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Investigations and comparison of a conventional sand filter and a modified sand filter for water purification.

Leela Bhargavi Katragadda[a], & D.Ramadevi[b]
Department of Civil Engineering, Meenakshi College of Engineering Chennai, INDIA.
Email(a): leelasid11@gmail.com; email(b): ramadevi.me@gmail.com

ABSTRACT

Water being a depleting resource needs to be treated in a sustainable way. The oldest-natural method of purifying drinking water is to use sand filters, made by using layers of sand and gravel placed at proportional depths and sizes. A few drawbacks like requirement of further disinfection, bad odour, inefficiency in removing chemicals like cholrine, fertilizers etc,. does not allow the usage of conventional method. Hence in this research work a Modified Sand Filter is constructed by partial replacement of sand with Granulated Activated Carbon in order to overcome all possible drawbacks.

GAC is a locally available material made from materials like coal, wood, coconut shell, nutshells or any carbonaceous materials, which makes it a "sustainable, cost efficient and eco friendly material" as it is a reuse material. The principle of water purification through GAC is adsorption of contaminants in the microscopic pores on its surface. GAC has small, low-volume pores that increase the surface area available for adsorption or chemical reactions. Due to its high degree of micro porosity, one gram of activated carbon has a surface area in excess of 3,000 m2 allowing it to remove particles ranging from 0.5 – 10 microns and therefore removes pesticides, chlorides and microplastics as well. It is observed from experimental results that various physical and chemical parameters (taste, odour, pH, turbidity, chloride and hardness) have been improved (IS 10500: 2012) after using the Modified Sand Filter. Therefore further experimentation can be done to check its efficiency in removal of other hazardous substances.

Keywords – Modified sand filter, Filter media, water purification, water treatment, sustainable, GAC.

RESUMEN

El agua, que es un recurso que se está agotando, debe tratarse de manera sostenible. El método natural más antiguo para purificar el agua potable es usar filtros de arena, hechos con capas de arena y grava colocadas a profundidades y tamaños proporcionales. Algunos inconvenientes, como el requisito de una mayor desinfección, mal olor, ineficacia en la eliminación de productos químicos como la clorina, fertilizantes, etc. no permite el uso del método convencional. Por lo tanto, en este trabajo de investigación se construye un filtro de arena modificado mediante el reemplazo parcial de arena con carbón activado granulado para superar todos los posibles inconvenientes.

El GAC es un material disponible localmente hecho de materiales como carbón, madera, cáscara de coco, cáscaras de nueces o cualquier material carbonoso, lo que lo convierte en un "material sostenible, rentable y ecológico" ya que es un material de reutilización. El principio de purificación del agua a través de GAC es la adsorción de contaminantes en los poros microscópicos de su superficie. El GAC tiene poros pequeños y de bajo volumen que aumentan el área de superficie disponible para la adsorción o reacciones químicas. Debido a su alto grado de microporosidad, un gramo de carbón activado tiene una superficie superior a los 3.000 m2, lo que le permite eliminar partículas de entre 0,5 y 10 micrones y, por lo tanto, elimina también pesticidas, cloruros y microplásticos. Se observa a partir de resultados experimentales que se han mejorado varios parámetros físicos y químicos (sabor, olor, pH, turbidez, cloruro y dureza) (IS 10500: 2012) después de utilizar el Filtro de Arena Modificado. Por tanto, se pueden realizar más experimentos para comprobar su eficacia en la eliminación de otras sustancias peligrosas.

Palabras clave: filtro de arena modificado, medios filtrantes, purificación de agua, tratamiento de agua, sostenible, GAC.

INTRODUCTION

Sand filters are used as a step in the water treatment process of water purification. There are three main types; rapid (gravity) sand filters, upward flow sand filters and slow sand filters. All three methods are used extensively in the water industry throughout the world. The first two require the use of flocculent chemicals to work effectively while slow sand filters can produce very high quality water with pathogens removal from 90% to >99% (depending on the strains), taste and odour without the need for chemical aids. Sand filters can, apart from being used in water treatment plants, be used for water purification in singular households as they use materials which are available for most people. The history of separation techniques reaches far back, as filter materials were already in use during ancient periods. Rushes and genista plants were used to fill sieving vessels that separated solid and liquid materials. The Egyptians also used porous clay vessels to filter drinking water, wine and other liquids.

ACTIVATED CARBON

Activated carbon, also called activated charcoal, is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions.

Due to its high degree of micro porosity, one gram of activated carbon has a surface area in excess of 3,000 m2 (32,000 sq ft) as determined by gas adsorption. An activation level sufficient for useful application may be obtained solely from high surface area. Further chemical treatment often enhances adsorption properties. Activated carbon is carbon produced from carbonaceous source materials such as bamboo, coconut husk, willow peat, wood, coir, lignite, coal, and petroleum pitch. It can be produced by one of the following processes:

- *Physical activation*: The source material is developed into activated carbon using hot gases. Air is then introduced to burn out the gasses, creating a graded, screened and de-dusted form of activated carbon. This is generally done by using one or more of the following processes:
- *Carbonization*: Material with carbon content is pyrolyzed at temperatures in the range 600–900°C, usually in an inert atmosphere with gases like argon or nitrogen

Activation/Oxidation: Raw material or carbonized material is exposed to oxidizing atmospheres (oxygen or steam) at temperatures above 250 °C, usually in the temperature range of 600–1200 °C.

- *Chemical activation:* The carbon material is impregnated with certain chemicals. The chemical is typically an acid, strong base, or a salt (phosphoric acid 25%, potassium hydroxide 5%, sodium hydroxide 5%, calcium chloride 25%, and zinc chloride 25%). The carbon is then subjected to lower temperatures (250–600 °C). It is believed that the temperature activates the carbon at this stage by forcing the material to open up and have more microscopic pores. Chemical activation is preferred to physical activation owing to the lower temperatures, better quality consistency, and shorter time needed for activating the material.

FIG. 1 - Granular activated carbon

SETTING UP THE FILTERS

The size of sand particles is specified by the effective size, which is the sieve size in millimeters that permits 10% of sand by weight to pass. Very fine sand is clogged quickly and rate of filtration is reduced. On the other hand very coarse sand permits suspended particles and bacteria to pass through the sand bed. Therefore, the size of sand for filter bed should be properly selected. Gravel and activated carbon also need to be sieved for the same reason. The sieved materials needs to be separated as per different sizes as the layers are arranged accordingly.

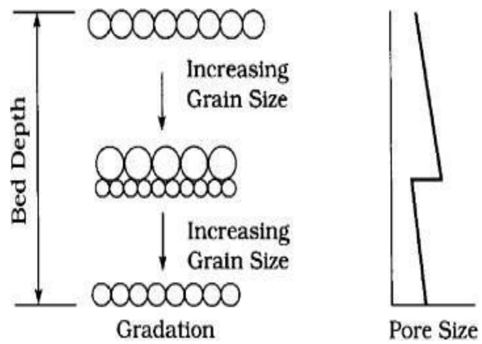

FIG. 2 – order of arrangement of filter media according to size

The sieves used for forming the filter bed are 0.3 mm, 0.6mm and 1.18mm.Therefore sieves of 2.36mm, 1.18mm, 0.6mm, 0.3mm and a pan are taken for sieving. Sand has been manually sieved through all selected sieves. The sand retaining on 2.36mm sieve is not used for the filtration. Sand from other sieves is carefully taken and stored.

The sieves used for forming the base are 2.36 mm and 4.75 mm. Therefore sieves of 10mm, 2.36mm, 4.75mm and a pan are taken for sieving. Gravel has been manually sieved through all selected sieves. The gravel retaining on 10 mm sieve is not used for the filtration. Gravel from other sieves is carefully taken and stored.

FIG. 3 – Sieving the materials

Activated carbon selected for the filter is Granulated Activated Carbon (GAC). The sieves used for forming the filter media are 0.3 mm, 0.6mm and 1.18mmand the same are used for sieving. GAC has been manually sieved through all selected sieves. GAC from all sieves is carefully taken and stored.

As the materials are locally chosen and may be little contaminated washing the filter media materials is a very essential step. It avoids the risk of filtered water possessing the properties of filter media. Hence all filter media is nicely washed and sundried before the installation of the filter.

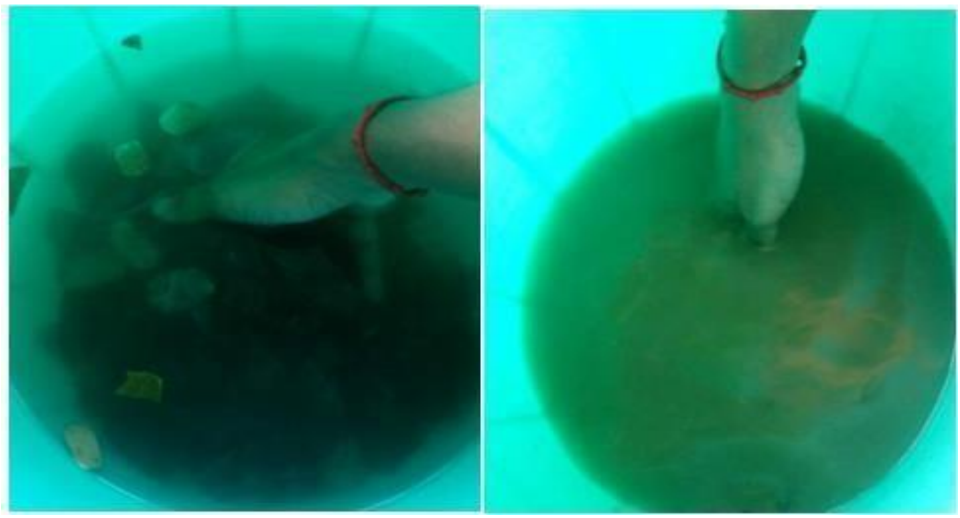

FIG 4 (A) Washing Gravel (Left Top) (B) Washing Sand (right top)

CONVENTIONAL SAND FILTER

To install the filtration tank an old fish tank has been chosen so that there is a clear view of the layers laid. The fish tank is properly cleaned and washed. An outlet pipe is set at the bottom of the tank for collecting the treated water. For setting up the outlet pipe a hole has been carefully filled and a pipe has been fixed. Next to form the base layer, the aggregate that has been washed and dried is used. Aggregates of size 4.75mm and 2.36mm are laid in decreasing order (larger ones at the bottom). The layers are neatly spread and well packed up to a height of 2cm each. Next to form the filter media sand of sizes are 0.3 mm, 0.6mm and 1.18mm are taken and laid in decreasing order (larger ones at the bottom). The layers are neatly spread and well packed up to a height of 2cm each. Finally water is carefully poured into the filter to give a uniform spread and uniform flow. The amount of inlet water and time taken has been noted as well.

INLET WATER = 1 liter

OUTLET WATER = 600 ml

TIME TAKEN = 56 minutes

FIG. 5 - Setting Up the Conventional Sand Filter

MODIFIED SAND FILTER

To install the modified sand filter the same fish tank has been reused after removing the old layers and is properly cleaned. To form the base layer, the aggregate that has been washed and dried is used. Aggregates of size 4.75mm and 2.36mm are laid in decreasing order (larger ones at the bottom). The layers are neatly spread and well packed up to a height of 2cm each. Next to form the filter media sand of sizes are 0.3 mm, 0.6mm and GAC of 0.6mm and 1.18mm sizes are taken and laid in decreasing order (larger ones at the bottom). The layers are neatly spread and well packed up to a height of 2cm each. Finally water is carefully poured into the filter to give a uniform spread and uniform flow. The amount of inlet water and time taken has been noted as well.

INLET WATER = 1 liter

OUTLET WATER = 720 ml

TIME TAKEN = 1hr 08 minute

FIG. 6 - Setting Up the Modified Sand Filter

RESULT

The laboratory tests for the following drinking water characteristics are conducted in a private lab for all three samples (only turbidity has been conducted in the college laboratory) and the results are compared with the IS for drinking water as per IS 10500 2012.

Table 1 – Permissible Limits of Various Physical and Chemical Parameters

S.NO	CHARACTERISTICS	ACCEPTABLE LIMIT
1	pH	6.5 - 8.5
2	Turbidity	<5 NTU/JTU
3	Total hardness	200 – 600 mg/l
4	Chloride	250 mg/l – 1000 mg/l

Table 2. - Comparison of Various Physical And Chemical Parameters Between Samples I, Ii, Iii

S.NO.	PARAMETERS	LIMITS	SAMPLE I (Source water)	SAMPLE II (Conventional Sand filter)	SAMPLE III (Modified Sand Filter)
1.	pH	6.5 - 8.5	8.91	7.6	7.2
2.	Turbidity	<5 NTU/JTU	12	6	4
3.	Chloride	200–600 mg/l	399.3	391.8	208.95
4.	Total Hardness	250-1000mg/l	706.45	258.7	367.64
5.	Electrical Conductivity	NA	1580	1045	981.79

Considering the results and comparison, the efficiency of the modified sand filter is relatively high and hence it could be considered for further experimentation in order to check if it could meet all other required parameters. 1) In addition to efficiency, the presence of activated carbon ensures a considerable amount of increase in taste and reduces any bad odour present in the source water. 2) Also as discussed in earlier chapter, research says that Activated carbon has the capability of removing the presence of micro plastics which is one the biggest concerns in today's era. 3) The presence of fertilizers and pesticides have also been reduced when treated with Activated Carbon says a few more studies. 4) Regarding the availability of GAC, it is a locally available material and is made from materials like coal, wood, coconut shell, nutshells or any carbonaceous source materials making the material a sustainable and eco friendly material as it is a reuse material. Also the properties and efficiency changes based on the primary raw material used for making GAC. 5) The cost of the GAC when brought in store is affordable or it can be easily made using waste or reusable materials like wood, coconut shells etc. which will reduce its cost further.

Therefore it is clear that the Modified sand filter made with partial replacement of sand with Granular Activated Carbon (GAC) in a conventional sand filter is more efficient, feasible, and sustainable and eco friendly - thus can be used for water filtration.

REFERENCES

IS 10500:2012 - Indian Standard DRINKING WATER SPECIFICATION

Water Supply Engineering – Volume I by Santhosh Kumar Garg

Water Supply Engineering – Volume II by Santhosh Kumar Garg. Water Supply Engineering – Dr. BC Punmia

Activated Carbon for Water and Wastewater Treatment: Integration of Adsorption and Biological Treatment by Ferhen Cecen

Activated Carbon Adsorption for Wastewater Treatment by Jerry R. Perrich. Chemistry of water treatment by Samuel D Faust and Osman M Aly

Novel Water Treatment and Separation Methods Simulation of Chemical Processes - Edited By Bharat A. Bhanvase, Rajendra P. Ugwekar, Raju B. Mankar.

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