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Headloss Variations in Counter-current Constant-rate Horizontal Filtration Employing Clay Turbidity

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Investigations carried out in the laboratory on the horizontal filters, operated under counter-current mode (ie, flow taking place from coarser to finer media), revealed that such filters, if properly designed, would prove to be far superior than the normal/conventional rapid sand filters. Variations in headloss along the various depths of the media, under constant head, constant rate flow conditions, are discussed to show the superiority of the proposed system.

INTRODUCTION

Counter-current (*ie*, flow taking place from coarser to finer media) horizontal filtration is bound to prove far superior than the normal/conventional rapid sand filters as it overcomes many of the shortcomings of the latter such as mud-ball formation, development of negative pressure, utilization of full media depths and rate of filtration.

The objective of the study, reported in this paper, was to carry out investigations on the headloss variations along the various depths of the media under constant-head and constant-rate flow conditions. Investigations were carried out in the laboratory on the horizontal filter model which were run under counter-current principle.

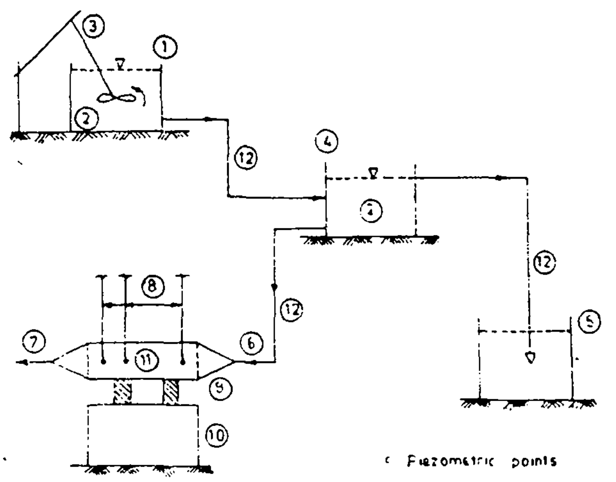
THEORETICAL RESUME

Craft[1] suggested that reverse graded sand is superior to normally graded sand. Knudsen[3] indicated effect of media selection on filter performance and operating economics. Efficient particle removal, lower headloss and larger filtration run times can be obtained by proper designing of media. Rao. *et al*[5], investigated filter headloss in relation to sand size and flow rate. Horvath[2] developed relationship between rate of filtration and hydraulic gradient for streamflow conditions prevailing within high rate sand filters. O'Melia[4] formulated a model for headloss and removal efficiency based on postulate that some retained particles could act as filter media and thereby improve efficiency. Small suspended particles were shown to produce much greater headlosses than larger particles.

METHODOLOGY

Experiments were carried out in the laboratory on a horizontal perspex filter model (10 cm × 10 cm × 65 cm) based on counter-current mode of operation. Filter was filled with two different sizes of sand (having NUC=1), namely 1mm (uniform size) having a media depth of 40 cm (adjacent to the inlet), and 0.7mm (uniform size) of 10 cm depth (adjacent to the outlet). Influent turbidity of 100 NTU was prepared with bentonite clay suspension in water and was fed through a constant-head tank. Influent was continuously stirred inside the tank for a uniform mix and to avoid settling of solids in the tank. Influent and effluent turbidities were monitored with the help of a Nephlometer and headlosses were recorded with the help of manometer tubes placed at 4 cm, 45 cm and 55 cm from the inlet end. The experiments were conducted under optimum constant-head (1.7m) and normal constant-rate of filtration (100 l/min m^2) conditions.

Discussions based on the observed headloss data



1. Over head tank 2. Influent water 3. Mechanical stirrer 4. Constant head tank 5. Overflow collection 6. Influent inlet 7. Effluent outlet 8. Piezometric tubes 9. Horizontal filter model (Perspex) 10. Sand 11. Filter media 12. Flexible pipe assembly for connections

Fig 1 Schematic diagram of experimental set-up

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and their plots at various depths from the inlet of the filter, are presented in this paper.

ANALYSIS OF RESULTS

The plots, depicted in Fig 2, show the variations in headloss along the various filter media depths with respect to the time of filtration, in the counter-current mode of flow through the filter. It is observed from Fig 2 that the patterns of headloss through the media

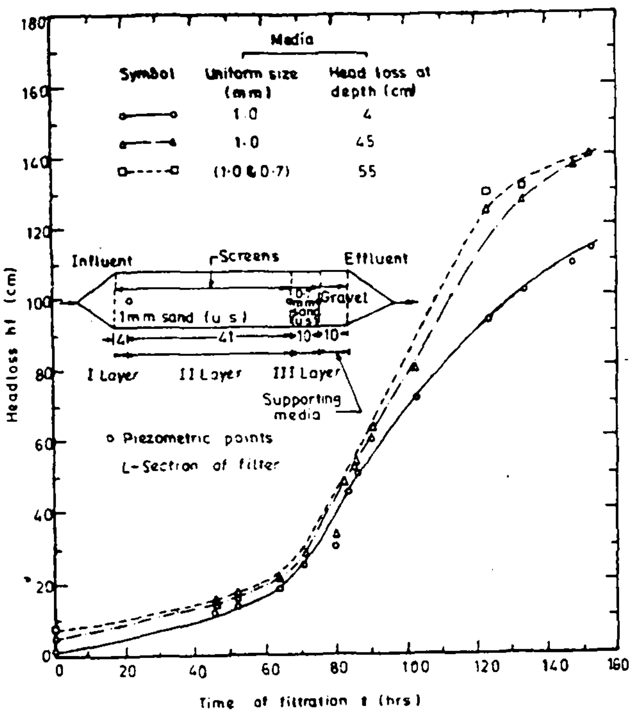

Fig 2 Variation of headloss with time of filtration

at various depths are almost similar. The headloss in each case increases first almost linearly but after a certain time it rises abruptly. The plots show that at any time the headloss is greater at larger depth as expected. The plots show that during the filter run, the headloss caused in the first 4 cm media depth is a significant proportion of the total headloss through the entire filter media depth. This indicates that the first layer of the coarse sand (1 mm uniform size having NUC=1) media plays an important role in arresting the impurities. The arrest of impurities and increase in headloss in the next 41 cm media depth (of same size) is therefore observed to be marginal. The majority of the turbidity thus gets removed in the initial media depth of 4 cm and the burden of impurities gets reduced for the last media depths where the void space is reduced due to the smaller media size.

However, in the initial stages, as the time of filtration increases, the contribution to headloss due to subsequent layers of media remains more or less constant. Upto around 20 h the headloss developed in the second layer is more in comparison to that in the first layer, after which time it is *vice versa*. This is because in the initial stages impurities penetrate deeper into the media, thus, building up headloss in the deeper layers. Once these layers are blocked to some extent, the impurities start depositing in the first layer and hence, the headloss in the first layer goes on increasing whereas there is no significant rise in the headloss in the subsequent layers, as there is very little deposition taking place. The contribution of the third deeper layer is almost insignificant in the initial stages, as very little impurities are left to pass to that deep extent.

The point of contraflexure in the headloss curve is observed at around 65 h at all depths, which shows that after this time headloss buildup is significant as the pores interstices are considerably decreased resulting in higher headlosses.

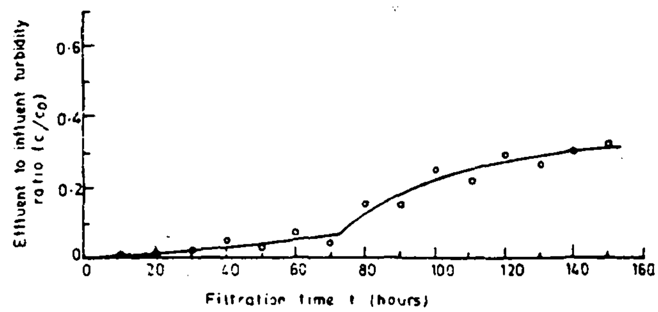

Fig 3 Variation of (C/C_0) with filtration time

The headloss curves tending to flatten out after about 70 h show a breakthrough in the effluent quality because at this time, the turbidity starts coming out in the effluent due to the action of hydrodynamic shearing forces which tend to flush out the deposited impurities. This shows that the filters with stated media specifications can be run safely upto around three days utilizing the counter-current mode of operation and with an influent turbidity of 100 NTU at an optimum constant head of 1.72 m and with a normal constant rate of filtration of 100 l /(min m^2). These operating data, when compared to the normal rapid sand filters, clearly show the superiority of the proposed system in the sense that even with a very high turbidity load, the filter can operate for much longer duration at a comparable filtration rate.

PRACTICAL APPLICATIONS

Properly designed counter-current horizontal filters may prove to be of immense use in the field, especially for small drinking water supply schemes, as much higher turbidity loads can be fed and still the filters can run far longer compared to conventional rapid sand filters. This shows that the advantages obtained can be of the order of about 15 times. Also, the headloss developed are not alarming, thus, eliminating the chances of development of negative pressure in the filter bed.

CONCLUSIONS

1. In a counter-current mode of operation in horizontal filters, coarser media placed in the beginning plays an important role in arresting most of the impurities. There is better utilization of the entire media and effluent gets absolutely polished by the last finer layers.

2. Breakthrough in turbidity occurs only after the point of contraflexure is reached in the headloss curve.

3. The length of filter run can be greatly prolonged even with a much higher influent turbidity load, by practising a counter-current mode of flow.

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DISCUSSION

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1. Can the author's data be fitted into Carman-Kozney equation for headloss and filter resistance ?

2. What is the backwash rate and back washwater discharge in percentage ? The experiments, reported in the paper, have been conducted using bentonite clay. In actual practice the raw water characteristics have different sizes of suspended particulate and organic matter, which may not give the same results as reported.

3. In the experiments reported, the length of the interval between backwashing is large. There may be fouling due to organics. There are possibilities for anaerobic conditions and release of gas affecting filter rate. The author may kindly comment.

Dr D S Bhargava, *Author*

1. Initial headloss can be determined from the filter specifications. During the filter runs, the Carman-Kozney equation requires determination of the specific deposits at the given instant. For specific deposits determination, a reference may be made to the author's methodology presented in *Water Research*, England, September 1986 issue.

2. Slightly more h_f can be expected in the situation stated by the discussor, depending on the amount and characteristics of the material to be removed.

3. The dissolved oxygen of the influent can prevent anaerobic situations. However, in extreme cases the effect on the h_f would be reflected.

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Dr Bhargava received BE (Civil) from MBM Engineering College, Jodhpur in 1959 ; Post Graduate Diploma (Public Health) from Roorkee University in 1960 ; ME from Roorkee University, and Ph D in environmental engineering. Since 1960, he has been with IIT, Kanpur; Regional Engineering College, Kurukshetra ; Birla Institute of Technology and Science, Pilani ; Regional Engineering College, Allahabad ; and MBM Engineering College, Jodhpur. He was with Central Board and Prevention and Control of Water Pollution before joining Roorkee University as Reader (Pollution Control) in 1979 and where is at present, Professor, Environmental Engineering. He has published over 120 papers.

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