Design and Construction of a Modified Rapid Sand Filter for Treatment of Raw Water

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Abstract

Day by day the quality of drinking water is deteriorating. Hence it is a need of the time to supply clean and safe drinking water to the public. Sand filtration is one of the techniques used for to obtain the clean water. According to the World Health Organization, water and sanitation are the primary drivers of public health. The main objective of this research work is to improve the filtration technologies to make them more sustainable and accessible for the public. This study focused on developing improved modified operating methods for rapid sand filtration technology. In this an attempt is made one modified rapid sand filter and compare with conventional rapid sand filter. The main objective to increase the overall efficiency of conventional rapid sand filters by some modification. For construction of modified filter PVC granules are used as capping material as well as ferric chloride also used. Both the material help to achieve the lower turbidity and total dissolved solid concentration.

Keywords: Sustainable, Construction, Rapid Sand Filter, Modified, Technologies

I. INTRODUCTION

Filtration is a fundamental unit process that is commonly used to help remove: particles present in surface water, precipitated hardness from lime-softened water, microorganisms (bacteria, viruses, and protozoan cysts), precipitates of aluminum and iron used in coagulation, and precipitated iron and manganese present in many well water supplies (Ben et.al. 1993; Gadkari 1980).

Filtration can be compared to a sieve or micro-strainer that traps suspended material between the grains of filter media. However, since most suspended particles can easily pass through the spaces between grains of the filter media, straining is the least important process in filtration. Filtration primarily depends on a combination of complex physical and chemical mechanisms, the most important being adsorption. Adsorption is the process of particles sticking onto the surface of the individual filter grains or onto the previously deposited materials. Forces that attract and hold particles to the grains are the same as those that work in coagulation and flocculation. In fact, coagulation and flocculation may occur in the filter bed, especially if coagulation and flocculation before filtration was not properly controlled. Incomplete coagulation can cause serious problems in filter operation.

Filters may be broadly classified as "rapid" or "slow" based on the rate at which they operate. A slow sand filter is a filter operated at very low filtration rates (usually 0.1~0.2 m/hr) without coagulation in pre-treatment (Cleasby 1993). Rapid sand filtration was introduced in the United States in the 1880s and has been widely accepted for municipal application because of its high productivity and flexibility in treating waters of different turbidities (Tate 1980). In drinking water treatment, the function of rapid sand filters is to remove particulate matter in the influent suspension and provide significant pathogen removal. In contrast to slow sand filters, rapid sand filters are operated at a much higher filtration rates (5~10 m/hr) and are frequently used in water treatment following pre-treatment of the raw water by chemical coagulation, flocculation, and sedimentation.

II. OBJECTIVES

The primary focus of this research is to design and construct a modified filtration system water treatment. The materials used for the design of modified filtration system; gravel, sand, PVC granules and ferric chlorides.

- To design modified rapid sand filter
- To increase the efficiency of conventional rapid sand filter
- Identify alternative methods for solving stated problem
- Perform experimental analysis on aspects of the design that must be tested
- Summarize the findings and draw conclusions as to how well the solution meets specific design criterion

III. MATERIALS AND METHODS

A. Collection of Sample

For the experimentation purpose 10 water samples were collected from Sabarmati River. All the precautions were followed while collecting the sample. The samples were stored at 4 º c to prevent contamination. The collected samples were transferred to the laboratory to carry out different experiments. Before experimentation all the samples bring to room temperature. Following is the summary of all the water sampling.

Table - 1
Summary of Sampling

Sampling No.	*Date of Sampling*	*Time of Sampling*	*Date of Analysis*	*Time of Analysis*
1	*23/2/2017*	*10:00am*	*24/2/2017*	*9:30am*
2	*27/2/2017*	*10:00pm*	*28/02/2017*	*9:30am*
3	*03/03/2017*	*10:00am*	*04/03/2017*	*9:30am*
4	*07/03/2017*	*10:00am*	*08/03/2017*	*9:30am*
5	*10/09/2017*	*10:00am*	*11/03/2017*	*9:30am*
6	*15/3/2017*	*10:00am*	*16/3/2017*	*9:30am*
7	*17/3/2017*	*10:00am*	*18/3/2017*	*9:30am*
8	*20/3/2017*	*10:00am*	*21/3/2017*	*9:30am*
9	*22/3/2017*	*10:00am*	*23/3/2017*	*9:30am*
10	*29/3/2017*	*10:00am*	*30/3/2017*	*9:30am*

B. Experimentations

Various experiments were performed for water i.e., pH, Turbidity and Total dissolved solids to determine the initial and final concentration. pH of the sample helps to determine the acidic or basic characteristics. Generally the pH scale varies from 0 to 14. 0 to 7 is acidic, 7 are neutral and 7-14 is alkali in nature. According to drinking point of view it plays an important role. Continuous use of acidic or alkali water create the serious health issues.

Turbidity of the sample is defined as the cloudiness and haziness due to presence of suspended or dissolved solids. The unit of measurement is NTU (Nephelometer Turbidity Unit). For drinking purpose the value should not exceed 10 NTU. The method is based on the comparison of the intensity of scattered light by sample with the intensity of sample with the intensity of light scattered by standard references solution.

Total dissolved solids (TDS) are a measurement of the total amount of dissolved inorganic compounds in water. It is determined by an instrument that measures the ability of water to conduct electricity. As the concentration of inorganic compounds increases, water becomes a better conductor of electricity. In natural water the dissolved solids present due to bicarbonates, carbonates, sulphates of calcium, magnesium, sodium and potassium. The amount of dissolved solids present in water is a consideration for its suitability for domestic use. Presences of dissolved solids in industrial water form scales, causes foaming in boiler, cause corrosion and interfere with the colour, and taste of the products. The permissible limit for total dissolved solids is 500 mg/L.

For experimentation A.P.H.A. Standards Methods for the Examination of Water and Waste Water, American, Public Health Association, Washington, D.C. 1985, 19th Edition was followed.

C. Fabrication of Model

Two models were fabricated for experimental point of view. One is conventional sand filter and other is modified sand filter. For conventional sand filter the materials base material is gravel and filter material is sand. For modified filter along with gravel and sand, ferric chloride and PVC granules also used.

1) Gravels

- Used as supporting material for filter.
- 4-5 layers of gravel, larger at bottom and smaller at top.
- Gravels sieved at 13.2 mm, 9.5 mm and 8 mm.

2) Sand

- Used as filter material.
- 2 layers of sand filter for filtration activity.
- Sand collected and sieved by 710 micron sieve.
- Properly cleaned and oven dried at 105 º C.

3) PVC Granule

- Used as capping material.
- Collected from local vendor of size 2-4mm.
- Washed properly and oven dried at 50º C.
- 2 layers in between the filter material.

4) Admixture

- 0.15 mg of Ferric chloride added to 1L of raw water.
- It acts as a disinfectant as well as coagulant.
- Increase the efficiency of overall modified filter.

Table - 2
Material arrangement in conventional filter

For setup-1 (Conventional sand filter)			
Layer-1	*Base material*	*Gravel*	*4.5 cm thickness*
Layer-2	*Filter material*	*Sand*	*4 cm thickness*

Table - 3
Material arrangement in modified filter

For setup-2 (Modified sand filter)			
Layer-1	*Base material*	*Gravel*	*7.5 cm thickness*
Layer-2	*Capping material*	*PVC granule*	*2.5 cm thickness*
Layer-3	*Filter material*	*Sand*	*3 cm thickness*
Layer-4	*Capping material*	*PVC granule*	*3 cm thickness*
Layer-5	*Filter material*	*Sand*	*3.5 cm thickness*

Fig. 1: Conventional Sand Filter

Fig. 2: Modified Sand filter

IV. RESULTS AND DISCUSSION

The result of pH didn't have much more effect on both type of filter. 10 samples were collected from Sabarmati River, the raw water, conventional and modified filter the pH is around 7.6 to 8.3. According to drinking point of view the pH is around 6.5 to 7.5.

Table - 4
Result summary of pH data

pH	*Raw Water*	*Conventional*	*Modified*
S1	*8.04*	*7.89*	*7.74*
S2	*8.24*	*8.3*	*7.89*
S3	*8.5*	*8.13*	*7.92*
S4	*8.4*	*8.1*	*7.85*
S5	*8.03*	*7.85*	*7.62*
S6	*7.93*	*7.8*	*7.62*
S7	*8.39*	*8.3*	*7.92*
S8	*7.92*	*7.73*	*7.72*
S9	*8.23*	*7.92*	*7.81*
S10	*8.09*	*7.9*	*7.73*

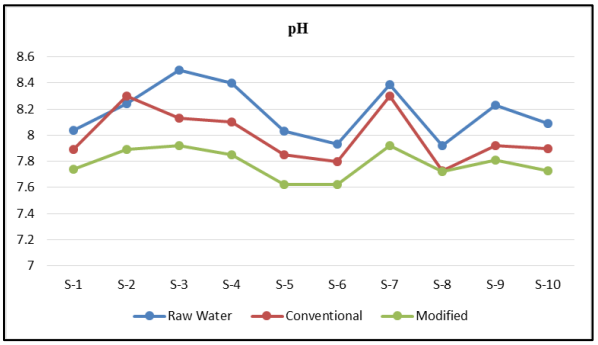

Fig. 3: pH result analysis

Filtration efficiency mainly depends on porosity of media used for filtration work. PVC granule capping depth – 5.5cm (2.5 and 3 cm), compared to sand and so larger particles remains on top after backwashing it also provides larger depth for filtration and improves performance by removing larger suspended particles at initial stage. Due to porous nature maximum throughput volume can be achieved and also run length is increased. This is the reason due to which modified sand filter has a better efficiency in terms of removal of turbidity with compare to conventional filter. In conventional filter turbidity is increased due to the filter media. When the raw water is passed through the sand particles, the water gains some turbidity. Ferric chloride also used as a admixture to modified filter. This also helps to achieve the efficiency of removal.

Table - 5
Result summary of turbidity data

Turbidity (NTU)	*Raw Water*	*Conventional*	*Modified*
S1	*7.6*	*18*	*3.8*
S2	*11.9*	*18.3*	*4.8*
S3	*12*	*21*	*3.9*
S4	*11.5*	*19*	*4.3*
S5	*11.8*	*19.2*	*3.4*
S6	*10.4*	*18.7*	*4.1*
S7	*11.5*	*19.2*	*4.3*
S8	*12.2*	*18.3*	*4.4*
S9	*9.4*	*18.4*	*3.2*
S10	*11.3*	*17.4*	*4.8*

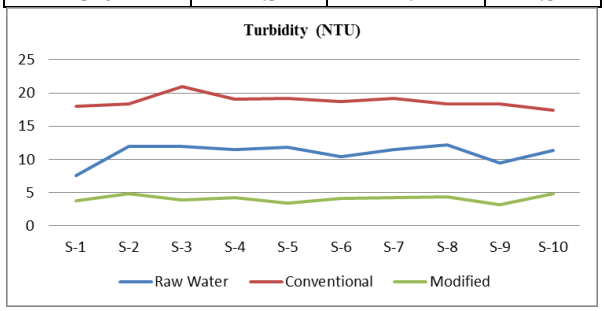

Fig. 4: Turbidity result analysis

In respect to total dissolved solids removal modified sand filter is able to remove the dissolved solids with compare to conventional filter. With drinking point of view TDS limit should be 650 mg/L. out of 10 samples, only one sample value is exceeding the prescribed limit. The better removal efficiency in modified sand filter is achieved due to two layers of sand with proper capping with PVC granules.

Table - 6
Result summary of total dissolved solids data

TDS (PPM)	*Raw Water*	*Conventional*	*Modified*
S-1	*915*	*820*	*780*
S-2	*632*	*570*	*450*
S-3	*850*	*730*	*650*
S-4	*740*	*630*	*425*
S-5	*680*	*530*	*410*
S-6	*780*	*660*	*520*
S-7	*710*	*640*	*480*
S-8	*690*	*595*	*482*
S-9	*680*	*600*	*490*
S-10	*650*	*580*	*520*

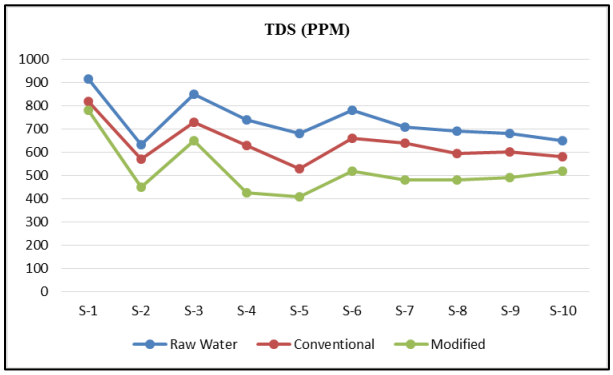

Fig. 5: Total dissolved solids result analysis

V. CONCLUSION

The conclusion can be drawn from this research work is:

- Instead of providing one sand layer of for filtration work, sand layer with two capping is also useful to carry out efficient filtration work.
- Capping with PVC granules with 2.5 cm and 3 cm capping layer increases turbidity removal efficiency.
- By using PVC granules as capping material, the washing period for sand filter can be increased. Because capping material helps to prevent the direct contact between sand and water, hence the sand particles didn't get clogged immediately.

By using ferric chloride as admixture (0.15 mg/L) following points are achieved:

- Very effective in the removal of high and low turbidity.
- Works over a wide pH range.
- Low cost.
- Makes a heavier floc that settles faster and works better in cold water.
- Produces higher sludge concentrations = Lower sludge disposal costs.

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