Comparative Analysis of Filtration Using Corn Cob, Bone Char and Wood Chippings

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Abstract

Water from two rivers and a borehole in Zaria, Nigeria were subjected to filtration without any pre-treatment in a model laboratory filter. Laboratory analysis carried out on the materials used showed that the sand and the medium size aggregate have an effective size and uniformity coefficient of 0.18 mm and 2.5 mm, and 2.17 and 1.76 respectively. While activated charcoal, activated bone char and the activated corn cob has effective sizes and uniformity coefficients of 3.33mm, 2.3mm and 2.2mm, and 1.97, 3.09 and 4.09 respectively. The chemical analysis of the filtrate water quality showed that there was an increase in pH in the range of 7.01 to 7.90 in all the activated carbons with the highest value accounted for by activated bone char. In terms of hardness removal, activated charcoal gave a better filtrate quality (10.4% removal). The activated bone char however, increased the hardness of each of the raw samples due to the presence of traces of calcium ion in it. Also activated corn cob had a very high tendency of reducing the acidity of the samples compared to the activated charcoal and activated bone char. While in the case of chloride, activated bone char gave a better removal (29%) compared to the activated charcoal (11.2%) and the activated corn cob (12.3%). In the case of alkalinity, the activated bone char and activated corn cob showed a gradual removal in the concentration than the activated charcoal in all the samples. The activated corn cob was more efficient in turbidity and ammonia nitrogen removal. It can therefore be concluded that each of the activated carbons has a different rate of removal of some of the contaminants in the raw water samples. While the activated corn cob is good in the removal of some of the physical properties, the activated born char plays important role in the removal of some of the chemical properties: chloride ion, alkalinity and the activated charcoal was suitable for the reduction of ammonia nitrogen concentration. Hence it is recommended that a mix of the three sources of activated carbons be used for a desirable result in filtration operations

Introduction

Filtration is one of the stages in water treatment. Under controlled condition in water purification/ treatment plant, it is an indispensable unit process (Culp and Culp, 1974). Filtration is a process in water treatment which removes suspended matter through the use of filters. The removal of suspended solids by filtration plays an important role in both the naturally occurring purification of groundwater and artificial purification of surface water done in treatment plants.

During filtration, the water to be treated is passed through a porous substance. The water quality improves by partial removal of suspended solids, colloidal matter and the reduction of number of bacteria, colour, odour etc.

According to Baker and Taras (1981), some of the various types of filter media used in filtration can be stable material like granular bed of sand, crushed stone, anthracite (hard coal), glass fibres, diatomaceous earth, activated carbon and coconut husk. In public and large private water supplies, granular beds of sand and activated carbons are almost exclusively used. It is cheap, inert, durable and readily available. Such bed allows penetration of impurities from the raw water without an immediate deterioration of the effluent quality.

Activated carbon is a black solid substance resembling granular or powdered charcoal. It is extremely porous with a very large surface area. Certain contaminants accumulate on the surface of the activated charcoal in a process called adsorption. The two main reasons that chemicals adsorb onto activated charcoal are a "dislike" of the water, and attraction to the activated charcoal. According to Kathy (2007), many organic compounds, such as chlorinated and non- chlorinated solvents, gasoline, pesticides and tri-halo-methane can be adsorbed by activated charcoal. Activated charcoal is effective in removing chlorine and moderately effective in removing some heavy metals. Activated charcoal will also remove metals that are bound to organic molecules. It is important to note that charcoal is not necessarily the same as activated charcoal. Activated charcoal removes vastly more contaminants from water than ordinary charcoal. Particle size also affects the rate of removal; smaller activated charcoal particles generally show higher adsorption rates (Camp, 1984 and Nikoladse et al, 1989).

In general, activated carbon is a carbon that has been treated or processed with oxygen to make it extremely porous and thus to have a very large surface area available for chemical reaction. These tiny holes give the charcoal a surface area of 300 – 200 m^2/g allowing liquids or gases to pass through the charcoal and interact with the exposed carbon (Ismail et al., 2009; Frederick, 1990 and Eckenfelder, 2000).

The main aim of the study is to determine raw water filtrate quality using various activated carbons incorporated with graded sand in a model filtration bed.

Materials and Methods

Materials: Various equipments were used for the collection, transportation and mixing of the samples – sand, gravel, wood char, corn cob and bone char. The sand was collected from four different locations along the Kubanni stream, Samaru – Zaria, Nigeria. Sieve analysis was conducted on the samples to determine the best sample. The result of the sieve analysis and the particle size distribution for all the sand samples is presented by: effective size (d_{10}), sieve size that permits 60% of the sample (d_{60}) and the uniformity coefficient (C_u). Similar processes were also carried out on the gravels collected.

Research materials used included buckets, head pans, shovels, hand gloves, sacks for the storage of the washed sand and gravel, burning sink, oven and draining tray.

Reagents such as ethylendiaminetetra acetic (EDTA), buffer solution, Nesslers reagent, Rochelle salt solution, phenolphthalein, methyl orange indicator, Sulphuric acid, eriochrome black T indicator, 0.1N sodium hydroxide, potassium chromate indicator, 0.14N silver nitrate, distilled water were used in conformation to standard methods (APHA, 1995).

While the raw materials used to obtain the carbon were wood, wood chips, corn cobs and bone obtained from timber shed, from threshers and the abattoir respectively.

Methods

***Activation of the Carbon*:** the material was separated and cleaned from other materials. It was then sun dried and burnt in the burning sink at 300-500 ^{0}C for 3-5 hours. The charcoal was then soaked in chemical solution (phosphoric acid) for 12-18 hours to become activated charcoal. It was then washed with distilled water, spread on a tray at room temperature to be drained. This was then dried in an oven at temperature of 110^{0}C for 3 hours, crushed or refined and sieved into sizes.

Sieve analysis of the activated carbon: The ratio of the sieve size that passes 60% of the particles to the one that passes 10% of the sand medium is the uniformity coefficient (Cu).it is a term for particles distribution. In the determination of Cu, the sample was thoroughly mixed and sieved through B.S. sieve sizes – 0.15, 0.3, 0.6 and 1.18. The sieves are arranged in descending order of sizes. (Twort et al, 1985)

The coefficient of uniformity is computed as;

$$\% \text{ passing} = \frac{100(w + w_2)}{w_1} \qquad (1.0)$$

$$Cu = \frac{p_{60}}{p_{10}} \quad (2.0)$$

Where: w_1 = initial weight of sand, w_2 = weight of sand retained, P_{60} = sieve size that passes 60% of the medium and P_{60} = sieve size that passes 10% of the medium

Filtration using the various types of activated carbons

Method 1: this is obtained when the activated bone char was incorporated with the sand bed filter, with the activated bone char at the top. This bed was used to filter the various water samples, replacing the activated carbon after each sample.

Method 2: this was where the activated wood char (charcoal) was incorporated with the filter bed media; with the activated charcoal at the top. The dual media was used to filter the samples, replacing the activated wood char after each sample.

Method 3: The same process was followed as in M1 and M2, but using the activated corn cob. The thickness of each layer of the filter bed was noted. However, the same thickness of the filter layers was used for the three methods.

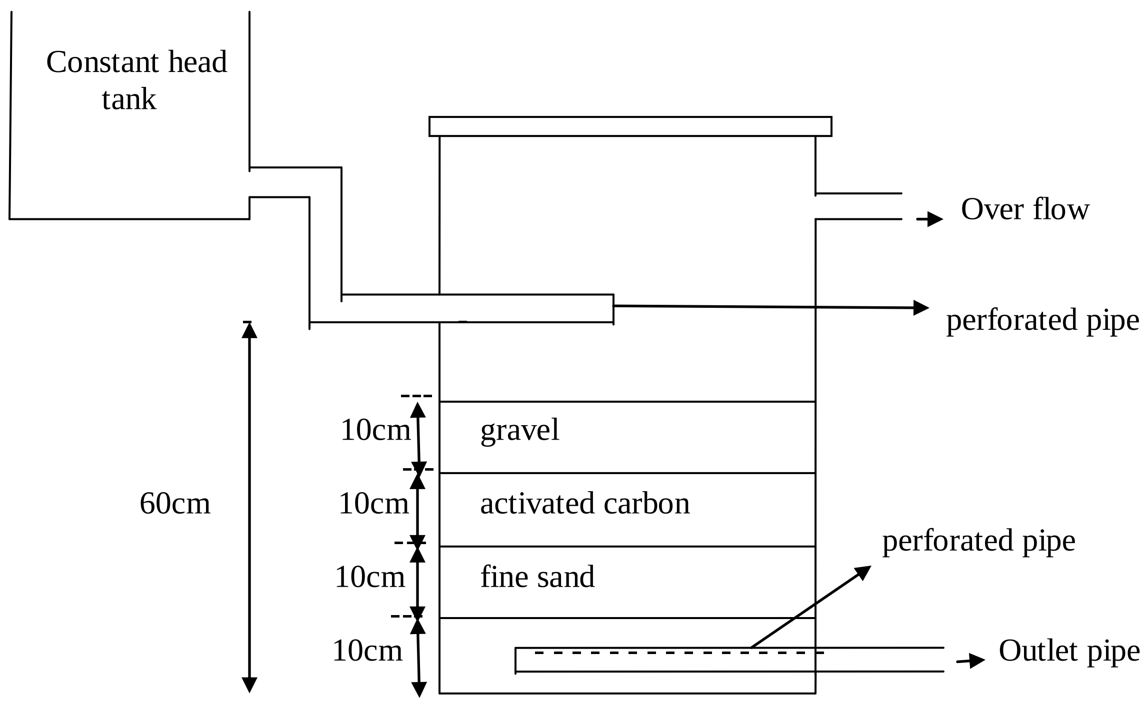

Figure 1: Laboratory set up of the filtration process

Quality Analysis: Water quality tests were carried out on the raw water and filtrate respectively to determine its pH, ammonia nitrogen, chloride, hardness, turbidity, acidity and alkalinity respectively on the basis of which the comparative analysis was made

Results and Discussion

Sieve Analysis: Figs. 2 and 3 is the particle size distribution curve obtained from the result of the sieve analysis for the fine sand and medium aggregate. It shows that the sand and the medium size aggregate have an effective size of 0.18mm and 2.5mm; and uniformity coefficient 2.17 and 1.76 respectively.

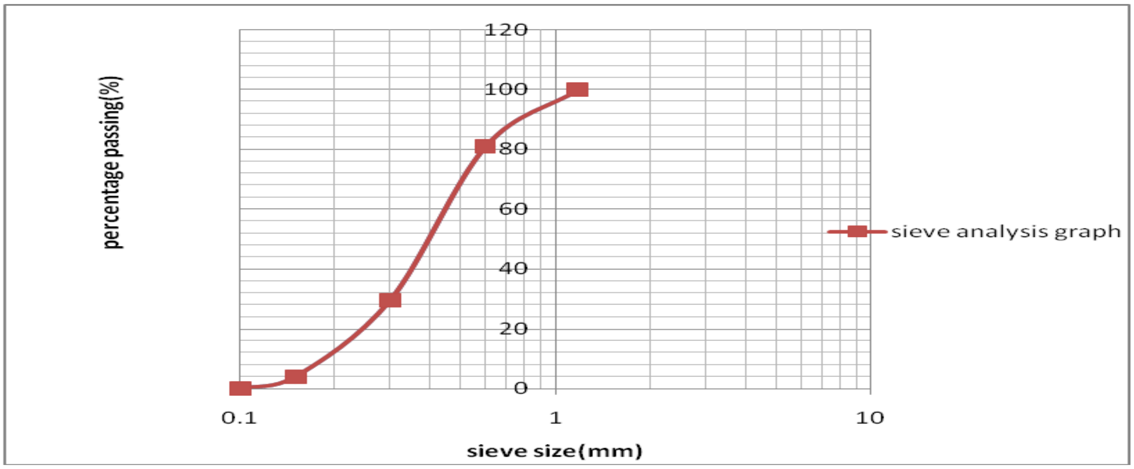

Figure 2: Particle size distribution curve for the fine sand.

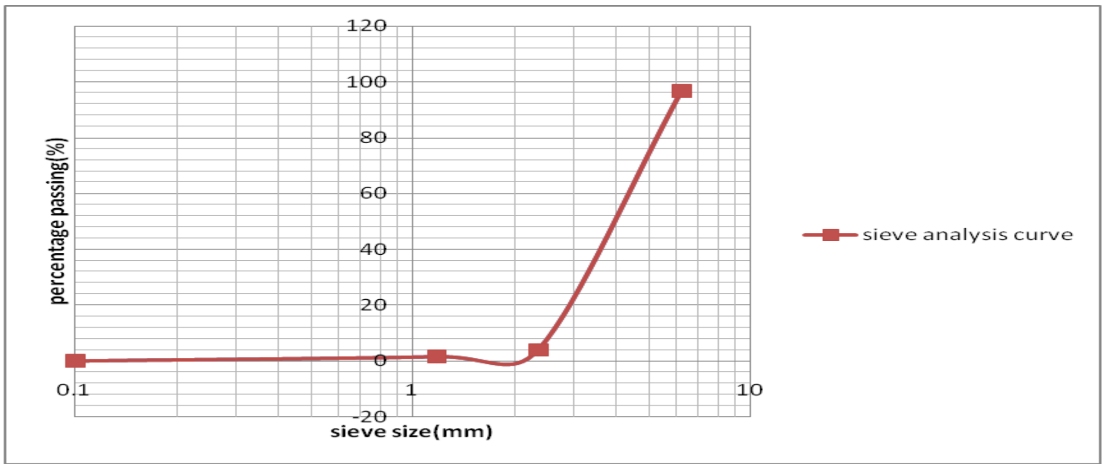

Figure 3: Particle size distribution curve for the medium aggregate

The particle size distribution curve for the activated carbon is as shown in figs. 4, 5 and 6 respectively. From the curve, it shows that the activated charcoal, activated bone char and the activated corn cob has effective sizes of 3.33mm, 2.3mm and 2.2mm; and uniformity coefficient of 1.97, 3.09 and 4.09 respectively.

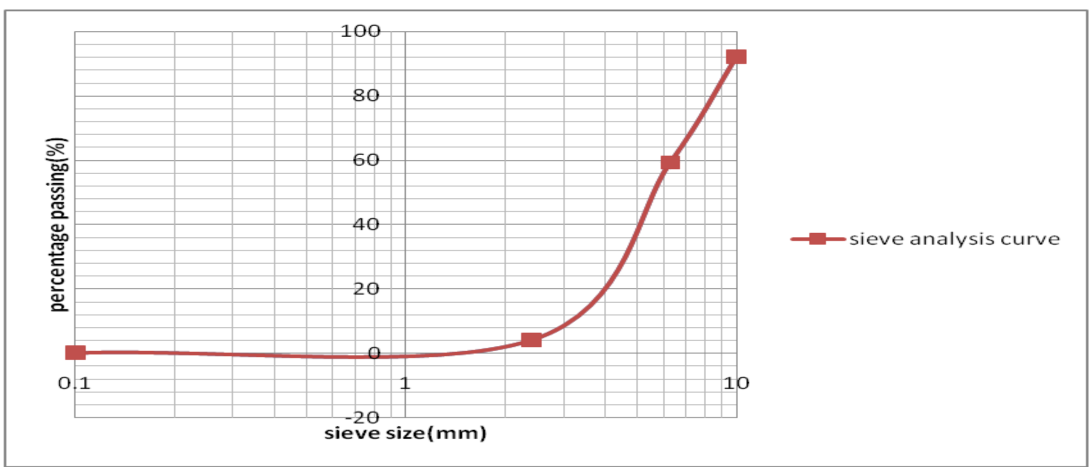

Figure 4: Particle size distribution for the activated charcoal

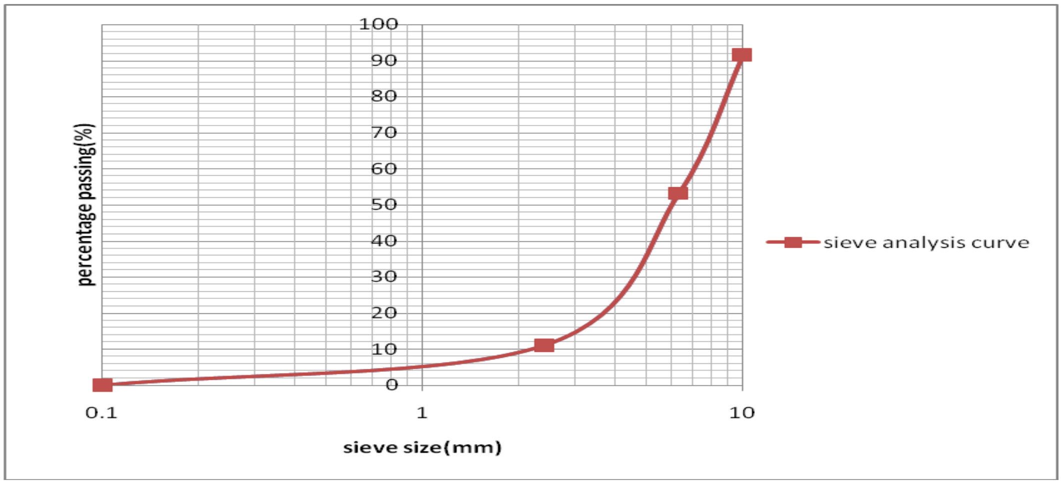

Figure 5: Particle size distribution for the activated bone char

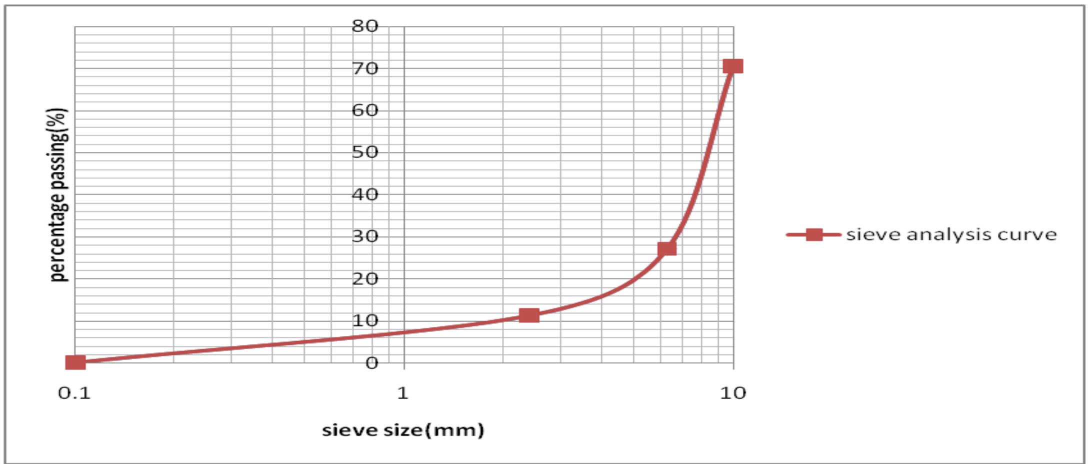

Figure 6: Particle size distribution for the activated corn cob

Table 1 shows the summary of the physical properties of the various media compared with the recommended values. Similarly, Table 2 to 7 shows the values for the laboratory tests (pH, hardness, acidity, chloride, alkalinity and turbidity) carried out compared with the recommended values.

Table 1: Physical properties of the sand, medium aggregate and the activated carbons used.

	Effective size (mm)	Uniformity coefficient
Kubanni sand	0.18	2.17
Medium aggregate	2.5	1.76
Activated charcoal	3.30	1.97
Activated bone char	2.30	3.09
Activated corn cob	2.20	4.09
Recommended value	0.15 – 0.35	1.5 – 3.0

The pH of the filtrates from the activated carbons increased from the range of 7.01 – 7.90. The activated bone char showed a higher pH value for all the filtrate from each of the raw water samples as shown in Table 2.

Table 2: pH values

	Raw Water	Activated charcoal	Activated bone char	Activated corn cob
Kubani river	7.36	7.60	7.57	7.90
River shika (Basawa)	7.05	7.65	7.47	7.83
Borehole (Danraka)	6.80	7.01	6.90	7.14
Standard value	6-8.5	6-8.5	6-8.5	6-8.5

Table 3 shows the variation of the hardness of the filtrate quality with the raw samples compared with the recommended value. It shows that the activated charcoal gave a better filtrate quality (10.4% removal). The activated bone char however, increases the hardness of each of the raw samples due to the presence of traces of calcium ion in it.

Table 3: Hardness values (mg/l C_aCO_3)

	Raw Water	Activated charcoal	Activated bone char	Activated corn cob
Kubanni river	111.11	106.21	121.21	110.61
River Shika (Basawa)	101.10	90.01	97.21	100.11
Borehole (Danraka)	141.41	118.80	161.19	122.22
Standard value	100	100	100	100

Table 4 shows that the activated corn cob has a very high tendency of reducing the acidity of the samples compared to the activated charcoal and activated bone char.

Table 4: Acidity values (mg/l C_aCO_3)

	Raw Water	Activated charcoal	Activated bone char	Activated corn cob
Kubanni river	25.00	19.00	15.00	15.00
River shika (Basawa)	10.00	10.00	10.00	5.00
Borehole (Danraka)	25.00	23.00	23.00	18.00

Table 5 show the variation of the chloride ion of the raw sample with the filtrate when the various activated carbons were used as filter media compared to the recommended value. The graphs shows that the activated bone char gave a better removal (29% averagely) compared to the activated charcoal (11.2%) and the activated corn cob (12.3%). However, the value of the chloride ion concentration for the raw samples is below the recommended value.

Table 5: Chloride values (mg/l)

	Raw Water	Activated Charcoal	Activated Bone Char	Activated Corn Cob
Kubanni river	14.11	13.35	8.89	12.38
River Shika (Basawa)	11.19	10.67	9.08	11.08
Borehole (Danraka)	70.05	53.51	48.16	50.81
Standard value	250	250	250	250

Table 6 shows the variation of the alkalinity of the raw sample and that of the filtrate. Danraka raw water sample has a high alkalinity compared to the two other samples. The activated bone char and activated corn cob showed a gradual removal in the concentration of the alkalinity than the activated charcoal in all the samples.

Table 6: Alkalinity values (mg/l C_aCO_3)

	Raw Water	Activated charcoal	Activated bone char	Activated corn cob
Kubanni river	2.00	2.00	1.00	2.00
River Shika (Basawa)	2.00	2.00	2.00	2.00
Borehole (Danraka)	3.00	3.00	2.00	3.00

Table 7 shows the difference in the ammonia nitrogen concentration of the raw samples and the filtrate quality. The raw samples have low concentration of ammonia nitrogen compared to the standard value (2mg/l). The activated corn cob showed a greater tendency for lowering the concentration of the ammonia nitrogen compared to the activated charcoal and activated bone char

Table 7: Ammonia nitrogen value (mg/l)

	Raw water	Activated charcoal	Activated bone char	Activated corn cob
Kubanni river	0.06	0.02	0.04	0.02
River Shika (Basawa)	0.12	0.06	0.08	0.10
Borehole (Danraka)	0.04	0.02	0.04	0.04
Standard value	2.00	2.00	2.00	2.00

Table 8 Shows that the raw water samples has turbidity values greater 5 NTU (WHO, 1995), except for the borehole in Danraka. The activated con cob, however gave a better reduction in the turbidity level of the raw water sample, hence a better filtrate quality

Table 8: Turbidity value (NTU)

	Raw water	Activated charcoal	Activated bone char	Activated corn cob
Kubanni river	30.00	26.00	23.00	17.00
River Shika (Basawa)	33.00	28.00	26.00	21.00
Borehole (Danraka)	5.20	5.21	5.20	5.20
Standard value	5.00	5.00	5.00	5.00

Conclusion

From the study, it was observed that each of the activated carbons has a different rate of removal of some of the contaminants in the raw water samples. While the activated corn cob is good in the removal of some of the physical properties, the activated born char was better in the removal of some of the chemical substances such as chloride ion and alkalinity. The activated charcoal was effective in the reduction of ammonia nitrogen concentration. It was observed that the pH, acidity and hardness of the filtrate was increased especially by the activated charcoal and activated bone char due to the presence of trace elements such as Calcium (Ca) and Sulphur (S) in them. The quality of the raw water used also affected the rate of removal of contaminants by the activated carbon from the various sources. The Kubanni River is turbid, hard and contains high acidity.

It was thus concluded that the various activated carbon from different sources may perform better if mixed together and used for filtration

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