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Reuse of Construction Debris as Viable Replacement of Sand Media in Rapid Sand Filtration

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Abstract: Worldwide, around 1.8 million people die every year because of diarrheal diseases like cholera. A large number of water borne diseases can easily be prevented, if we supply safe drinking water to the people. Clean and safe drinking water is a rare commodity and there exists a dire need for pure drinking water. Filtration is a key unit operation in water treatment plant. Rapid sand filtration has long served and continues to do so, as an effective filtration method in water treatment plants. Because of recent boom in construction industry in India, there is non-renewable exploitation of river sand causing severe ground water depletion on one hand and increasing the price of sand on the other hand. Hence, there exists a challenge to look for a suitable alternative material which could be thought of replacing sand as media in rapid sand filtration. Generation of Construction and Demolition (C&D) waste has caused various problems in the recent past and therefore its handling and disposal demand considerable attention. This work focuses on developing an alternative media for rapid sand filtration using construction debris and evaluating its performance to meet the specifications. Rapid sand filtration studies are performed by using two filtration columns, one with river sand and other with concrete waste debris as media. Both materials have been sieved and adjusted for its size specifications for rapid sand filtration. Initial test results indicate comparable performance from two filtration columns in terms of removal of turbidity. With increasing number of trials (time of operation), it has been observed that better results were obtained for the concrete waste debris as media. Therefore, on the basis of results obtained, crushed, sieved, washed and dried concrete waste can be used as an alternative to river sand for rapid sand filtration.

Keywords: *Construction & Demolition Waste (C&D), Construction Debris, Rapid Sand Filtration, Water Treatment Plant*

1. Introduction

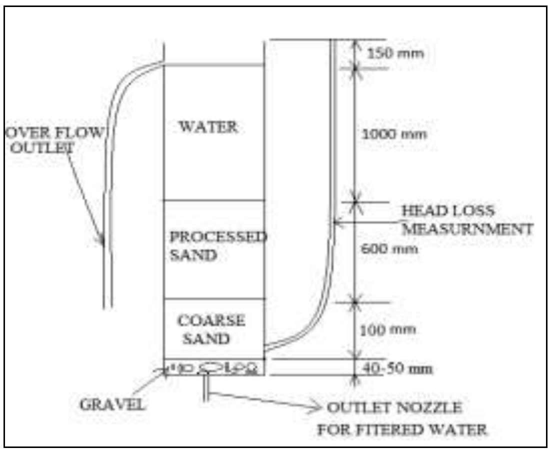
Water treatment plant plays an important role in safeguarding the health of people in any country. Chlorine disinfection is widely accepted as an effective disinfection process in water treatment plant throughout the world and thereby saving millions of lives from waterborne diseases. For efficient chlorine disinfection, effective filtration of water for turbidity and/or suspended particles removal is a pre-requisite. In conventional water treatment plant, the filtration of water after coagulation/flocculation/settling is carried out in a rapid sand filtration unit [1, 2, 3]. Historically, clean river sand of specified sizes is used as an effective media for rapid sand filtration [4]. However, the recent boom in the construction sector in India has put a stress on economical availability of river sand for water filtration. In this context, it is imperative to search for an alternative material to replace river sand in rapid sand filtration units. As per BIS [5], a minimum of 150-200 lpcd (135 lpcd for lower income groups) of drinking water is to be supplied to our population. When we consider the water treatment plants of whole country, there is a huge requirement of river sand. Because of increasing price of river sand, a search for an alternative material for rapid sand filtration is essential to have an affordable water treatment in our country. In this context, Construction and Demolition waste (C& D waste) appears to be a suitable option to replace river sand in rapid sand filtration. Recent research on C&D waste finds lot of reuse applications like road works (embankment and subgrade construction, sub-base construction, rigid base construction), as aggregates in recycled concrete for preparing concrete bricks, pavement blocks, as an inert fill material for low lying areas, landscaping etc. [6]. From the review of literature, there was no report on re-use of C&D waste as filtration media. Therefore, the objective of this work is to explore the feasibility of using construction debris as a filter media in rapid sand filtration unit.

Two numbers of filtration columns were designed and operated to evaluate the performance. In one column, river sand and in other, construction debris was used as filtration media. Lake water from VIT Chennai campus / simulated water were used as source of raw water. Parameters like pH, turbidity, hardness of input and filtrate were monitored to evaluate the performance. The results of this study indicate that construction waste debris could serve as a sustainable alternative to the river sand in rapid sand filtration.

2. Materials and Methods

2.1. Experimental Sample

Water collected from a lake located inside the VIT Chennai Campus was initially used for the study. Later its characteristics were simulated to synthesize turbid water using Bentonite clay. pH of the experimental sample was constant with value of 7.79 and the turbidity was in the range of 15.8 NTU to 16.2 NTU.



(a)

(b)

Figure 1 *(a) Schematics of Filtration column setup (b) Installed Filtration units*

2.2. Preparation of filter media and filter column

The dried river sand was initially subjected to sieve analysis and the particle size distribution curve was obtained and is represented by the term, stock sand (or available sand). As per specifications, for rapid sand filters, the effective size ranges from 0.45 mm and higher with uniformity coefficient ranging from 1.5 and lower. This stock sand did not meet the requirements and hence based on a series of calculations as described in [7], the stock sand particle size distribution was modified and represented as processed sand. The similar process was utilized for concrete waste debris, except that it was first crushed manually to visible finer gradation prior to carrying out sieve analysis of stock sample. Further, 2M Nitric acid was used to acid wash both the processed sand and concrete waste debris. Subsequently, both the filter media were washed several times with tap water until their pH was brought back to the neutral range. Prepared material was then finally dried prior to use. The prepared sand media and concrete waste debris media characteristics by sieving were: effective size = 0.45 mm to 1.2 mm and uniformity coefficient = 1.45.

A PVC pipe of internal diameter 75 mm with 1.9 m length was used as a filter column. The bottom 40 to 50 mm of the column was filled with gravel of size varying from 10 mm to 25mm. A manometer was fixed to the filter column at the bottom to measure the head loss during filtration. The next 100 mm of the column was filled with coarse sand greater than 4.5 mm. The prepared sand media (or construction debris) was filled above the coarse sand bed to a height of 600 mm. Operating head maintained was 1000 mm (constant head) by providing an overflow. An 80 L capacity vessel was used to store coagulated water and this water was pumped to the filtration column using a calibrated Peristaltic pump (Miclins, India) at predetermined rate of flow. The filtrate was collected through a 6 mm nozzle from the bottom of filter. Figure 1 shows the schematic representation and the installed laboratory scale filtration units designed and developed for the present study.

2.3. Filter operation

The filters were run at filtration rate of $5m^3/m^2/h$ using experimental sample. During each filter run, operational parameters like time for filtration, head loss, flow rate and filtrate quality (performance) parameters like pH, turbidity, and hardness were monitored. Initially all the performance parameters were measured for the coagulated water prior to the filter run. Thereafter, samples were collected via the outlet nozzle from both the filtration columns in succession of one hour, for measuring the performance parameters. Simultaneously, head loss was also noted in one hour intervals. Samples were then analyzed for pH, turbidity, and hardness (both permanent and temporary). All analyses were carried out in triplicate and as per Standard Methods [8].

3. Results and Discussion

3.1. Alum coagulation of lake water

The optimum alum dose for coagulation was determined by carrying out jar testing procedure. During a typical jar test, a known volume of coagulant stock solution was added to the turbid water, and the tester immediately triggered the stirrer to rapidly mix the solution for 1 min at 100 rpm and then slowly mix the solution at 30 rpm for 20 min. After coagulation, the solution was settled for 30 min. Supernatants were taken and the residual turbidity was measured. Figure 2 shows the typical Turbidity v/s Alum Dosage curve and 30 mg/L was the optimum dose. The optimum dose of 30 mg/L was employed for bulk coagulation of experimental sample prior to filtration.

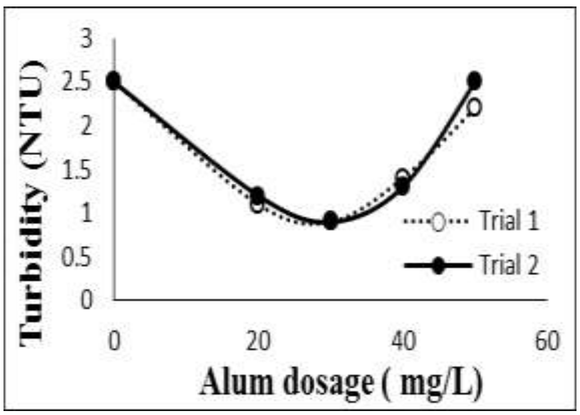
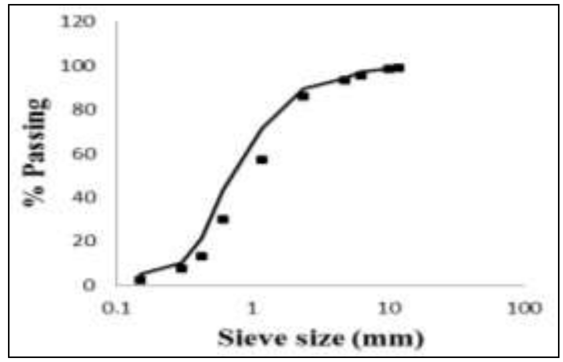


Figure 2 *Turbidity v/s Alum dosage curve*

3.2. Preparation of filter media

Stock sample of river sand collected from the VIT Chennai construction site was first subjected to sieve analysis and particle size distribution curve was obtained for the same. On the other hand, construction and demolition waste collected from the VIT Chennai construction site was first crushed into small (or fine) pieces and then sieve analysis was performed. Figure 3 shows typical graphs of the sieve analysis of the river sand and crushed concrete waste debris. They are termed as stock sample. Based on the series of calculations, they were converted to processed media samples. Figure 4 shows the particle size distribution curves of processed media materials.



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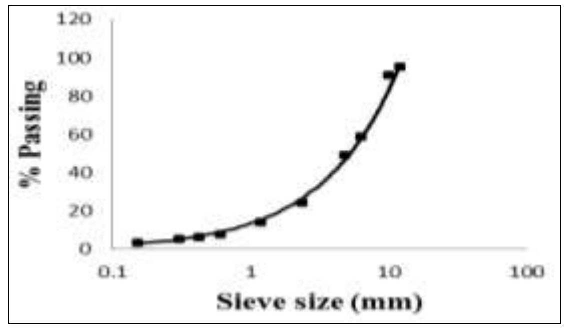

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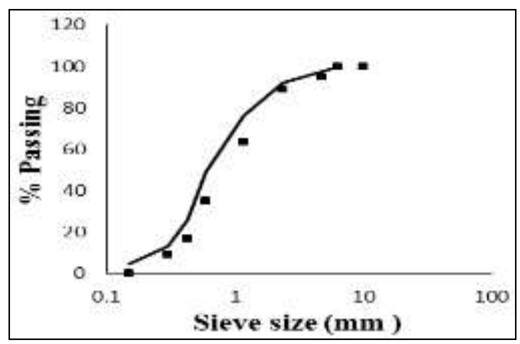
Figure 3 *Particle size distribution curves for stock samples (a) River sand and (b) Concrete waste debris*



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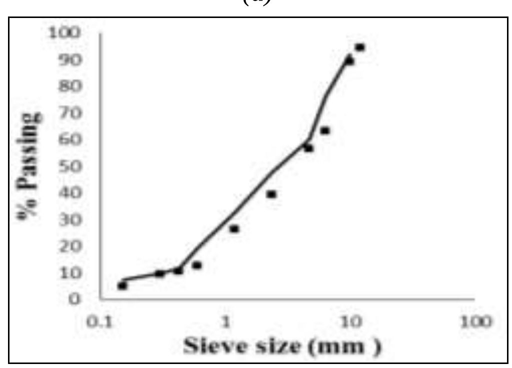
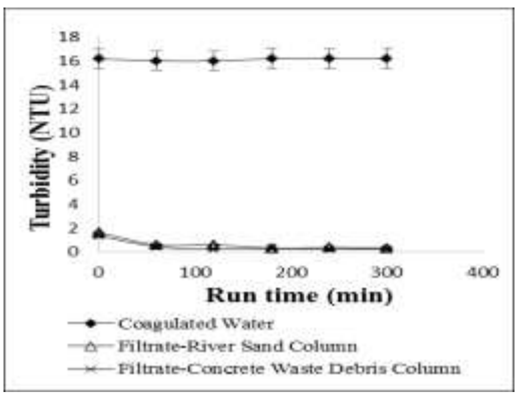


(b)

Figure 4 *Particle size distribution curves for processed samples (a) River sand and (b) Concrete waste debris*

3.3. Performance evaluation of filters

To evaluate the performance of the filters, pH and turbidity of the coagulated water and filtrate were determined during the whole filtration period. The variations are shown in Figure 5. Symbols shown in the figures are mean values associated with these measurements and the variabilities are within 5%. The filter operation was done for 300 minutes. From Figure 5(b), it can be observed that the filtrate pH dropped to 7.40 and 7.61 for river sand and concrete waste debris, respectively. The higher pH in case of concrete debris could be as a result of leaching of carbonate ions which are there in cement concrete. However, both pH values are within the limits of drinking water standards [9]. The filtrate turbidity was in the range of 0.30–1.70 NTU for the case of river sand filter and 0.20-1.40 NTU for the filter with concrete waste debris as the filter media. The filtrate turbidity from both the setups always remained less than 2 NTU. These values indicate that the performance of both filters is comparable and meeting standards [9]. Moreover, the clarity of the filtrate from filter with concrete waste debris was always superior.



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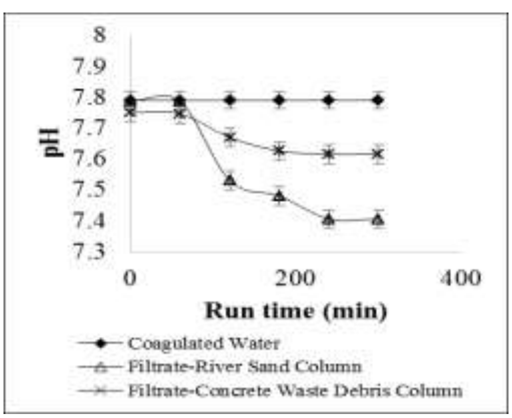

(b)

Figure 5 *Performance evaluations of filters (a) Turbidity removal (b) pH variation*

There is an apprehension that when cement concrete debris are used as a filter media, the hardness of the filtrate may get increased as a result of leaching of Calcium and Magnesium ions from composite (concrete). Therefore we measured the Total Hardness (T.H.) and Permanent Hardness (P.H.) of filtrate to assess the utility of filtrate. The average T.H. and P.H. of the coagulated water were 435 mg/L (as $CaCO_3$ equivalent), and 335 mg/L (as $CaCO_3$ equivalent) respectively. Figure 6 shows the variation of T.H. and P.H. as a function of time. It is observed from the figure that hardness reduces with time of filter operation because efficiency of leaching of calcium and magnesium is getting reduced with time of operation. The hardness value of filtrate from two setups is well within the range of 500 mg/L specified by WHO. This is evident from the Figure 6 that after 200 minutes operation the values are almost constant.

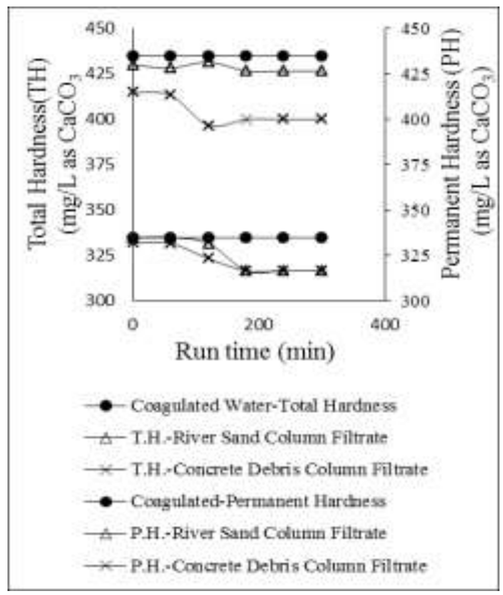

Figure 6 *Total Hardness (T.H.) and Permanent Hardness (P.H.) v/s Run time*

Also, it was observed that head loss increased (10 mm to 50 mm) with the time of filter operation for both the filter columns, but the change was steeper in case of concrete waste debris column.

4. Conclusions

A filter consisting of 600 mm depth of crushed, sieved and washed concrete waste debris as processed material was found to show superiority in turbidity removal when compared with conventional sand filter possessing similar specifications. Optimum alum dose of 30 mg/L was employed for coagulation prior to filtration. This filter achieved 90 to 92% of turbidity removal over 6 hours of service time. Turbidity as much as 16 NTU had been successfully handled in the filter. The filtrate pH reduced to 7.40 and 7.61 for river sand and concrete waste debris, respectively. The filtrate quality was meeting standards set by BIS for drinking water. From the results of limited study of this work, it is possible to replace the river sand used in rapid sand filtration units of water treatment plants with concrete construction debris available in the locality. However, a detailed pilot plant study is essential before field application.

5. Acknowledgement

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