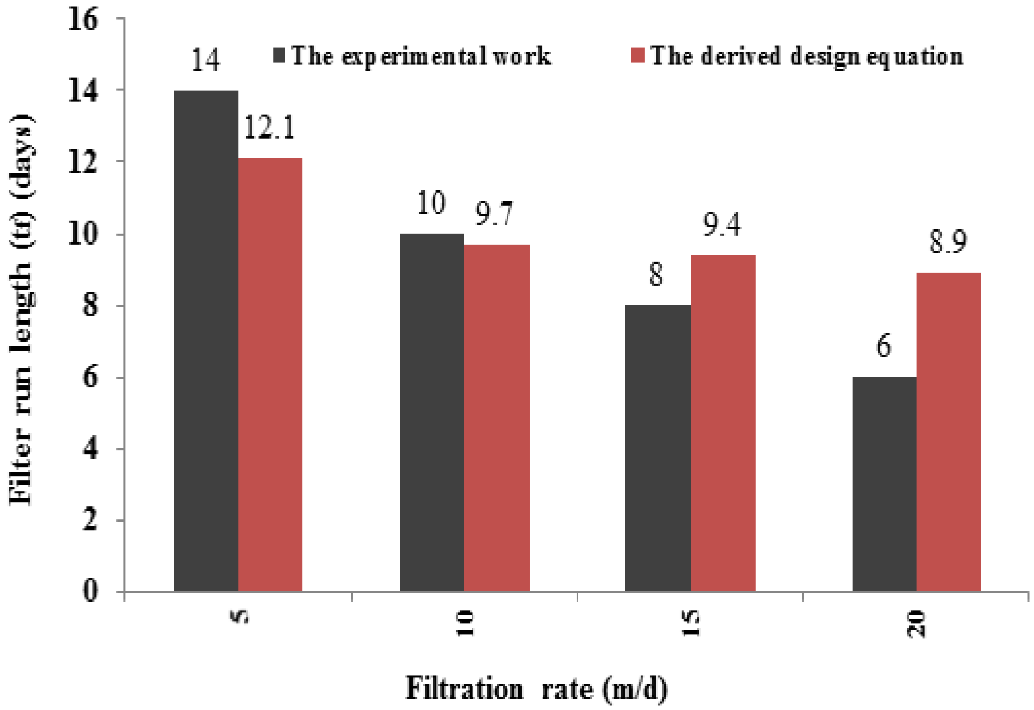



**Figure 5:** The filter run length versus the filtration rate

**4. Conclusions**

Fabrics filtration through capillary action is an effective tool for treating water at the site of use. It is applied in reducing the turbidity of the extracted groundwater to below the permissible limit of the international standards, provided that the other parameters are met. The obtained results revealed that the optimum range (design criteria) of the filtration rate is between 5-10 m/d to obtain a filtered water turbidity of less than 1.0 NTU. In addition, the estimated values of filter run length using a derived design equation are convergent with those obtained experimentally. The filter run lengths are between 10 to 14 days for the filtration rates of 10 to 5 m/d respectively. Therefore, the filtration using fabric capillary is simple and does not need for proficient manpower. However, this work can be extended to study the fabrics filtration efficiency for various groundwater resources.

**References**

[1] El-Sayed, S.A. (2018). Study of groundwater in northeast Cairo area, Egypt. Journal of Geoscience and

Environment Protection, 6: 229-251.

[2] Clasen, T; and Smith, L. (2005).The Drinking Water Response to the Indian Ocean Tsunami, Including the Role of Household Water Treatment. Geneva. World Health Organization.

[3] IFRC (2008).Household water treatment and safe storage in emergencies. Geneva. International Federation of Red Cross and Red Crescent Societies (IFRC).

[4] El-Gamal, H.F; El-Hadidy, A.M; and Fadel, H.A. (2013).Investigation of a new water treatment method: By fabric capillary action. The 17$^{th}$ International Water Technology Conference, 5–7 November 2013, Istanbul, Turkey.

[5] Fadel, H.A. (2014). Water treatment by fabric capillary action: New technologies with ancient origins. American Water Works Association, 106(12): 44-50.

[6] Yevate, A; and Mane, S. (2017).Low cost water purifier by using natural herbs. International Journal for Science and Advance Research In Technology, 3(9): 112-115.

[7] Acharya, S; Sharma, S.K; and Khandegar, V. (2018).Hydro geochemical assessment of groundwater quality in vicinity of Dwarka, Delhi .Pollution Research, 37(1): 209-220.

[8] WHO.(2011).Guidelines for Drinking-water Quality. Fourth Edition, World Health Organization.

[9] Fadel, A; El-Hadidy, A; and Fadel, H. (2012). New water treatment method: By fabric capillary action. Proc. AWWA, Annual Conference and Exposition, Dallas, Texas.

[10] Hartland, S. (2004).Surface and Interfacial Tension: Measurement, Theory, and Applications . Surfactants Science Series, Volume (119), Marcel Dekker, Inc. USA.

[11] Ayoub, M. (2018). Removal of iron and manganese by the fabric capillary action. The International Journal of Engineering and Science, 7(10): 28-31.

[12] APHA (2012). Standard Methods for the Examination of Water and Wastewater. 22$^{nd}$edition. APHA, AWWA, and WEF, Washington.

[13] Young, D.F; Munson, B.R; Okiishi, T.H; and Huebsch, W.W. (2007).A Brief Introduction to Fluid Mechanics.4th edition, John Wiley & Sons, Inc., USA.