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A study of coconut shell - activated carbon for filtration and its comparison with sand filtration

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Abstract: In India, the quality of raw water available for drinking purpose varies significantly resulting in modifications to the conventional water treatment scheme consisting of aeration, chemical coagulation, flocculation, sedimentation, filtration and disinfection. Different alterations in these stages could lead to improvised levels of water quality. A novel solution to reinstate the sand filtration process is by utilizing activated carbon (AC) derived from coconut shell. A pilot scale study of filtration unit with different grades (on size basis) of coconut shell activated carbon (CS-AC) such as WTD816, WTE830 and WTE124 was carried out. These AC's were assembled at different depths independently as well as in combination. This work examined reduction and removal of iron, turbidity, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in river water by making different arrangements of CS-AC in the filtration unit. Also its comparison with sand, a conventional practice in water treatment plants in India was done to reduce these parameters. Finer grade activated carbon (AC-III) showed the maximum iron removal (95%). It also showed reduction in COD, BOD and to some extent turbidity in all types of arrangement which was not so in case of traditional sand filtration process. This technique is advantageous and it also helps in utilization of an agricultural waste.

Introduction:

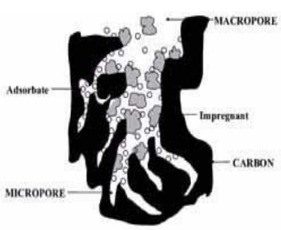
India accounts for 2.45% of land area and 4% of water resources of the world but represents 16% of the world population. With the present population growth-rate (1.9 per cent per year), the population is expected to cross the 1.5 billion mark by 2050. The Planning Commission, Government of India has estimated the water demand increase from 710 BCM (Billion Cubic Meters) in 2010 to almost 1180 BCM in 2050 with domestic and industrial water consumption expected to increase almost 2.5 times. The trend of urbanization in India is exerting stress on civic authorities to provide basic requirement such as safe drinking water, sanitation and infrastructure. The rapid growth of population has exerted the portable water demand, which requires exploration of raw water sources, developing treatment and distribution systems. The raw water quality available in India varies significantly, resulting in modifications to the conventional water treatment scheme consisting of aeration, chemical coagulation, flocculation, sedimentation, filtration and disinfection.

The 40 year old conventional drinking water treatment plant of the Manipal University at Parkala supplies almost 6 million liter drinking water per day to the whole university campus. The water is pumped from the Baje Dam positioned at the upstream side of Swarna River which is approximately 13km away. The river water is pumped and stored in back pressure tank of 50000 liter capacity at Hiriadka. From there it is finally pumped to the treatment plant where the water passes a 3m diameter aerator to liberate dissolved gasses and volatile substances. After aeration and alum dosage water enters into the clarriflocculator for settlement of heavy clumps of particles and coagulants. From there it is directed towards two rapid sand filters of 39.6m^2 area each. Before distribution to the university the filtered water is disinfected by chlorine. Compliance with the drinking water regulation was guaranteed every time.

However, discussion about constant change in the raw water quality due to increasing industrial settling, agricultural run-offs and urbanization around the surface water resulted in thinking about a further improvement of the existing water treatment process with respect to removal of iron, suspended solids and overall organics. This will also help to meet the drinking water standards more strongly. Therefore, in this paper a study is being done using an activated carbon for the filtration process. A lot of agricultural waste and by product have successfully converted to activated carbon for examples macadamia nutshell [1-2], paper mill sludge [3] and peach stones [4]. Coconut-based agricultural wastes have gained wide attention as effective biosorbents due to low-cost and significant adsorption potential for the removal of various aquatic pollutants. The various parts of coconut tree such as coir, shell, pith etc. have been extensively studied as biosorbents for the removal of diverse type of pollutants from water. For several years activated carbon has gained wide application in the treatment of waste water. However, this paper deals with AC derived from coconut shell in water treatment for the production of polished water for drinking purpose at commercial level. This technique can also be looked upon as the solitary treatment in the water treatment plant with few modifications in the future.

Due to their high carbon content and hardness, coconut shells are an excellent raw material source to produce activated carbon. Activated carbons that are produced using coconut shells as the raw material are often sourced in geographic regions where coconuts are harvested, including India, Malaysia, Sri Lanka, and the Philippines. Activated carbons produced from coconut shells typically have a tighter, more microporous pore structure than their coal-based counterparts. This is due to the inherent pore structure of the raw material coconut shell as compared to raw material coals. This microporosity lends itself towards certain applications where activated carbon is used. Also, coconut shell-based carbons tend to be harder, more resistant to abrasion, and lower in ash than similar grades of coal-based carbons. The major advantage with the coconut shell activated carbon is that it is an outstanding material for applications requiring taste, odor and dissolved organic chemical removal from water with suspended particle present. In addition, its balanced pore structure (fig. 2) gives a more efficient adsorption range and it imparts a high “polish” to the filtered water.

The most unique function of this material is its ability to adsorb the organic matter present in the water which would otherwise react with the chlorine from disinfection to form ‘Disinfection by-products’ (DBPs). Studies have suggested that exposure to very high levels of certain DBPs resulted in kidney and liver damage, reproductive effects, and cancer. It has been estimated that almost 90000 nuts are required to yield 1 tonne of activated carbon.



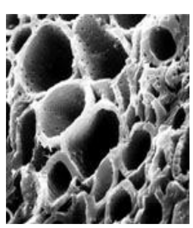


Fig. 1: Internal pore structure in AC. Fig. 2: Shape of coconut pore by SEM

Method:

For conducting the pilot scale study of filtration different grades of CS-AC viz WT D816, WTE830 and WTE124 depending upon their sizes were procured from Indo German Carbons Limited, Kerala. These CSAC were of size 8*16 US mesh size (I, coarser), 8*30 US mesh size (II, medium), and 12*40 US mesh size (III, finer). Similarly, different grades of Ennore sand such as Grade I - coarser (1mm<particle size<2mm), Grade II - medium (0.5mm<particle size< 1mm) and Grade III - finer (0.05mm<particle size<0.5mm) was obtained from materials and concrete laboratory of Civil department, MIT manipal.

The aim is to study the pilot scale filtration process as shown in fig. 3 through coconut shell-activated carbon (CS-AC). A jar of 1.64m^3 volume and of height 17cm was taken as a column where different grades of activated carbon such as AC-I of size 8×16 US mesh (coarse), AC-II of size 8×30 US mesh (medium) and AC-III of size 12×40 US mesh (finer) were used independently as well as jointly in layers. Firstly, to study removal efficiency by each individual CS-AC different sized of them were maintained at depth 4cm and 8cm separately. Raw water was directly passed through different US mesh sized CS-AC without any prior treatment to check its reduction ability. To compare CS-AC removal ability with conventional sand filtration CS-AC layers were made. At the base 5cm gravel bed was installed. On top of it 3cm of AC-I, 3cm of AC-II and 2cm of AC-III was positioned respectively making total 8cm depth of activated carbon.

Fig. 3: Filtration column set-up

The characteristics of the raw water before and after the treatment are analyzed by different lab tests to find efficiency of the process. The parameters tested are iron, BOD, COD, pH, Turbidity, TDS. Each parameter is tested and comparison is done for removal efficiency specifically for iron and total organics in the form of BOD and COD. The BOD and COD were analyzed using Standard Methods for The Examination of Water and Wastewater (APHA, 1998).

PROPERTY	COCONUT SHELL ACTIVATED CARBON SIZE			
	8×16 US MESH (I)	8×30 US MESH (II)	12×40 US MESH (III)	ASTM TEST METHOD
MOISTURE (%)	3.6	3.8	3.4	D 2867
APPARENT DENSITY (GM/CC)	0.504	0.508	0.520	D 2854
CTC (%)	58.4	57.6	60.2	D 3467
BALL POINT HARDNESS (%)	99.0	98.6	98.8	D 3802
ASH (%)	2.0	2.4	2.6	D 2866
pH	10.28	10.29	10.32	D 3838

Table 1: Laboratory analysis report
(source: Indocarb)

Results and discussion:
Table 2 shows the characteristics of surface water which was used as the influent for the filtration set-up. It shows that the iron content is 0.4mg/L which is higher than the permissible limit. Fig. 4 shows the comparison between different US mesh size activated carbon with respect to raw water characteristics. In raw water iron content was 0.4 mg/L but after passing through activated carbon it came down to 0.2 mg/L and 0.02 mg/L by AC I,II and AC III respectively. Similarly, BOD in raw water was 1.3mg/L which reduced to 0.8 mg/L by AC III, 0.48mg/L by AC II and 0.96 mg/L by AC I. COD of river water was found to be 5.7 mg/L but after AC filtration it came down to 5 mg/L, 4.2 mg/L, 3 mg/L by AC I, AC II and AC III respectively. Turbidity also reduced to 1.7 NTU from initial value of 2.1 NTU of raw water.
CS-AC were maintained at a depth of 4cm in the column. There was only 50% reduction by AC I & II in iron removal but it was observed that AC III could reduce iron up to 95%. Reduction in BOD and COD is also illustrated in figure 4.6 but is not that pronounced. It was only 26%, 63% and 38% for BOD and COD was 12%, 26% and 47% by AC I, II and III respectively.

Table 2: Raw water characteristics

PARAMETER	VALUE
pH	7.2
TDS	22.03 ppm
EC	41.22 µS
Turbidity	2.1 NTU
Total Hardness	16 mg/L
Iron	0.4 mg/L
BOD	1.3 mg/L
COD	5.7 mg/L
Total Coliform MPN/100 ml	240/100 ml

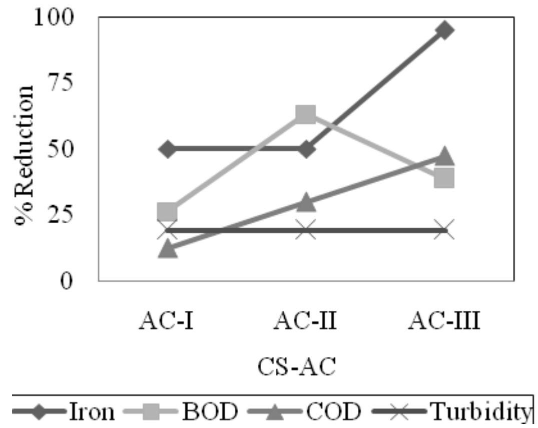


Fig. 4: Percentage reduction by different grades of CS-AC at 4cm depth

Fig. 5 shows the reduction in iron, BOD, COD and turbidity after passing raw water through different sizes of coconut shell activated carbon when depth is maintained at 8cm. It shows the comparison between different US mesh size activated carbon with raw water when the depth of activated carbon in the column was increased to 8cm. Similar parameters were checked as at 4cm depth. It was noticed that there was no further reduction in iron content and turbidity in all the three mesh size activated carbon when depth was increased to 8cm but remarkable reduction was observed in case of COD and BOD. BOD in raw water was 1.3 mg/L which came down to 0.96 mg/L, 0.9 mg/L and 0.8 mg/L by respective activated carbons. COD reduction was observed as 2.24mg/L, 1.12 mg/L and 1.28 mg/L from initial value of 5.7mg/L.

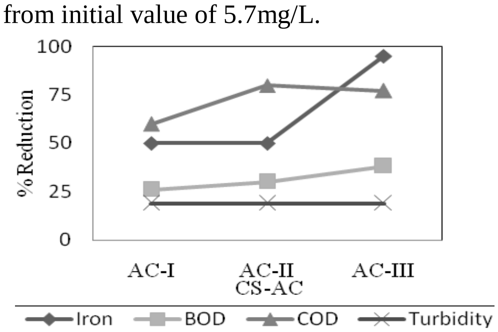


Fig. 5: Percentage reduction by different grades of CS-AC at 8cm depth

Fig. 6 represents the amount of reduction of specific parameters when raw water is passed through different grades of activated carbon which were made into layers and sand layers. This investigation was done in order to compare it with the typical formation of sand layers in the traditional sand filtration method. Table 3 can be referred for the same.

It was observed that when river water was passed through layers of activated carbon there was evident reduction in iron which was 70%. BOD was reduced to almost 26% from raw water and COD came down to 53%. There was no reduction in case of sand layers for these parameters but turbidity came down to 1.7 NTU from initial value of 2.1 NTU.

Table 3: Comparison table for AC layers and sand layers with raw water

Parameters	Raw Water	Ac Layers	Sand Layers
Iron	0.4 mg/L	0.12 mg/L	0.4 mg/L
BOD	1.3 mg/L	0.96 mg/L	1.29 mg/L
COD	5.7 mg/L	2.68 mg/L	5.7 mg/L
Turbidity	2.1 NTU	1.4 NTU	1.7 NTU
pH	7.2	8.3	7.9
EC	41.22 µS	41.2 µS	41 µS
TDS	22.03 mg/L	21 mg/L	20 mg/L

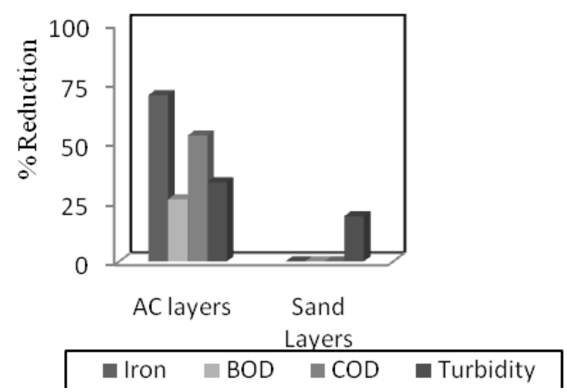


Fig. 6: Percentage reduction by CS-AC layers and sand layers

Conclusion:

Considerable pollution of natural waters brings about a situation where meeting the growing requirements for drinking water and domestic water is not possible in many plants using traditional technological systems. It can be predicted that the river water quality will not remain same in the future. There will be increase in agricultural practices, industrial settlement and urbanization around the river which would ultimately lead to the contamination of water resources. In the present study it was observed that there is maximum reduction in chemical oxygen demand, biochemical oxygen demand and iron content of water by finer activated carbon i.e. AC-III. Reduction in COD and BOD proves that the organic compounds can be efficiently removed by coconut shell activated carbon. Whereas in case of sand filters negligible reduction in iron, BOD and COD was observed. Turbidity reduction was almost same in both types of filtration materials. So, coconut shell activated carbon can be looked upon for future treatment of water in removing suspended solids, iron and total organic carbon instead of sand filtration in the treatment plants. This technique is highly advantageous, inexpensive and cost-effective and in turn there will be utilization of a waste which would be otherwise simply dumped. Various literature reviews also gave a remarkable evidence of removal of wide range of pesticides from coconut shell activated carbon. Thus, this improvisation can be rendered as a novel method for drinking water treatment taking environment into concern.

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