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Comparative Study of Gravel and Anthracite as Media in Up flow Filter

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Abstract

Removing turbidity is one of the challenge to deal against water crisis. Excess turbidity cause poor implementation in water supply schemes. Roughing filter can reduce turbidity to a permissible level for slow sand filter operation. Anthracite having greater surface area and porosity than that of gravel, helps in better removing particulates. Modified roughing filtration systems have proven to produce water of exceptional quality with occurrence of minimum head loss. This research was carried out to compare the turbidity removal performance of anthracite media to gravel media.

Two identical filter columns with (230×230×1570) cubic milimeters in internal dimensions were operated at same time. Filter media used in gravel media consist of 2 - 4.75, 4.75 - 9.5 and 9.5 - 12.5 mm sizes and in combined model consist of 2 - 4.75, 4.75 - 9.5 mm anthracite and with 9.5 - 12.5 mm sizes gravel in layers. Four set of experiments were performed at flow rates 0.5, 0.75, 1, 1.5 m/h.

The depth of anthracite having media depth 20, 40 and 60 cm reduced turbidity by more than 5, 7 and 9 NTU in an average than the corresponding depth of gravel. Decreasing the filtration rate from 1.5 to 0.5 m/h, turbidity removal efficiency in combined model increased from 87 to 93 percent and effluent turbidity decreased from 28 to 15 NTU, while in gravel model turbidity removal efficiency increased from 82 to 88 percent and the effluent turbidity decreased from 36 to 25 NTU.

Keywords

Water Treatment – Turbidity – Surface Water – Gravel – Anthracite

1. Introduction

In our country, most of water supply schemes come using water from surface sources. The major water quality problem is related to seasonal attributes like in wet seasons the turbidity in these sources increases drastically which causes poor implementation of such water supply schemes. Nepal Drinking Water Quality Standards limits turbidity within range of 5 NTU in normal condition and 10 NTU when other sources are not available. In Nepal, although the basic water supply coverage is 86.5percent only 29.1 percent of population are in access of safe drinking water [1].

One possible solution is the effective treatment of wastewater. For suspensions with particulates that do not readily settle, roughing filtration provides superior treatment to basic sedimentation methods [2] and represents an attractive alternative to more costly conventional coagulation methods Roughing filters are primarily used to separate the water from the fine solids that are only partly retained, or not at all, by stilling basins or sedimentation tanks. In terms of the technical labor requirements, daily operation, maintenance costs and treatment efficiency and effectiveness, roughing filtration is a simple, efficient and cheap pre-treatment technology for the treatment of drinking water or wastewater when compared to conventional systems, such as chemical coagulation methods [3]. Roughing filter can be used without slow sand filter if raw water taken from well protected catchment area and having minor bacteriological contamination [2]. Actually, it has been found that with pre-roughing filtration, slow sand filters can achieve filter runs that are 5 times longer than without pre-roughing filtration. Roughing filters can have filter runs up to a year with raw water that is periodically high in solids loads [4].

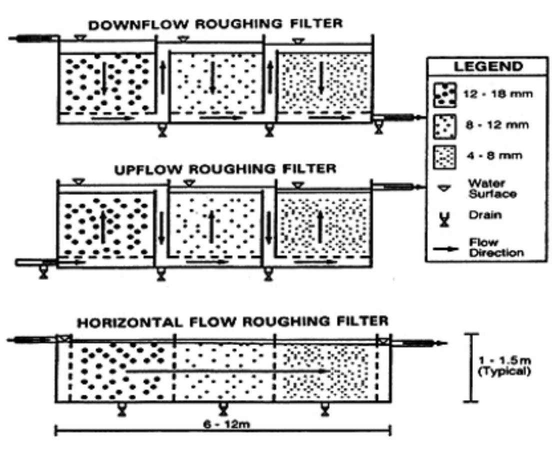
1.1 Roughing Filter : Roughing filters are defined as filters with grain sizes larger than 2 mm [5]. They are claimed to perform "natural" treatment process as no chemicals are generally used and as they do not require sophisticated mechanical equipment. Roughing filters are basically boxes filled with gravel or coarse sand. The efficiency of roughing filtration is primarily based on the large surface area available in the gravel bed which facilitates to remove impurities from the water. These mechanisms are of physical, chemical and biological nature. The classification of filters is shown in figure 1.

Characteristics	Intake filtration	Roughing filtration	Rapid sand filtration	Slow sand filtration
Filter material size (mm)	6 - 40	4 - 25	0.5 - 2	0.15 - 1
Filtration rate (m/h)	2 - 5	0.3 - 1.5	5 - 15	0.1 - 0.2

Source: Maung (2006)

Figure 1: Classification of filters

There are various types of roughing filters such as downflow roughing filters (DRF), horizontal flow roughing filters (HRF) and up flow roughing filters (URF) whose schematic diagram is shown in Figure 2



Source: Lin, *et al.*, (2006)

Figure 2: Diagram of horizontal, up flow and down flow roughing filter

1.2 Upflow Filter and Removal Mechanism: The flow direction in up flow gravel filter reduces interferences due to temperature or density differences, improves the hydraulic behaviour and results in a more homogenous retention time and thus a better process of treatment [6] . Using different grades of filter media in roughing filter promotes the penetration of particles throughout the filter bed and takes an advantage of large storage capacities offered by small media [7]. Up flow filters can be used in series for more contaminated water where first unit filled with coarse grain and last one with fine. The bulk of solid matter is removed by the coarse filter fraction, the medium sized gravel has the polishing effect, and the finest gravel ought to remove only the remaining traces of solid matters. Therefore, individual filter length of roughing filters are often designed in a 3:2:1 ratio. Uniformity coefficient (Cu) for roughing filter is defined as the ratio of largest and smallest size of filter media fraction (Cu= dmax / dmin), it should be equal or less than 2 [2]. The filter bed is composed of different kinds of local materials in different layers placed in the order of decreasing sizes in the direction of flow. Upflow roughing filters are more efficient in solid removal than other types of roughing filter [4].

2. EXPERIMENTAL SET UP

Two identical models were constructed using fiber glass material (230*230*1570) mm3 in internal dimensions. Water with turbidity flows from clear water tank to mixing tank through 20 mm diameter pipe and is fed to both models. Schematic diagram of filter model is presented in Figure 3 and 4 and media detail is presented in figure 5

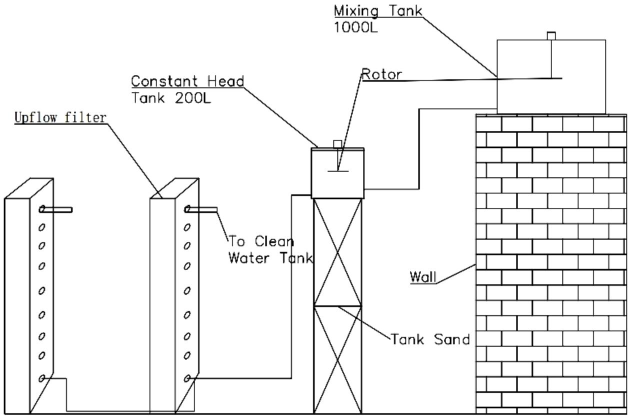


Figure 3: Schematic diagram of filter model setup

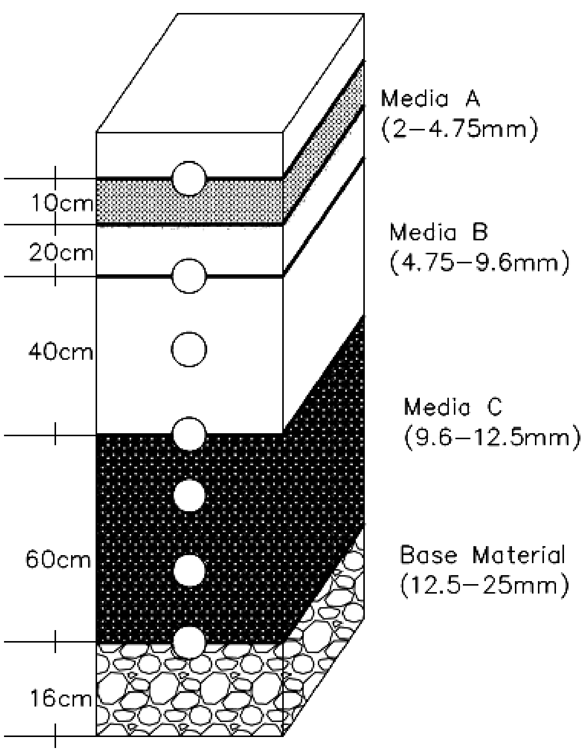


Figure 4: Detail Drawing of Filter model

Category	Filter media size (mm)	Filter media depth (cm)
Media first	2-4.75	20
Media second	4.75-9.5	40
Media third	9.5-12.5	60
Base material first	12.5-19.6	8
Base material second	19.6-25	8

Figure 5: Different media used in model

Uniform turbidity of around 200 NTU was maintained throughout the experiment. Four sets of the experiment were performed at the rate 0.5, 0.75, 1, and 1.5 m/h. Turbidity of water from each port was measured hourly. Both filters were operated until the available head of 90 cm was exhausted. Method of analysis is shown in figure 6.

S.N.	Parameter	Methods	Frequency
1	Turbidity	Digital Turbidity meter model LT-33	Hourly
2	Discharge	Volumetric method	Daily
3	Temperature	Thermometer	Daily
4	pH	Digital pH meter kit	Daily
5	Head loss	Piezometer tube	Daily

Figure 6: Methods of analysis and Instruments

3. Result and Discussions

The influent turbidity was maintained around 200 NTU throughout the whole experiment. Effluent turbidity obtained by both filters at these flow rates are shown in Figure 7 and 8

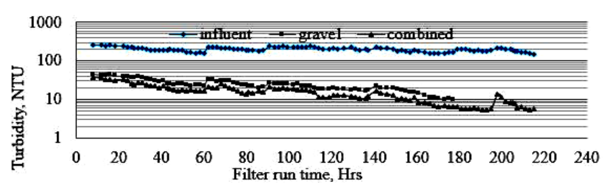


Figure 7: Turbidity vs. Filter runs time at 0.5m/h

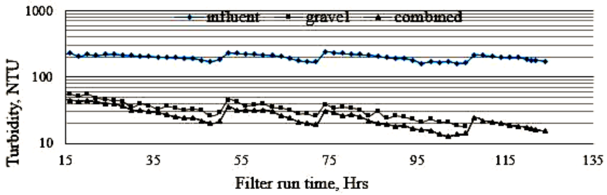


Figure 8: Turbidity vs. Filter runs time at 1.5m/h

At 0.5 m/h filter operation, the effluent turbidity decreased from 45 to 10 NTU in gravel model and from 37 to 5 NTU in the combined model as shown in Figure 7. Similarly at 1.5m/h filter operation, the effluent turbidity decreased from 64 to 18 NTU in gravel model whereas it decreased from 55 to 15 NTU in the combined model as shown in Figure 8. The time of termination of filter run was decided on the basis of terminal head loss exceeding a certain specified maximum head loss. Filter run hour was decreased with increase in the flow rate.

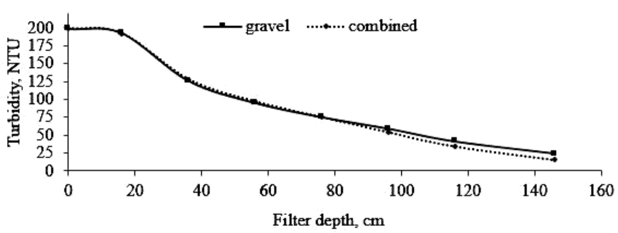


Figure 9: Turbidity Removal profile along filter depth at 0.5 m/h

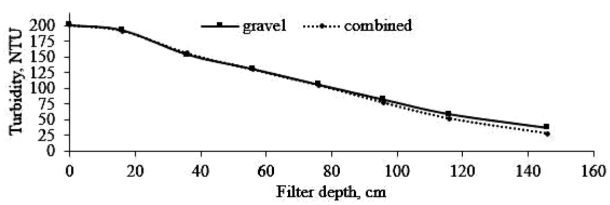


Figure 10: Turbidity Removal profile along filter depth at 1.5 m/h

It is seen from the figure above that the removal of turbidity is high in coarse fraction and decreases gradually towards outlet. The combined media model slightly and in a similar manner outperformed gravel model in every set of experiments in terms of turbidity removal. However, it was observed that depth of filter media required to reduce turbidity to desired level was directly proportional to the filtration rate. In all of the above figures, the variation in turbidity removal between two models is seen only after around 80 cm depth and that is justified by the fact that both the models have same sized gravel up to that length. A full length of 120 cm of media reduced 200 NTU influent turbidity to 24 and 15 and 36 and 28 NTU in gravel and combined model at 0.5 and 1.5m/h respectively. Observing various flow rates, 20, 40 and 60 cm depth of anthracite reduced turbidity by more than 5, 7 and 9 NTU in average than the corresponding depth of gravel. Whereas in whole experiment, combined model surpassed the gravel model by about 4.2 percentage in terms of turbidity removal i.e. 8 NTU

4. Conclusions

The benefit from using dual filter against mono filter is justified by these conclusions.

- In all the repetitions with changing flow rate, the combined filter surpassed the termination time of gravel filter with an average of 20 percent i.e. 30 hours.
- The depth of 20, 40 and 60 cm anthracite reduced turbidity by more than 5, 7 and 9 NTU in an average than the corresponding depth of gravel.
- While increasing filtration rate from 0.5 to 1.5 m/h, the effluent turbidity in gravel model increased from 25 to 36 NTU whereas that in combined model increased from 15 to 28 NTU.
- In overall experiment, combined model surpassed the gravel model by about 4.2 percentage i.e. 8 NTU in terms of turbidity removal.

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