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Evaluation of Turbidity Removal Performance of Upflow Gravel Filter

Akrur Nath Sharma [1], Iswar Man Amatya [2]

[1, 2] *Department of Civil Engineering, Environmental Engineering Program, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal*
Corresponding Email: [1] akrur1@gmail.com, [2] iswar@ioe.edu.np

Abstract
Surface water source serve as a major source of water in hilly region of Nepal which experience water quality problem especially high turbidity during rainy season. Gravel filteration is one of the promising turbidity removal technology as compared to basic sedimentation and conventional coagulation methods. Upfow Gravel Filter of (230*230*1570) mm3 internal dimension was constructed and setup was done at IOE examination control division building. The turbidity removal in upflow gravel filter at different flow rates was studied at varied influent turbidity. Nephelometric turbidity meter was used to measure turbidity. It was observed that effluent turbidity is inversely proportional to the depth of filter media, assuming other parameters same and the depth of filter media required to reduce turbidity to desired level was directly proportional to filtration rate.

Keywords
Upflow Gravel Filter –Filtration Rate – Turbidity

1. Introduction

Most of the water supply schemes in hilly region of Nepal uses surface water source (Springs and streams) in order to fulfill the requirement of drinking water. The major water quality problem is related to seasonal attributes i.e. turbidity in rainy season. There are cases where water supply schemes have been dropped out due to high turbidity e.g. Pipara WSS, Banke district [1]. An average of 80 minutes is spent per water fetching trip in Karnali region. More than 60 percent of water sources in Kalikot, Jumla and Muguare considered to be contaminated by polluted run-off and excessive turbidity [2]. Water quality is especially poor during the rainy season when high levels of rainfall stimulate sediment re-suspension, increasing turbidity. Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern as it may provide shelter to the pathogens. National Drinking Water Quality Standard limits turbidity within 5 in normal condition and 10 NTU when other sources are not available [3]. Since most of the water sources in the country are the streams, it would be beneficial for us to have a treatment process which reduces turbidity at a low cost. For suspensions with particulates that do not readily settle, roughing (Gravel) filtration provides superior treatment to basic sedimentation methods and represents an attractive alternative to more costly conventional coagulation methods [4].

1.1 Roughing Filtration

Roughing filtration is the removal of suspended solids by passage of water through relatively coarse media such as gravel or coarse sand or burnt clay pottery pieces. 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 main features of this technology are low operation and maintenance, use of locally available materials and resources which make these filters affordable and sustainable in the long run [4]. Roughing filters are divided into vertical-flow (downflow roughing filters (DRF) and upflow roughing filters) filters and horizontal flow roughing filters (HRF).

1.2 Upflow Gravel Filter

In an UGF the water passes through the gravel bed from the bottom to the top. During this passage impurities are retained in the filter. Upflow filtration has the advantage that the heavier particles are removed first at the bottom of the filter. When the time comes to clean the filters, these can be removed by opening the fast drainage valve, allowing gravity to drain and clean the filter[5] . Two types of UGF exist i.e UGF in layers and UGF in series. In the UGF in layers, gravel is placed in layers of different grain sizes, ranging from coarse at the bottom to fine at the surface. UGF in series is used for more contaminated water. This system comprises of two or three units with different gravel sizes, each unit being filled mainly with one gravel size, starting with coarse grains in the first and moving to fine in the last unit. The flow direction in upflow filter reduces interferences, due to temperature or density differences, improves the hydraulic behaviour and results in a more homogeneous retention time and thus a better process of treatment[6]. The recommended values by different researchers for the rate of filtration, size of filter media and the depth of the filter medium show a considerable variation. Some preliminary design guidelines for roughing filters is shown in Table 1.

Table 1: Recommended guidelines for upflow gravel filter from researchers.

Parameters	Okun and shultz [7]	Glavis et al [6]	Wegelin [4]	Brikke & Bredero [8]
Filtration rate(m/h)	4 – 8	0.3 – 0.75	0.3 – 1	0.6
Filter length (m)	1.5 – 3	0.85 – 1.25	0.6 – 1	1.5
Filter Media (mm)	0.7 – 60	1.6 – 19	20 – 4	25 – 3

Surface and straining filtration are not likely to play a dominant role in roughing filtration. Filter cake development in UGF are limited by particle drift and secondary particle detachment[9]. Gravel filters need to be cleaned for the purpose of removing accumulated particulate matter and replenishing the solid storage capacity of the filter. Cleaning can recover initial head loss. The frequency of cleaning is dependent on the loading of particulate matters and biological activity in the filter [10].

2. Experimental Setup and Operation

UGF was constructed by fiber glass of (230*230*1570) mm3 internal dimension. The model was setup in IOE examination control division building.

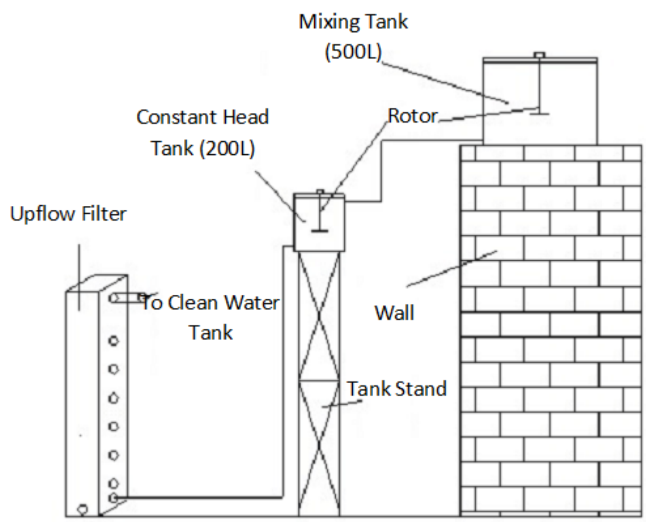

Figure 1: Schematic diagram of the upflow gravel filter setup

Base material used in this study were 16 cm depth of 12.5-25 mm gravel which were obtained by properly sieving through standard sieves. Filter media used for this study were 2-4.75, 4.75-9.6 and 9.6-12.5 mm diameter gravel.

Table 2: Description of Upflow gravel filter

Components	Dimension or size	Remarks
Mixing tank	500 ltr	HDPE Water tank
Constant head tank	200 ltr	HDPE Water tank
Operating ball valve	20 mm each at two tanks	For two tanks
Flow regulating valve	20 mm Brass Gate Valve	For flow control mechanism
Inlet pipe	20 mm PPR pipe line, tee and piezometer	Connection pipe
Filter tank	(0.23*0.23*1.57) cm^3	Glass fiber double layer tank
Ball cock for flow control at constant head tank		Polythene ball cock
Sampling ports	6 nos. 20mm sampling port at 20 cm c/c in vertical direction	Using tank nipple, ball valve and nozzle at each port
Outlet	20 mm ball valve and nozzle	

First Sampling port P1 was placed 16 cm above the base of the filter. All remaining sampling ports are placed at the interval of 20 cm. 10 cm clear water level was maintained in the upflow filter and outlet is placed 10 cm above the uppermost media level.

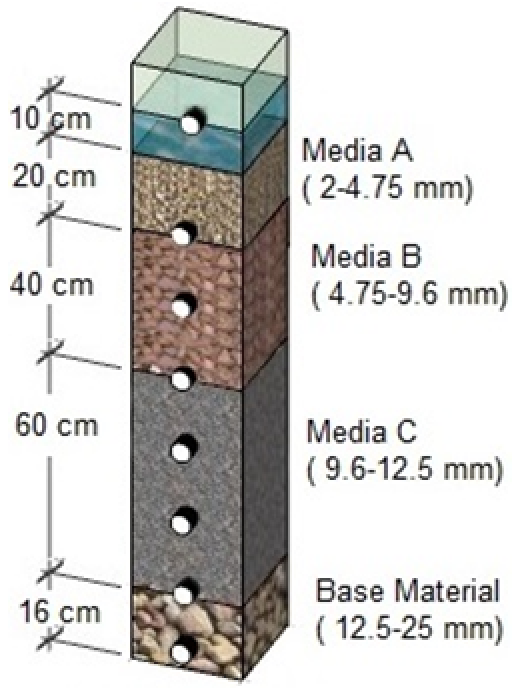

Figure 2: Schematic diagram of the upflow gravel filter

During first experimental run, filter was operated at the velocity of 0.5 m/h and natural ground water was used to run the filter. Model raw water of varied turbidity was prepared by using artificial suspension which was used during the second experimental run. In this study turbidity was measured by Nephelometric turbidity meter manufactured by Labtronics India. Manufacturer's instructions were followed while calibrating the instrument. Besides, section 2130 B, Standard Methods [11], was followed while measuring turbidity.

3. Results and Discussion

The total length of the filter media is 120 cm which consist of media A of depth 60 cm, media B of depth 40 cm and media C of depth 20 cm. The turbidity removal along the media depth was plotted at the final hour. Turbidity goes on decreasing as the water progress along the filter length but the turbidity removal decreases gradually as water approaches towards outlet. Figure 3,4 and 5 shows turbidity removal along filter length at flow rates 0.5m/h, and 1.0 m/h respectively.

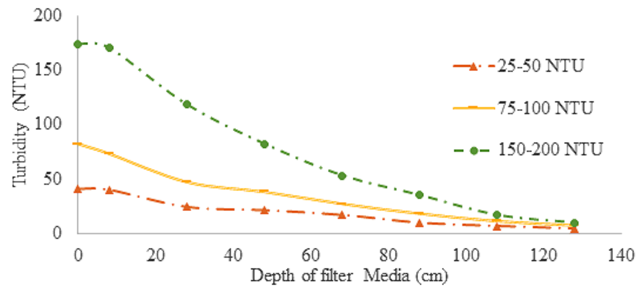

Figure 3: Turbidity removal profile along filter depth at 0.5 m/h

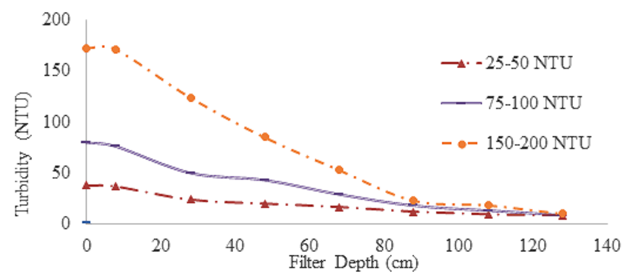

Figure 4: Turbidity removal profile along filter depth at 0.75 m/h

Removal of turbidity in the coarser fraction of the filter

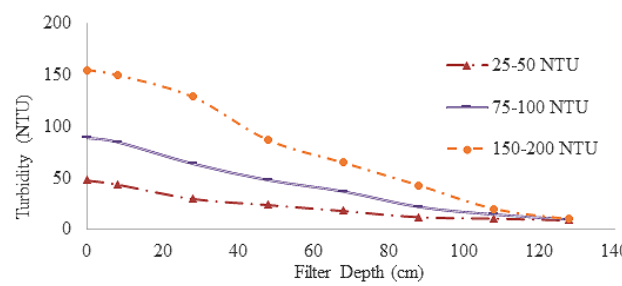

Figure 5: Turbidity removal profile along filter depth at 1.0 m/h

media is high. It was observed that effluent turbidity is inversely proportional to the depth of filter media, assuming other parameters same. It may be due to the large solids storage capacity of the coarser media or settling of heavier particle. It is observed that depth of filter media required to reduce turbidity to desired level is directly proportional to filtration rate. At filtration rate of 0.5 m/h, 80 cm depth of filter is sufficient to reduce turbidity to less than 10 NTU for inlet turbidity less than 50 NTU. At filtration rate of 0.75 m/h, 100 cm depth of filter is sufficient to reduce turbidity to less than 10 NTU for inlet turbidity less than 50 NTU. At filtration rate of 1.0 m/h, 120 cm depth of filter is sufficient to reduce turbidity to less than 10 NTU for inlet turbidity less than 50 NTU.

4. Conclusion

The outcomes of this experimental work is the relation between effluent turbidity and filter media which is the effluent turbidity is inversely proportional to the depth of filter media, assuming other parameters same. On the other hand depth of filter media required to reduce turbidity to desired level is directly proportional to filtration rate.

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