Water Filtration

ESE3401 Water & Wastewater Engineering 1 Lab Report

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1 Introduction

An experiment was conducted to investigate the basic characteristics of different filter media used in the water filtration process. The composition of the filters investigated are given in Table 1. Each filter tube had a 172 mm internal diameter, and contained approximately 80 cm of filter media.

Sieve Designation Number	Screen Opening (mm)	Weight (g)		
		Filter 1 (Fine)	Filter 2 (Coarse)	Filter 3 (Mixed)
7	2.40		250	
14	1.20		1250	750
25	0.76	500	2000	1500
36	0.42	2000	500	250
72	0.21	1000		
100	0.15	500		
Gravel		15 cm	15 cm	15 cm
Anthracite	2.50			15 cm

Table 1: Composition of the filters investigated.

Each filter media was evaluated for its general hydraulic characteristics, its ability to remove turbidity, and its performance during a backwash run. The most favourable filter media was then recommended for use in the treatment of raw water.

2 Objectives

For each filter media:

1. Find relationship between filtration rate and head loss
2. Investiage effect of time length of filter run
   (a) Find relationship between time length of filter run and head loss
   (b) Investigate ability in removing turbidity at end of filter run

3 Procedure

3.1 Relationship between filtration rate and head loss

1. Turbid water was prepared and fed into a constant head tank.
2. Water was supplied from the constant head tank into each filter at various flow rates. Flowrates from 0.4 L/min–1.2 L/min were used in steps of 0.2 L/min.
3. For each flow rate, the head loss through each filter media was recorded.

3.2 Effect of time length of filter run

1. Turbid water was prepared and fed into a constant head tank.
2. The initial turbidity of the prepared turbid water was measured.
3. Water was supplied from the constant head tank into each filter at 0.6 L/min.
4. Head loss through the each filter was measured at the start of each filter run.
5. For Filters II and III, subsequent measurements were taken at 5 min intervals.
6. For Filter I, subsequent measurements were taken at 1 min intervals till the 10th minute. Thereafter, measurements were taken at 5 min intervals.
7. The filter runs were terminated when additional head loss increased to 0.30 m or after 30 min of operation.
8. Turbidity of effluent was measured for each filter.

4 Results

4.1 Relationship between filtration rate and head loss

See Appendix A.1 for tabular results for each filter. Figure 1 shows the plot of head loss, H, versus filtration rate, V.

4.2 Effect of time length of filter run

4.2.1 Relationship between filtration rate and head loss

See Appendix A.2 for tabular results for each filter. Figure 2 shows the plot of head loss, H, versus time length of filter run, T.

4.2.2 Effect of time length of filter run

Table 2 on page 4 shows the turbidity results obtained at end of each filter run.

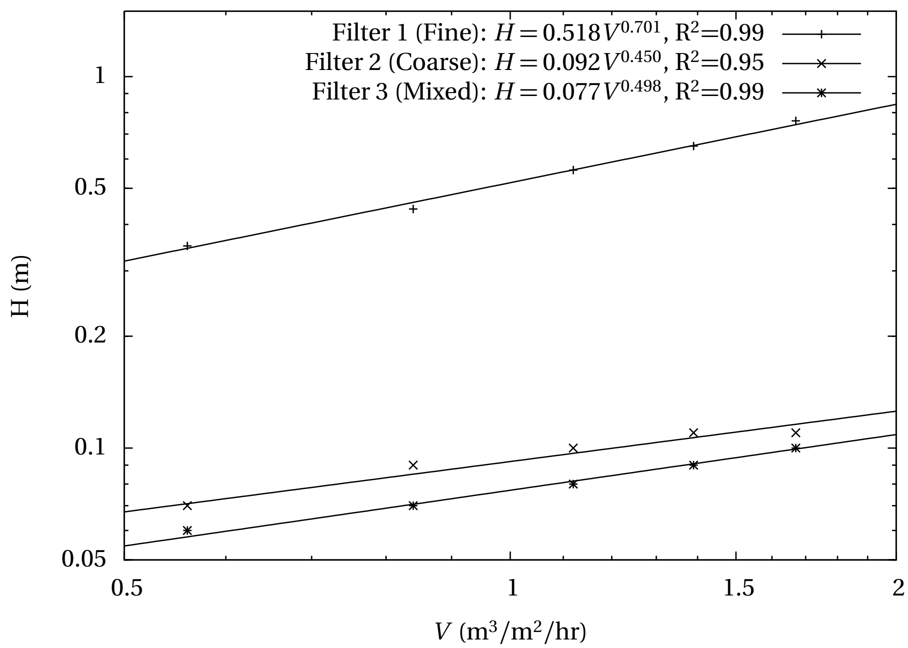

Figure 1: Log-log plot of head loss, H, versus filtration rate, V.

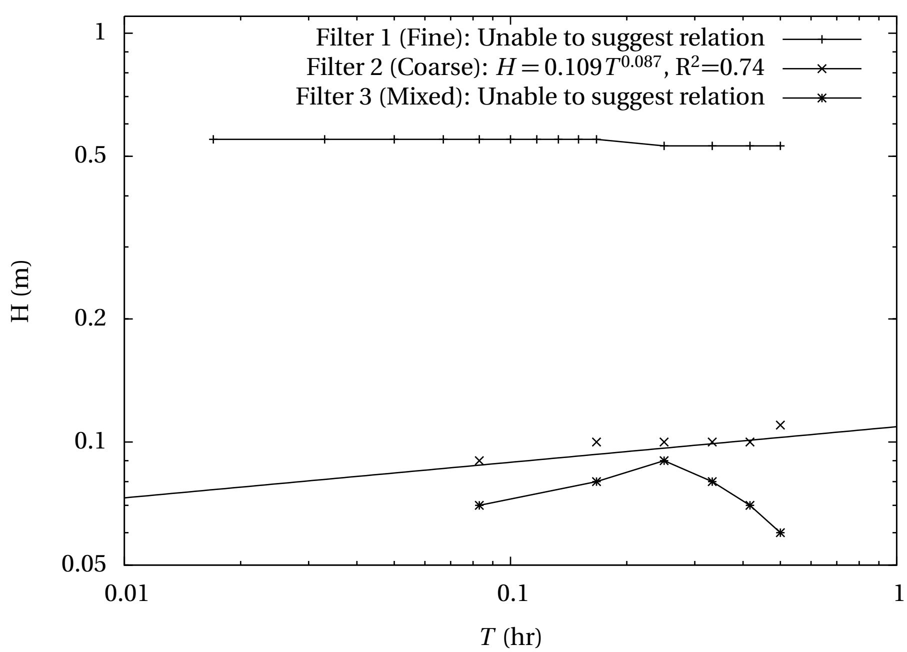

Figure 2: Log-log plot of head loss, H, versus time length of filter run, T.

	Turbidity (NTU)		
	Sample 1	Sample 2	Average
Initial Turbidity			796.5
Filter 1 (Fine) Final	50.7	49.8	50.3
Filter 2 (Coarse) Final	61.8	60.9	61.4
Filter 3 (Mixed) Final	55.6	55.8	55.7

Table 2: Turbidity results at end of each filter run.

5 Discussion

5.1 Relationship between filtration rate and head loss

Figure 1 and tables in Appendix A.1 summarize the fitration rate and head loss results.

Least squares regression was conducted on the data. Within the range of data, a $H = kV^n$ form of equation was optimal in relating head loss and filtration rate. A linear relation was less successful for the coarse media filter.

After minor manual curve fitting, the following equations relating head loss and filtration are suggested:

$$\begin{array}{rll} \text{Filter 1 (Fine):} & H = 0.518V^{0.701} & \mathrm{R}^2{=}0.99 \\ \text{Filter 2 (Coarse):} & H = 0.092V^{0.450} & \mathrm{R}^2{=}0.95 \\ \text{Filter 3 (Mixed):} & H = 0.077V^{0.498} & \mathrm{R}^2{=}0.99 \end{array}$$

The fine media filter experienced the greatest head losses. It was also characterised by the largest exponent in the relationship between filtration rate and head loss. Thus, smaller pore sizes amplify the relationship between filtration rate and head loss.

5.1.1 Relationship between finer media particles and head loss

The mixed media filter had considerably more of its media retained on the largest sieve than the coarse media filter. However, the head losses through both filters were fairly similar. Furthermore, all filters included gravel, which appears to have little to no comparative effect on head loss.

This strongly suggests that it is the finer particles in a media have the greatest effect on head loss.

5.2 Effect of time length of filter run

5.2.1 Relationship between time length of filter run and head loss

Figure 2 and tables in Appendix A.2 summarize the length of filter run and head loss results.

Head loss was expected to increase over time, and the effect was expected to be most pronounced for the fine media filter. However, no significant effect could be deduced from the data obtained. A filtration run of 30 min is thus insufficient to create a sufficient effect on head loss.

A relationship between time length of filter run and head loss could only be suggested for the coarse media filter. However, the suggested relation is only fairly representative due to the reasons given above.

$$\text{Filter 2 (Coarse):} \quad H = 0.109T^{0.087} \quad \mathrm{R}^2{=}0.74$$

5.2.2 Ability in removing turbidity at end of filter run

Table 2 summarizes the turbidity results at the end of the filter run. The fine media filter had the best removal ability. Thus, smaller pore sizes improve removal ability.

The mixed media filter had a significantly better removal ability than the coarse media filter. Furthermore, the pore sizes were comparable, or larger for the mixed media filter.

Thus, anthracite has a significantly better turbidity removal ability than sand. This is probably due to the large surface area present in anthracite for absorption.

5.3 Backwash characteristics

5.3.1 Filter 1 (Fine)

The fine media filter experienced a moderate rate of solids removal during backwash. A low backwash pressure was sufficient to completely fluidize the media column. However, there was considerable loss of filter media during the backwash.

5.3.2 Filter 2 (Coarse)

The coarse media filter experienced the slowest rate of solids removal during backwash. A high backwash pressure was required to fluidize the media column.

5.3.3 Filter 3 (Mixed)

The mixed media filter experienced the fastest rate of solids removal during backwash. The media column did not need to be fluidized completely for solids removal. This is probably due to most of the solids being absorbed into the anthracite.

6 Conclusion

The relationship between filtration rate and head loss was found to be best described in the form $H = kV^n$, where H is head loss, V is filtration rate and k and n are constants. Linear relationships were less successful for the coarse media filter but could be used as a good approximation. The fine media filter suffered significantly higher head loss than the coarse media and mixed media filters at all filtration rates.

A time length of 30 min was found to be too short to suggest relationships between time length of filter run and head loss. The fine media and mixed media filters had better ability in removing turbidity at the end of the filter run than the coarse media filter.

The mixed media filter had the most favourable backwash characteristics. It experienced the quickest solids removal, only required a low backwash pressure, and did not suffer from any noticeable loss of filter media.

Based on the the above experiemental findings, a mixed media filter is recommended for the treatment of raw water.

A Additional tables

A.1 Relationship between filtration rate and head loss

Flow rate, Q (L/min)	Filtration rate, V (10^{-3} m^3/m^2/hr)	P_{top} (kPa)	P_{bot} (kPa)	Head loss, H (m)
0.4	0.56	14.9	19.3	0.35
0.6	0.84	14.8	18.3	0.44
0.8	1.12	14.7	17.1	0.56
1.0	1.39	14.5	16.0	0.65
1.2	1.67	14.3	14.7	0.76

Table 3: Filtration rate and head loss results for Filter 1 (Fine)

Flow rate, Q (L/min)	Filtration rate, V (10^{-3} m^3/m^2/hr)	P_{top} (kPa)	P_{bot} (kPa)	Head loss, H (m)
0.4	0.56	15.0	22.2	0.07
0.6	0.84	14.9	21.9	0.09
0.8	1.12	14.8	21.7	0.10
1.0	1.39	14.7	21.5	0.11
1.2	1.67	14.6	21.4	0.11

Table 4: Filtration rate and head loss results for Filter 2 (Coarse)

Flow rate, Q (L/min)	Filtration rate, V (10^{-3} m^3/m^2/hr)	P_{top} (kPa)	P_{bot} (kPa)	Head loss, H (m)
0.4	0.56	15.0	22.3	0.06
0.6	0.84	14.9	22.1	0.07
0.8	1.12	14.8	21.9	0.08
1.0	1.39	14.7	21.7	0.09
1.2	1.67	14.6	21.5	0.10

Table 5: Filtration rate and head loss results for Filter 3 (Mixed)

A.2 Effect of time length of filter run

Time, (s)	P_{top} (kPa)	P_{bot} (kPa)	Head loss, H (m)	Time, T (h)
0	14.7	17.2	0.55	0.000
1	14.7	17.2	0.55	0.017
2	14.7	17.2	0.55	0.033
3	14.7	17.2	0.55	0.050
4	14.7	17.2	0.55	0.067
5	14.7	17.2	0.55	0.083
6	14.7	17.2	0.55	0.100
7	14.7	17.2	0.55	0.117
8	14.6	17.1	0.55	0.133
9	14.6	17.1	0.55	0.150
10	14.6	17.1	0.55	0.167
15	14.3	16.9	0.53	0.250
20	14.1	16.7	0.53	0.333
25	13.9	16.5	0.53	0.417
30	13.7	16.3	0.53	0.500

Table 6: Time length of filter run and head loss results for Filter 1 (fine).

Time, (s)	P_{top} (kPa)	P_{bot} (kPa)	Head loss, H (m)	Time, T (h)
0	14.9	21.8	0.10	0.000
5	14.7	21.7	0.09	0.083
10	14.6	21.5	0.10	0.167
15	14.4	21.3	0.10	0.250
20	14.2	21.1	0.10	0.333
25	13.9	20.8	0.10	0.417
30	13.7	20.5	0.11	0.500

Table 7: Time length of filter run and head loss results for Filter 2 (coarse).

Time, (s)	P_{top} (kPa)	P_{bot} (kPa)	Head loss, H (m)	Time, T (h)
0	14.8	22.0	0.07	0.000
5	14.8	22.0	0.07	0.083
10	14.7	21.8	0.08	0.167
15	14.5	21.5	0.09	0.250
20	14.2	21.3	0.08	0.333
25	14.0	21.2	0.07	0.417
30	13.7	21.0	0.06	0.500

Table 8: Time length of filter run and head loss results for Filter 3 (mixed).