DIRECT IN-LINE FILTRATION OF TURBID WATER THROUGH FLOATING MEDIA

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ABSTRACT

Filtration as a unit operation is commonly used in municipal water purification plants to produce high quality potable water to comply with stringent potable water quality standards. This study was conducted to evaluate the expanded polystyrene foam beads as a filtrating media in in-line direct filtration mode. The hydraulic properties of the foam beads as a filtering media have been determined. The optimum operational conditions to produce treated water turbidity less than 1.0 NTU for at least 8 hr. of operation continuously without head loss more than 0.90 m have been investigated. A pilot plant was constructed and installed in the laboratory of sanitary engineering in the faculty of engineering El-Mansoura University. The design of the pilot plant facilitates the measuring of turbidity and head loss at different depths of the filter media. The experimental work was planned to be done in two phases. The first phase was designated to study the hydraulic properties of the foam media. The second phase was to study the operation conditions and the behavior of the different sizes of foam beads as a filtrating media. Experimental results showed that the foam filtration media have small initial head loss. To facilitate the washing of dirties, the expansion of the foam media bed must be about 25%. The washing velocity of media depends on the media size and the required expansion percentage. The expanded polystyrene can be successfully used as an alternative filtration media in the rapid filters for water purification.

Keywords: Direct Water Filtration, Expanded Polystyrene Beads

1 INTRODUCTION

The World Health Organization (WHO) estimated that approximately 22% of the population does not have good access to potable water (Marsidi, 2018). The principal goal of water treatment plants is to minimize the risks from biological, chemical and physical contaminants in raw water by reducing them to acceptable levels. Conventional treatment systems mainly comprise coagulation; flocculation, sedimentation, filtration, and disinfection before treated water are discharged to consumers. A conventional water treatment plant performs well for low-level organic and inorganic contaminants. Rapid sand filters are usually used after coagulation and flocculation and are primarily utilized to remove turbidity.

Depth Filtration is the removal of suspended material within and on the surface of the filter bed. The filter media used in deep filters is coarse particle with size (0.15-3.0 mm) and depth of (1.8 - 2.4 m) where the media is cleaned in place and put back into service. In general, as the filter media size becomes larger, the depth of media required to produce a specific water quality becomes more (Cleasby & Logsdon 1999). Sand media backwashing result in a hydraulic grading of filtering media bringing the fine grains to the top of the bed and the coarser one at the bottom. So, in down-flow filtration the raw water to be treated comes first into contact with fine filtering materials, which clogs easily with rapid increasing of the filter resistance and shortened the filtration run.

Direct filtration is a surface water treatment process that includes coagulant addition, rapid mixing, flocculation, and filtration. In some cases, the flocculation tank is omitted, and the process is referred to as direct in-line filtration with flocculation occurring in the filter itself (Fadel, 1984, Cleasby & Logsdon 1999).

Recently, a number of new synthetic filter-media such as foam plastic media have been developed, which are called floating media and are now available for the filtration of water and wastewater. Foam plastic media are manufactured from polyvinyl chloride, polyurethane, polyethylene, and polypropylene or other polymer materials. The synthetic floating media can be used as contact flocculator or/and in place of sand for deep bed filtration (Ben Aim *et al.*,1993; Ngo & Vigneswaran 1995; Visvanathan *et al.*,1996; El-Etriby & Myrzakhmetov 1997; Chiemchaisri *et al.,* 2003; Chiemchaisri *et al.*, 2009; Kwon *et al.*, 2014).

Floating media filters differ from the conventional sand filters in many ways. First, because of its specific gravity, which is less than 1.0, therefore a retaining grate is placed at the top of the filter in order to maintain the media inside the filter in submerged state. Second, under the action of floating force, the grains (beads) of filter media are sorted downward for size, with the large grain size at the top of the filter and the small one at the bottom. So, the direction of downward filtration simply coincides with the direction of a uniform decrease in pore size through the filter depth. Third, floating media filters are washed with down-flow water, therefore the media expands downward and the gravitational force direction of the deposited solids coincides with the direction of wash water, so that the required volume of water for washing is less than for sand filters (Jorba, 1980; El-Etriby & Myrzakhmetov 1997). There is no need for air in washing process. Floating media filters are also claimed to have high storage capacity and low head loss development compared to the conventional sand filters (Chiemchaisri *et al.,* 2003; Kwon *et al.*, 2014).

During the filtration of chemically pretreated water through the floating media filters, the flocculation process can take place through the media itself (Ngo & Vigneswaran 1995). So, floating filter media has led to the creation of remarkable advancements in the filter operation and in design, where more than a treatment process can occur in the same unit (Chiemchaisri *et al.*, 2003; Kwon *et al.*, 2014).

Expanded polystyrene beads filters are effective and promising not only for potable water purification but also for sewage filtration. In advanced wastewater treatment filtration study (El-Etriby & Myrzakhmetov 1997), up to a filtration rate of 15.8 m/hr, the filtrate quality improved as filtration run progressed and deterioration of filtrate quality was not observed at the end of the filter runs (56-57hr), where total head loss was 2.0 m. The wash water volume required was around 1.0% of filtrated water. The successful experimental results lead to recommend the use of expanded polystyrene beads filters for secondary effluent treated wastewater.

The scope of this research is the evaluation of expanded polystyrene foam beads as a filtrating media in direct filtration mode. Specifically, the main objectives of this study were the following:-

1 Determination of the hydraulic properties of the foam beads as a filtering media, (i.e. head loss and media expansion percentage with different velocity)
2 Investigate the effect of operational conditions on the filtration process performance (i.e. filtration rate, alum dose, media size, layer configuration and flow direction)

2 METHODS, MATERIALS AND EQUIPMENTS

The research work was planned to be in two phases.

1. First phase was to study the hydraulic properties of the foam media.
2- Second phase was to study the effect of operational conditions on the filter performance and treated water quality.

A pilot plant was constructed to conduct a series of laboratory experiments. The pilot plant design allows the measurement of turbidity and head loss through the various depths of filter media. It was installed in the laboratory of sanitary engineering in the faculty of engineering El-Mansoura University.

As shown in figure (1), the pilot plant consisted of the following main parts:- 1- Storage tanks, 2- Constant head tank, 3- Alum storage tank, 4- Coagulant dosing system, 5- Filtration column, 6- Piezometric table for measuring head loss through the filter media, and 7- Ratometer for measuring the flow of washing water.

The filtration column was a perspex pipe with a length of 3 m and a diameter of 0.135 m. A Perspex cone was fixed in the bottom of the column, and provided with the outlet pipe of diameter 19.0 mm. A screen was fixed at the height of 2.0 m to prevent the escaping of the media. During the filtration mode the media was fully submerged, so the outlet level of the filtrate water must be higher than the level of that screen. The column had each 0.10 m a sample point for taking water samples, and to measure the head at these points. The operation of the pilot plant was controlled by 11 valves. The valves position and the piping connection allowed either normal down-flow filtration operation, or up-flow filtration and washing the filter media.

Different beads sizes of these media were used; firstly foam beads of size (3.0 - 4.0) mm were studied. Secondary, the size (1.6 - 2.0) mm was used and finally the graded crushed foam media was used. The crushed foam sizes were in range 0.6 – 4.0 mm with effective size 1.7 mm and uniformity coefficient 1.84. The dual layers of beads size (3.0 - 4.0) mm and beads size (1.6 - 2.0) mm or crushed foam media were also studied. The media depth in the filtration column was about 100 cm. The physical characteristics of the used media are shown in table (1).

Table 1. Characteristic of Used Foam Media.

Media size, mm	Density, kg/m^3	Porosity, %
Beads 3- 4	15.23	37.23
Beads 1.6-2.0	33.7	38.7
Crushed foam 0.6-4.0	24.95	44.26

Nephelometric turbidimeter model Lamotte2020 was used to measure the turbidity. The coagulant used in this study was aluminum sulfate $Al_2(SO_4)_3.16\ H_2O$. The dose was expressed in the form Al^{+3}, each 1.0 mg Al^{+3} /lit equal 11.68 mg /lit as $Al_2(SO_4)_3.16\ H_2O$.

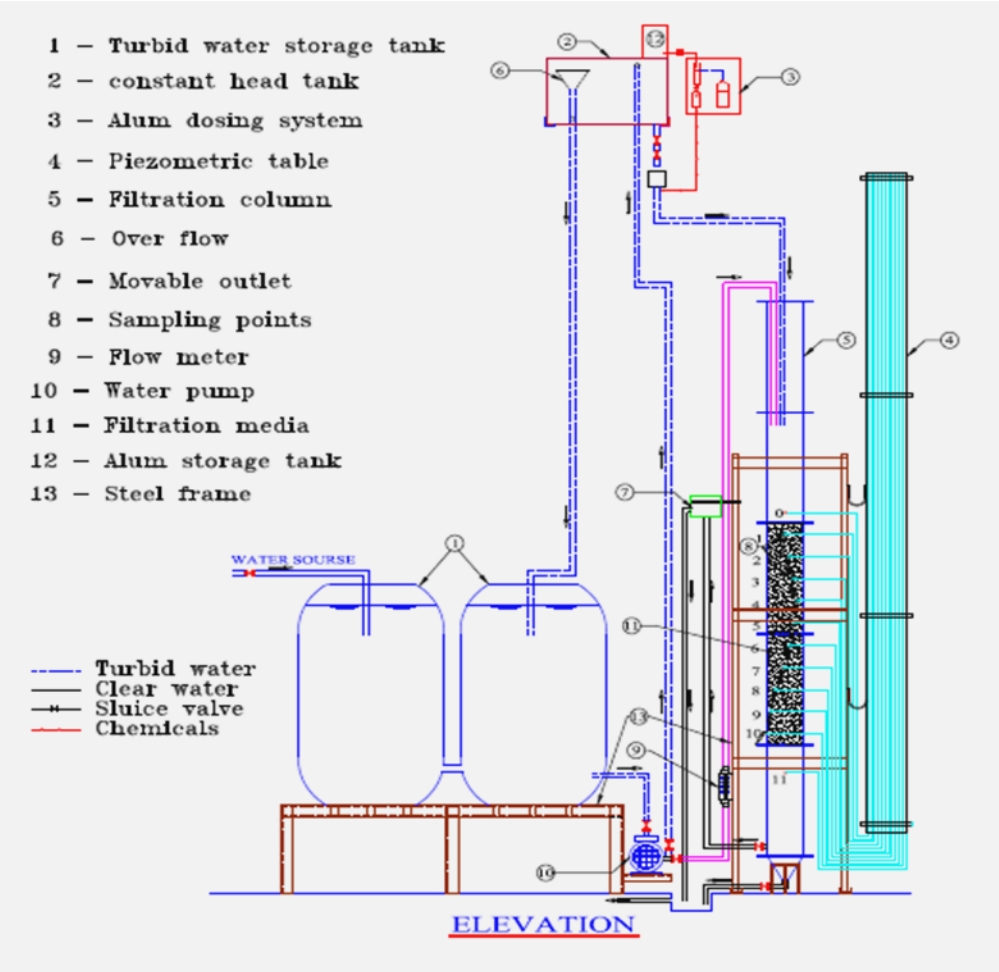

Figure 1. The pilot plant

Synthetic turbid water was prepared by using tap water and bentonite or fine local clay. The bentonite used in this study was produced by Egypt Bentonite & Derivation Company, Alexandria. The fine clay with particle size less than 63 micron was used for preparing the required clay turbid water. The synthetic turbid water was prepared in two levels, low turbidity in the range of 9-13NTU, and moderate turbidity in the range of 17-25 NTU.

To expect the suitable coagulant dose for each turbidity level a standard jar test was conducted. The suitable alum dose for various turbidity levels and raw water types was determined as shown in table (2).

Table 2. Predicted alum dose for various turbidity levels.

Turbidity level	Predicted dose mg Al^{+3}/lit
Low level of bentonite turbid water	2.0
Moderate level of bentonite turbid water	3.5
Low level of clay turbid water	1.5
Moderate level of clay turbid water	3.0
Natural surface water	3.0

The run was considered successful if the following three conditions were achieved. The effluent turbidity was less than 1.0 NTU; the head loss was less than 0.8 m; and the run length was equal to or greater than 8.0 hours.

2.1 Filter Run Comparison Criteria

Two comparison criteria were used to evaluate the filter runs and comparing between them. The first criteria was the theoretical depth index (Ks) proposed by Jorba (1980, 1992). The theoretical depth index (Ks) is direct proportion to the depth of filtration media and inversely proportion to the average raw water turbidity, filtration rate and length of filter run. The theoretical depth index criterion can be expressed by the following form:

$$Ks = \frac{\Psi x}{v\, t\, c_o} \qquad (1)$$

Where:

Ψ = Constant of the proportionality
x = Media depth, m
v = Rate of filtration, m/hr
t = Run length, hr
C_o = Average turbidity of raw water, NTU

The constant of the proportionality Ψ depends upon the technological characteristics of the filter such as the type and size of the filtering media, the number of layers, the direction of the filtration process,……act. For making a comparison between a set of runs conducted in the same filter, this constant can be equal 1.0 and the value of the theoretical depth index criterion can be calculated by using the following expression:

$$Ks = \frac{x}{v\, t\, c_o} \qquad (2)$$

From expression (2), it is clear that as the depth of the filtering media is more utilized and a higher quantity of turbidity can be removed the value of the theoretical depth index (Ks) decreased. So, in case of the filter run has less theoretical depth index (Ks), this means that a better combination of the variables appeared in expression (2) have been already realized.

The second criterion was the filter capacity (X), NTU - cubic meter of turbidity removed per meter of head loss (Mintz, 1966, Fadel, 1984) . The filter capacity can be calculated by the following expression:-

$$X = \frac{(c_o - c_e).v.a.t}{h} \qquad (3)$$

Where:

C_o = Average turbidity of raw water, NTU.
C_e = Average turbidity of filtrate, NTU.
v = Rate of filtration, m/hr.
a = Filter area, m^2.
t = Run length, hr.
h = Head loss due to solid accumulation, m

From expression (3), it is clear that as X value increased the filter productivity is also increased.

3 RESULTS AND DISCUSSION

3.1. Hydraulic Properties of Foam Beads as a Filtration Media

Using clean water, the hydraulic properties of the foam beads as a filtration media was determined. The hydraulic gradient through different beads size of media was measured at different down-flow velocities that shown in figure (2). In this figure it is clear that, at velocities up to about 45 m/hr the media is stable, and the hydraulic gradient increase linearly with increasing the velocity. Generally, for each media size there is a critical velocity at which the pressure drops essentially balance the up lift force on the media particles. At the velocity higher than that critical velocity, the particles begin to move down in the flow direction by drag force, i.e. start to fluidize. The initial hydraulic gradient of the used media has a maximum value of 0.12 m at filtration rate up to 12.5 m/hr.

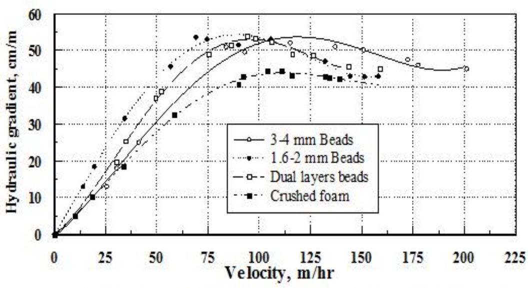

Figure 2. The relation between the down-flow velocity and the hydraulic gradient of foam beads media

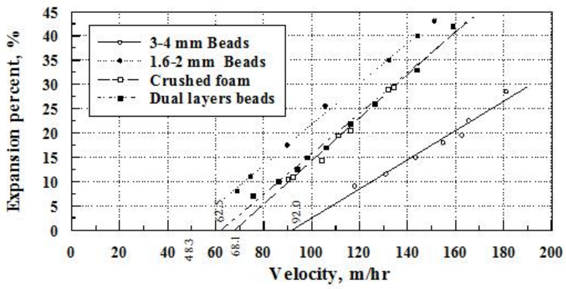

Figure 3. The relation between down-flow velocity and media expansion percentage

The expansion percent of different beads size of foam media was measured at different velocities. The relations between media expansion and velocities are shown in figure (3). The relations can be expressed as a liner equation as shown below.

For 3-4 mm media size,

$$V_{3-4} = 3.325\, e + 92.0 \quad (4)$$

For 1.6-2 mm media size,

$$V_{1.6-2.0} = 2.382\, e + 48.31 \quad (5)$$

For dual layers media,

$$V_{d.l} = 2.25\, e + 68.1 \quad (6)$$

For crushed media,

$$V_{crushed} = 2.4\, e + 62.48 \quad (7)$$

Where:

V = Down flow water velocity, m/hr, e = media expansion, %

During media washing process, the wash down water velocity must be greater than the critical velocity to fulfill certain expanded depth. Experimentally, it was found that the expansion of the media must be greater or equal 25% in pulsing mode using quick open-close wash valve for about 3 minutes to achieve adequate media cleaning.

The critical velocity, where e = 0.0, and the required backwash velocity, at e =25%, for different filter media were determined from the above equations and listed in table -3.

Table 3. Critical velocity and the required backwash velocity

Media condition	3 – 4 mm	1.6 – 2.0 mm	Dual layers	Crushed Foam
Critical Velocity, m/hr	92.0	48.30	68.10	62.50
Backwash Velocity, m/hr	175.13	107.86	124.35	122.50

3.2. Limits of Filtration Variables

3.2.1 Filtration Process through Foam Media of Beads Size (3– 4) mm.

A 25 runs were executed using only bentonite turbid water. These runs were classified to 4 groups, (1 to 4), according to the flow direction and the level of water turbidity. All runs were terminated due to turbidity breakthrough. Table (4) shows the average results of these runs and the calculated values of the comparison criteria Ks and X.

In the experimental runs of group 1, the maximum filtration rate that fulfilled the required conditions of the successful run was 5.0 m/hr, where the length of the run was 12.0 hrs. From runs No. 3, 4 & 5 it is clear that the suitable alum dose was 1.5 mg Al^{+3}/lit. According to Ks values, run No.2 & 3 had good conditions, but according to X values run No. 2 was the best in this group. In group 2, the down-flow filtration rate 5.0 m/hr with alum dose 1.5 mg Al^{+3} /lit was the best condition - run No. 9. In group 3, the maximum filtration rate that fulfilled the required conditions of the successful run was 3.25 m/hr, where the length of the run was 9.0 hrs According to Ks and X values and filtration rate, run No. 14 achieved the best results in this group.

In group 4, run No. 21 had the best results depending on the Ks value. However, run No. 19 achieved the best results depending on the X value. Runs No. 20, 21, 22 & 23 showed that the optimum alum dose for the moderate bentonite turbidity was 2.0 mg Al^{+3}/lit.

3.2.2 Filtration Process through Foam Media of Beads Size (1.6-2.0) mm.

To study the filtration process through the foam media of beads size of 1.6-2.0 mm, 17 experimental runs, from run No. 26 to No. 43, were conducted. These runs were classified to 6 groups (5-10), according to the flow direction, type and the level of synthetic water turbidity. All runs except runs Nos. 40, 42, were terminated due to turbidity breakthrough. Tables 5 and 6 show the average results of these runs, and the calculated values of the comparison criteria Ks and X.

In group 5, the maximum filtration rate can be applied to achieve the required filtration performance was 5.0 m/hr, where the length of the run was 10.5 hrs- run No 26. Runs No. 27 & 28 showed that the optimum alum dose was 1.0 mg Al^{+3}/lit. According to Ks values and the filtration rate run No. 26 achieved the best results in this group, but according to X values run No. 27 was the best.

In group 6, the down-flow filtration rate 5.0 m/hr with alum dose 1.0 mg Al^{+3} /lit run (No. 30) was able to have the best results in this group.

The runs of groups 7 & 8 have proved that it was hard through foam beads of size 1.6 – 2.0 mm to achieve long run for filtering water of moderate turbidity 19 - 24.3 NTU. That may be due to the mineralogy properties of bentonite as a swelling soil that its deposits have weak resistance to shear stresses created by higher velocity in the voids between small foam beads.

Table 4. The Average Results of Runs of filtration Bentonite Turbid Water through Foam Beads of Size 3-4 mm.

Group No.	*Run No.*	R.O.F, m/hr	**Alum dose** as Al^{+3}, mg/lit	**Turbidity (ave.)**, NTU		**Run length,** hr	Head loss, cm			**Ks** $x10^{-3}$	**X**
				Influent	Effluent		Ho	H_f	ΔH		
■Low Water Turbidity											
- Up-flow direction											
Group No.1	1	**3**	1.5	10.53	0.63	15	0.8	5.5	4.7	2.110	135.61
	2	**4**	1.5	10.7	0.33	15	1	6	5	1.558	178.03
	3	**5**	1.5	10.7	0.54	12	1.3	6.4	5.1	1.558	171.01
	4	**5**	2	11.1	0.31	7	1.3	7.2	5.9	2.574	91.57
	5	**5**	3	10	0.19	7	1.3	8	6.7	2.857	73.32
	6	**7**	1.5	11.8	0.67	4.5	1.8	8.1	6.3	2.690	79.62
	7	**8**	1.5	10.2	0.52	3.25	2.2	10.5	8.3	3.771	43.38
	8	**9**	1.5	10.17	0.47	2.5	2.5	7.3	4.8	4.370	65.05
- Down-flow direction											
Group No.2	9	**5**	1.5	11.5	0.73	12	1.2	12.9	11.7	1.449	79.02
	10	**7.2**	1.5	10.4	0.76	6.5	2.4	21.7	19.3	2.055	33.44
	11	**8**	1.5	11.93	0.61	4	3	12.3	9.3	2.619	55.73
	12	**9**	1.5	10.15	0.61	4	3.1	19	15.9	2.737	30.90
■Moderate Water Turbidity											
- Up-flow direction											
Group No.3	13	**2.7**	1.5	18.33	0.57	10	0.8	9.5	8.7	2.021	78.85
	14	**3.25**	1.5	19.6	0.55	9	0.8	8.1	7.3	1.744	109.20
	15	**4**	2	19.9	0.43	5.5	0.9	8	7.1	2.284	86.31
	16	**5**	1.5	19	>>1.0	--					
	17	**5**	2	20.3	1.33	3.5	1.2	6.6	5.4	2.815	87.95
	18	**5**	3	19.4	1.04	3	1.2	4.4	3.2	3.436	123.13
- Down-flow direction											
Group No.4	19	**2.5**	3	17.12	0.58	12	0.6	3.8	3.2	1.947	221.84
	20	**3.25**	3	22.36	0.47	8	0.9	5.4	4.5	1.720	180.94
	21	**3.25**	2	19.95	0.502	9.5	1.1	10.1	9	1.623	95.45
	22	**4**	2	20.81	0.7	7.5	1.1	7.8	6.7	1.602	128.82
	23	**4**	3	23.2	0.7	6.5	1.2	7.5	6.3	1.658	132.85
	24	**5**	2	19.8	1.23	3	1.2	4.4	3.2	3.367	124.53
	25	**5**	3	21.62	0.83	3	1.2	5.7	4.5	3.084	99.14

In group 9, the maximum filtration rate can be applied to achieve the required filtration performance was 12.5 m/hr, where the length of the run was 14.0 hrs- run No 40. According to Ks values and X values run No. 40 able to achieve the best results in this group.

In group 10, the maximum filtration rate can be applied to achieve the required filtration performance was 10 m/hr, where the length of the run was 12.0 hrs - run No 43. According to Ks values run No. 42 was the best one, but according to X values and filtration rate run No. 43 was better.

Generally, the filtration rates which fulfilled the required conditions of the successful run to filtrate raw water with clay turbidity were higher than that for raw water with bentonite turbidity. That may be due to that clay and bentonite has different mineralogy properties.

Table 5. The Average Results of Runs of Filtration of Bentonite Turbid Water through Foam Beads of Size 1.6-2.0 mm

Group No.	*Run No.*	**R.O.F** m/hr	**Alum dose** as Al^{+3}, mg/lit	**Turbidity (ave.), NTU**		**Run length,** hr	**Head loss, cm**			**Ks** $x10^{-3}$	**X**
				Influent	Effluent		Ho	H_f	ΔH		
■Low Water Turbidity											
- Up-flow direction											
Group No.5	26	**5**	1.5	11.2	0.23	10.5	2.3	34.4	32.1	1.701	25.67
	27	**6**	1	11.5	0.27	6	3.2	21.3	18.1	2.415	31.96
	28	**6**	1.5	12	0.35	5.5	3.1	21.3	18.2	2.525	30.22
	29	**7**	1.5	12.1	0.36	4.5	4.4	24	19.6	2.624	26.99
- Down-flow direction											
Group No.6	30	**5**	1	10.2	0.54	10.5	3.3	25.3	22	1.867	32.98
	31	**6**	1	11	0.39	5.5	3.3	27.7	24.4	2.755	20.53
	32	**7**	1	11.5	0.47	4.5	3.5	25.1	21.6	2.761	23.01
	33	**7**	1.5	12.7	0.78	6	3.6	26.1	22.5	1.875	31.83
■Moderate Water Turbidity											
- Up-flow direction											
Group No.7	34	**3.25**	1.5	21.9	0.36	5.5	1.4	10.3	8.9	2.555	61.89
	35	**4**	1.5	20.6	0.43	5.5	2.2	11.9	9.7	2.207	65.45
	36	**5**	1.5	19.4	0.42	3.5	3.3	12.8	9.5	2.946	50.02
- Down-flow direction											
Group No.8	37	**3.25**	1.5	24.3	0.6	5.5	1.4	12.4	11	2.302	55.10
	38	**4**	1.5	18.7	0.46	5	2.2	12.7	10.5	2.674	49.71
	39	**5**	1.5	19	0.52	4	3.3	16	12.7	2.632	31.10

Table 6. The Average Results of Runs of Filtration of Clay Turbid Water through Foam Beads of Size 1.6-2.0 mm.

Group No.	*Run No.*	**R.O.F** m/hr	**Alum dose** as Al^{+3}, mg/lit	**Turbidity (ave.), NTU** Influent	Effluent	**Time length**, hr	**Head loss, cm** Ho	H_f	ΔH	**Ks** x10^{-3}	**X**
■Low Water Turbidity											
- Up-flow direction											
Group No.9	40	**12.5**	1	9.42	0.36	14	10	93.3	83.3	0.607	27.23
	41	**15**	1	11.48	0.4	5	10.7	62.3	51.6	1.161	23.04
■Moderate Water Turbidity											
- Down-flow direction											
Group No.10	42	**5**	1.5	18.83	0.0238	26.5	3.3	92.8	89.5	0.401	39.83
	43	**10**	1.5	19.77	0.13	12	5.5	66.1	60.6	0.422	55.64

3.2.3. Filtration Process through Dual Layers Beads (0.50 m of Size 3-4 mm & 0.50 m of Size 1.6-2.0 mm)

To study the filtration process through dual layers beads, 14 runs, from run No. 44 to No. 57, were executed. These runs were classified to 4 groups (11-14), according to the type and the level of synthetic water turbidity. All runs were terminated due to turbidity breakthrough. Tables 7 and 8 show the average results and the calculated values of the comparison criteria Ks and X.

Table 7. The Average Results of Runs of Filtration the Bentonite Turbid Water through Dual Layers (0.50 m of 3-4 mm &0.50 m of 1.6-2.0 mm).

Group No.	*Run No.*	**R.O.F** m/hr	**Alum dose** as Al^{+3}, mg/lit	**Turbidity (ave.), NTU** Influent	Effluent	**Run length,** hr	**Head loss, cm** Ho	H_f	ΔH	**Ks** x10^{-3}	**X**
■Low Water Turbidity											
Group No.11	44	**5**	1.5	12.5	0.33	5.5	2.6	13.3	10.7	2.909	44.75
	45	**7**	1.5	13.4	0.56	3.5	3.2	12.8	9.6	3.046	46.88
	46	**8**	1.5	11.9	0.25	3	4	14.1	10.1	3.501	39.61
	47	**9**	1.5	13.3	0.41	2	4.5	13.2	8.7	4.177	38.15
■Moderate Water Turbidity											
Group No.12	48	**3**	2	20.3	0.26	6	1.6	7	5.4	2.737	95.57
	49	**4**	2	19.9	0.17	5	1.8	8.1	6.3	2.513	89.61
	50	**5**	2	21.1	0.7	3	2.6	8.3	5.7	3.160	76.80
	51	**7**	2	20.3	0.8	1.5	4	8.4	4.4	4.692	66.57

Table 8. The Average Results of Runs of Filtration the Clay Turbid Water through Dual Layers (0.50 m of 3-4 mm & 0.50m of 1.6-2.0 mm)

Group No.	*Run No.*	**R.O.F** m/hr	**Alum dose** as Al^{+3}, mg/lit	**Turbidity (ave.), NTU**		**Run length,** hr	**Head loss, cm**			**Ks** $x10^{-3}$	**X**
				Influent	Effluent		Ho	H_f	ΔH		
■Low Water Turbidity											
Group No.13	52	**7**	1	11.4	0.08	20	3.2	48.1	44.9	0.627	50.50
	53	**10**	1	11	0.14	14	4.8	49	44.2	0.649	49.21
	54	**12.5**	1	11.6	0.4	11.5	5.6	55.6	50	0.600	46.07
	55	**15**	1	12.1	0.17	4	7.2	38.8	31.6	1.377	32.41
■Moderate Water Turbidity											
Group No.14	56	**7**	2	20	0.18	9	3.2	29.5	26.3	0.794	67.92
	57	**10**	2	20.2	0.11	5	5.3	27.3	22	0.990	65.32

Once again runs in groups 11 & 12 have proved that it was hard through these foam beads to achieve enough long run for filtering water with bentonite turbidity that may be due to the same reason mentioned before.

In runs group 13, the maximum filtration rate that fulfilled the required conditions of the successful run was 12.5 m/hr, where the length of the run was 11.5 hrs - run No 54.According to Ks values and the filtration rate run No. 54 was the best run in this group. But according to X values run No. 52 was better.

In group 14, the maximum filtration rate that fulfilled the required conditions of the successful run was 7.0 m/hr, where the length of the run was 9.0 hrs - run No 56. According to Ks and X values and the filtration rate, run No. 56 was the best one in this group.
Generally, the stability of bentonite flocs which formed in media was less than the stability of clay flocs, so it was scoured quickly.

3.2.4. Filtration Process through the Crushed Foam Media

To study the filtration process through the crushed foam media, 11 runs, from run No. 58 to No. 68, were executed. These runs were classified in 4 runs groups from 15 to 18 according to the type and level of the synthetic water turbidity. All runs were terminated due to turbidity breakthrough. Tables 9 and 10 show the average results of these runs and the value of the comparison criteria Ks and X.

Table 9. The Average Results of Runs of Filtration Bentonite Turbid Water through Crushed Foam Media

Group No.	*Run No.*	**R.O.F** m/hr	**Alum dose** as Al^{+3}, mg/lit	**Turbidity (ave.), NTU**		**Run length,** hr	**Head loss, cm**			**Ks** $x10^{-3}$	**X**
				Influent	Effluent		Ho	H_f	ΔH		
■Low Water Turbidity											
Group No.15	58	**5**	1.5	13.61	0.51	8	1.9	6.8	4.9	1.837	110.25
	59	**6**	1.5	12.7	0.28	6.5	2.2	10.2	8	2.019	67.94
	60	**7**	1.5	12.1	0.36	4.5	3.3	15.9	12.6	2.624	33.28

■Moderate Water Turbidity											
Group No.16	61	**3**	3	20.5	0.12	12	1.1	8.5	7.4	1.355	123.49
	62	**4**	3	25.62	0.33	5	1.6	5.7	4.1	1.952	126.95
	63	**5**	3	20.93	0.64	2.5	2.1	8.1	6	3.822	44.80

Table 10. The Average Results of Runs of Filtration Clay Turbid Water through Crushed Foam Media

Group No.	*Run No.*	**R.O.F** m/hr	**Alum dose** as Al^{+3}, mg/lit	**Turbidity (ave.), NTU**		**Run length,** hr	**Head loss, cm**			**Ks** $x10^{-3}$	**X**
				Influent	Effluent		Ho	H_f	ΔH		
■Low Water Turbidity											
Group No.17	64	**10**	1	12.2	0.08	14	4.5	45.7	41.2	0.585	53.12
	65	**12.5**	1	10.17	0.2	12	6.9	47.5	40.6	0.656	45.04
	66	**15**	1	11.2	0.27	6	8.7	42	33.3	0.992	33.51
■Moderate Water Turbidity											
Group No.18	67	**7**	2	19.1	0.05	15	3.7	45.5	41.8	0.499	62.89
	68	**10**	2	19.9	0.1	9	4.5	38.9	34.4	0.558	65.54

In group 15, the maximum filtration rate that fulfilled the required conditions of the successful run was 5.0 m/hr, where the length of the run was 8.0 hrs- run No 58. According to Ks & X values, run No. 58 was the best one in this group.

In group 16, the maximum filtration rate that fulfilled the required conditions of the successful run was 3.0 m/hr, where the length of the run was 12.0 hrs- run No 62 that may be due to increasing the alum dose to 3.0 mg Al^{+3}/ lit. According to Ks and X values and the filtration rate run No. 62 was the best one in this group.

In group 17, the maximum filtration rate to achieve the fulfilled required conditions of the successful run was 12.5 m/hr, with run length of 12.0 hrs- run No 65. With respect to the filtration rate run No. 65 was the best one in this group. But with respect to Ks and X values, run No. 64 was achieved better results.

In group 18, the maximum filtration rate to achieve the fulfilled required conditions of the successful run was 10.0 m/hr, where the length of the run was 9.0 hrs- run No 68. With respect to the filtration rate and X value, run No. 68 was the best one in this group. But with respect to Ks values, run No. 67 was better.

Generally, the filtration rates which could be used to adequate the required conditions of the successful run to purify the clay turbid water were higher than that of the bentonite turbid water.

Monitoring turbidity variations with depth showed that the first 0.30 to 0.40 m of the depth remove about 60 to 70% of the water turbidity.

The crushed foam media was a good competitor to the virgin media used in this research because of the high filtration rate which could be used through it, and from the other side it has the lowest price.

4 CONCLUSIONS

According to the laboratory studies, the following conclusions could be drown.

1. The foam filtration media has small initial head loss.
2. The washing velocity of media depends on the media size and the required expansion.
3. To facilitate the washing of dirties, the expansion of the foam media bed must be about 25%.
4. The efficiency of filtration process depends on the nature and the mineralogy properties of the suspended and colloidal matter.
5. The expanded polystyrene media can be successfully used as an alternative in the rapid filters for water purification.

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