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STUDY OF WATER FILTRATION WITHOUT CHEMICAL PRE-TREATMENT

J. O. Jeje

Department of Civil Engineering, Obafemi Awolowo University, Ile – Ife.

Email of Corresponding Author: jemails2000@yahoo.co.uk

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ABSTRACT: *This research work focused on studying water purification without chemical pre-treatment. In the studies, alternative approaches were carried out to develop a filter bed suitable for filtering water without the use of chemical treatments that is also cost effective. Polyvinyl Chloride (PVC) pipes (100 × 1700) mm were used as filter boxes. The experiment carried out during the study was divided into two major parts; that is slow sand and rapid sand filter parameters. The slow sand filter consisted of two filter pipes, one consisting of a stratified layer of sand of size range of 0.20 – 0.60 mm with a depth of 700 mm as filter medium. The turbidity, filtration rate and head loss of the effluent across the filter were monitored for 15 days. It was found that slow sand filter plus granular activated carbon (GAC) and rapid sand filter plus GAC were more effective in the removal of turbidity. Turbidity reduced with the increase in time. Rapid sand filter was found to be the least effective in the removal of bacteria while slow sand filter plus GAC was the most effective. The slow sand filter unit gave a very high coliform count compared to other filter units. It was found that the filtration rate plays a vital role in the mechanism of filtration.*

KEYWORDS: Schmutzdecke layer, Head loss, Rapid sand filtration, Slow sand filtration, Granular activated carbon (GAC).

INTRODUCTION

A typical water treatment plant consists of aeration, coagulation, flocculation, sedimentation, filtration, chlorination and distribution units. The treatment is necessitated by the possible pressure of some impurities such as dissolved gases, dust, minerals, organic matter, microorganisms and other pollutants (Cescon *et al.*, 2016). This research focuses on the filtration unit that removes mainly suspended solids, microbes, mineral, colour and taste. Filtration is a mechanical or physical operation which is used for the separation of solids from fluids by interposing a medium to fluid flow through which the fluid can pass, but the solids in the fluid are retained. This separation depends on the pore size and the thickness of the medium as well as the mechanism that occurs during filtration (Cescon *et al*., 2016). Gravity filters consist essentially of an open topped box usually made of concrete, drained at the bottom and partially filled with a filter medium. Gravity filters are subdivided into rapid and slow filters.

Most treatment plants make use of the rapid sand filters which require physicochemical treatment of the water such as coagulation and flocculation and also sedimentation of the water (Dastanaie, 2007). This research was concerned with filtration without chemical pre-treatment, where the unit was expected to remove turbidity, colour, taste, dissolved gases and remove a high proportion of the coliform bacteria and perhaps virtually all pathogenic bacteria and viruses that the raw water may contain. The most common method of surface and ground water treatment is filtration using a sand medium. The modern sand filter used in municipal practice consists of an open water tank generally greater than 3 m deep, containing a layer of sand 600 – 900 mm thick supported on a gravel 150 – 300 mm thick. As the filtration continues, the sediment removed from the water builds up in the sand layer resulting in an increasing headloss through the sand layer. The filter is cleansed by reversing the flow of water. This process is known as backwashing. Water is admitted under pressure into the underdrain system at such a rate that the upward flow of water will expand the sand bed about 50% (Ritson *et al*., 2014).

The normal mechanisms of rapid filtration may be spent between those mechanisms which operate to bring particles into contact with the sand grains and those which operate to hold the particles in contact with the sand grains (Davies, 2012). The former includes straining, sedimentation, initial and centrifugal forces and diffusion; the latter includes electrostatic attraction, van der waals forces, adherence and chemical bridging. All these operate in slow sand filtration, but to a far lesser extent flow with rapid sand filtration. However, with slow sand filtration, there is the additional purification process of biological activity (Fuentes-López *et al*., 2018; Tan *et al*., 2013). As a filter goes to operation at the beginning of a fresh water run, as a result of settlement from the water and straining at the sand surface the accumulation of a layer of alluvial mud, organic waste, bacterial matter, algae, etc. in intimate contact with the top of the sand bed. This is known as the filter skin or schmutzdecke layer (Jeje & Oladepo, 2018; Slavik *et al*., 2013; Soyer *et al*., 2010).

This study focuses primarily on the comparison of the rapid sand and slow sand filtration unit; with and without granular activated carbon. It includes laboratory investigations of filtration and parameters which include head loss, normalised head loss, turbidity, flow rate, among others.

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MATERIALS AND METHODS

Materials and Equipment

The materials and equipment that were used in the project are sand, gravel, granular activated carbon (GAC), PVC pipes, manometers, turbidimeter, water (obtained from Opa Dam), pipes and appurtenances and an effluent basin.

Methods

i Conversion of palm kernel shells to carbon

The palm kernel shells were initially fired by local means to reduce the fumes that would be produced in furnaces during carbonisation. Initial stage of the conversion (carbonisation) was carried out by heating the palm kernel shell contained in porcelain dishes, in a muffle furnace in the absence of air at 600ºC for 15 minutes, after evolution of fumes had ceased, carbonised shells were cooled rapidly in water. The carbonised shells were crushed and activated by heating in the presence of air at a temperature of 800ºC for 15 minutes. The activated carbon passing through the sieve 1.18 mm – 2.36 mm was used.

The effective sizes and uniformity coefficient of the sand sample were also determined.

ii Charging the filters and experimental runs

The bed materials were introduced into the filter pipes and the filter medium arranged. The air bubbles in the manometer were removed by pouring clean water in the filter. The raw water was then run through the filter. A constant head was maintained with the aid of a drilled 15 mm hole at the top of the supernatant level; this acted as a control valve. The opening of valve 1 for each filter pipe to a predetermined level and the opening of valve 2 fully started the filtration process. The head loss and flow rates were then simultaneously monitored for each of the filter units. Filters 1 and 2 were set to have slow sand filtration rate while 3 and 4 had rapid sand filtration rate. The closing of the second valve put an end to the filtration run.

Filtration Parameters

i. Determination of flow rate

Flow rates were determined using the direct method. This involves the measurement for the effluent volume with a measuring cylinder and the time for the 100 ml cylinder to be filled up. The effluent volume per second per square metre of filter cross sectional area was taken as the flow rate (ml/s.m^2). The flow rates were adjusted to be between 0.65 – 6.5 l/min.m^2 for filter units 1 and 2 and 65 – 196 l/min.m^2 for units 3 and 4 (Morita and Reali, (2019) for slow sand filters and rapid sand filters respectively. The filters ran for six hours daily after which the direct method was carried out to determine the flow rate of each of the filter units.

ii. Head loss and turbidity measurement

Head loss was measured by reading the water levels in the manometers and then making the appropriate calculations with readings (Equation 1). The turbidity of samples was measured with a HACH 2100A turbidimeter.

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$$\text{Normalised headloss} = \frac{\text{Actual headloss} \times 0.2}{\text{Filtration rate}} \text{ .... Equation 1}$$

iii. Bacteriological analysis

The coliform and E. coli count were also determined in a microbiology laboratory.

RESULTS AND DISCUSSION

Head Loss and Filtration Rate

The normalised head loss was calculated for the actual head loss using equation 1. The normalised head loss can be predicted when constant filtration rate is maintained. The variations of head loss and normalised head loss with time are as shown in Figures 1, 2, 3 and 4. The rate of increase in the head loss was slightly less for the first eight days of run after which the head loss increased rapidly. The normalised head loss also increased with time although it was seen to be much lower than the actual head loss.

The filtration rate was seen to be declining during the experimental run. The filtration rate investigated was generally in the range of 0.65 – 6.5 l/min.m^2 for slow sand and 65 – 195 l/min.m^2 for rapid sand filtration. The variation of filtration rate with time is shown in Figures 5 and 6. The results show that at the early stage of filtration, the blocking of the filter was only close to the surface. This indicates that formation of the schmutzdecke layer is within the first week of filtration. Then after this, both filtration rate and head loss changed rapidly with time indicating that the blocking of the filter increases down the filter bed.

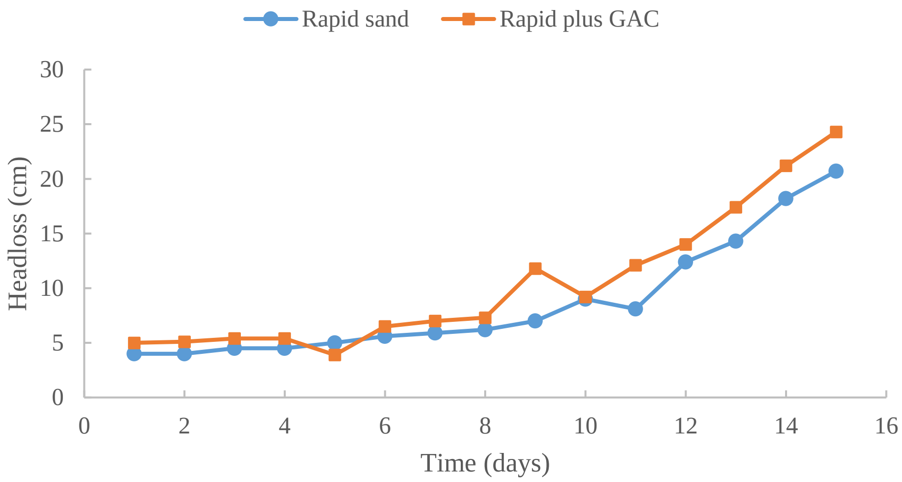

Figure 1: Variation of head loss with time for rapid sand filtration

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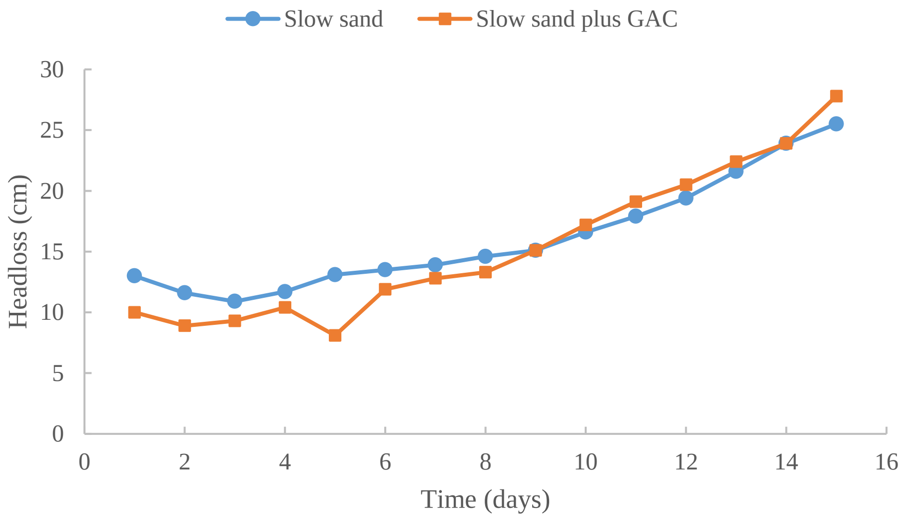

Figure 2: Variation of head loss with time for slow sand filtration

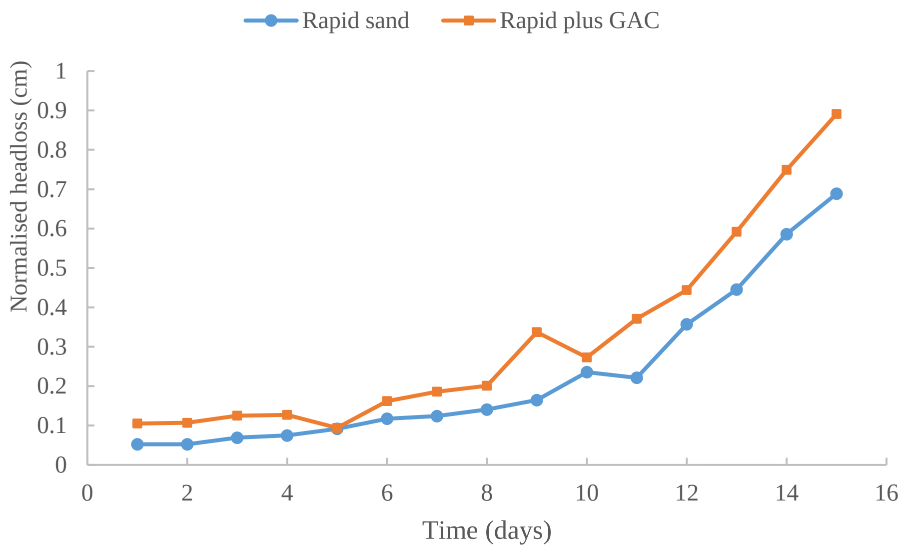

Figure 3: Variation of normalised head loss with time for rapid sand filtration

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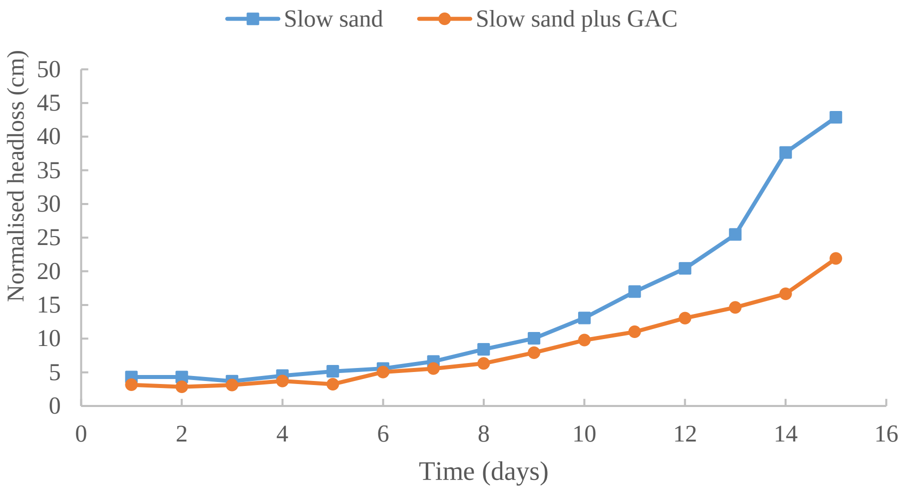

Figure 4: Variation of normalised head loss with time for slow sand filtration

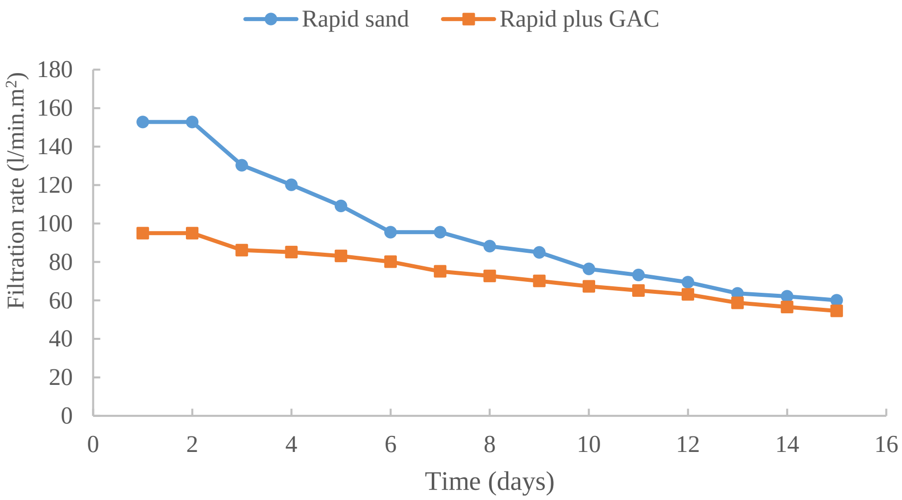

Figure 5: Variation of filtration rate with time for rapid sand filtration

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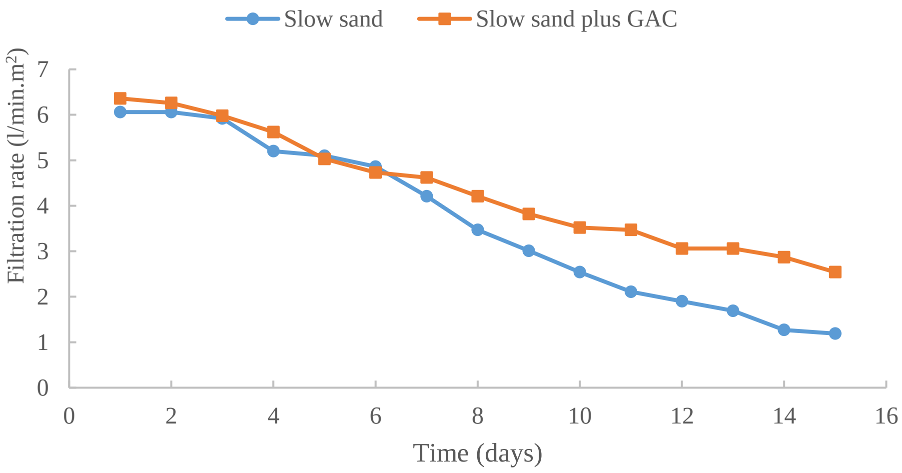

Figure 6: Variation of filtration rate with time for slow sand filtration

Turbidity and Bacteriological Analysis

Table 1 shows the variation of turbidity with time. The Table shows the turbidity of raw water (unsieved), sieved raw water and treated water i.e. for rapid sand, rapid plus GAC, slow sand and slow sand plus GAC filtration. The influent turbidity varied between 5.4 – 18 NTU. This shows that the sieve was effective in removing turbidity up to 86% from the influent. The filters were shown to be effective in reducing turbidity.

Table 2 shows the amount of coliform removed by the filter, the table shows a slight removal of the E. coli at the beginning of the filtration. This was due to the immaturity of the formed schmutzdecke layer.

Table 1: Variation of turbidity with time in different filter bed media

Time (days)	Turbidity (NTU)					
	Influent		Treated Effluent			
	Unsieved	Sieved	Rapid Sand	Rapid + GAC	Slow Sand	Slow Sand + GAC
1	15	12	8	8	5	5
2	14	14	6.5	6	5	4.5
3	16	13	6.5	5.2	4.2	3.7
4	12.2	11	5.9	5.2	6.1	4.2
5	5.4	4.8	2	1.8	1.2	1
6	13	12	8	7	5	4
7	14	10	7	6	5	4.9
8	7.5	5	2.6	2.4	1.4	1.2
9	10	7	6.8	6.1	5.9	5
10	7.4	6.7	2.2	2	1.4	1.2
11	18	18	5	5	3	3
12	18	16	4.5	3	2.5	2

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13	10	9.5	5.1	4.2	3.1	1.9
14	9	8	6.5	6	4.9	3.1
15	13	10	5.9	4.3	2.2	2

Table 2: Water quality report – coli MPN test at 37ºC (cells/100 ml)

Day	Raw water	Rapid	Rapid + GAC	Slow	Slow + GAC
3	**149**	143	139	120	115
13	**120**	79	49	110	33

CONCLUSION

From the research, it was discovered that the schmutzdecke layer was developed within a few days of the filtration phase. The amount of coliforms removed per 100 ml of the treated water improved with time as the filter improved in maturity and the strength of turbidity increased with time. Rapid sand filter was found to be the least effective in the removal of bacteria followed by rapid sand plus Granular Activated Carbon (GAC), and slow sand filter plus GAC. Granular activated carbon introduced into the filters was found to be effective in the removal of turbidity, colour and odour compared with filters without GAC. The presence of GAC in the filters helped in the high reduction of bacteria (coliforms) compared with filters without GAC. The flow rate decreased with time due to increasing head loss across the filter bed with time irrespective of the type of filter. Straining mechanism in filtration is very significant in the treatment of water in a filter.

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