VOL. 2, NO. 9, Oct 2012 ISSN 2225-7217

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

Comparison of the Adsorptive Capacity of Raw Materials in Making Activated Carbon Filter for Purification of Polluted Water for Drinking

[1] Inegbenebor Adedayo I, [2] Inegbenebor Anthony O, [3] Boyo Henry. I

[1] Department of Chemistry, Covenant University, Canaanland, Ota, Ogun State Nigeria
[2] Departments of Mechanical Engineering, Covenant University, Canaanland, Ota, Ogun State Nigeria
[3] Departments of Physics, University of Lagos, Akoka, Lagos.
[1] dayoinegbenebor@yahoo.com

ABSTRACT

A comparative work was carried out to ascertain adsorptive capacity of raw materials in making activated carbon filter for purification of polluted water for drinking. Three raw materials were chosen for this work, they are palm kernel shells, coconut shells and bamboo. The raw materials were carbonized and then activated in a designed and constructed anaerobic furnace at a temperature of 1000^{o}C in the presence of steam to get a high mechanical resistance carbon. The adsorptive properties determined for the activated carbon of the raw materials are hardness, ash content, apparent density, porosity, iodine value and methylene blue. To test for the adsorptive capacity of the materials, muddy water from a pond in an industrial area where effluents are discharged was collected and analyzed for physical and chemical properties. There after the muddy water was filtered with the activated carbon made from the raw materials. The filtrated water was further subjected to analysis. Results of Laboratory-Scale experiments and assessment of the entire process showed palm kernel shells activated carbon to be the most effective for water purification followed by coconut shell and bamboo respectively.

Keywords: *Purification; Activated carbon filter; Palm kernel; Cocoanut Shell; Bamboo adsorptive capacity; Drinking Water*

1. INTRODUCTION

Undoubtedly quality of water is one of the most important natural resources of the world. It plays a vital role in the development of communities; hence a reliable supply of water is essential, it needs to be maintained all the time for human and industrial use. As for human consumption, quantity and quality of drinking water have been recognized as increasingly critical issues for the coming years. Among the factors that contribute to the looming water crises are continued population growth and urbanization (Shi et al., 2012). Also of note are deteriorating water infrastructure, increasing influence of waste water and bios lids on drinking water sources, a growing number of emerging contaminants, and uncertain future water availability and quality due to climate change. Therefore, one of the most important tasks at any water treatment plant is safeguarding the quality of drinking water from the above influence. It has been reported that there are limitations in achieving this safety (Dmikonka et al., 2007). Worldwide, the drinking – water sector is increasingly aware of the limitations of end-product testing for ensuring safety. One limitation is the steady increase in the number of potentially occurring pathogens and chemicals that need to be monitored. As a result of this, it has been questioned recently (Bartrand et al., 2007) whether the conventional water treatment processes, which are based on rapid sand filtration and chlorination and have stayed largely unchanged for years, can adequately remove the many chemical and microbial contaminants simultaneously, which lead to water pollution. Water pollution is any contamination or change in the quality of water through contact with chemical, physical and biological elements obviously, the effect of such water will be harmful (Nikoladze et al., 1994). When humans drink polluted water, it can have serious effects on their health, they may contact diseases like typhoid, dysentery and cholera, among others (Wells, 1977).

There are several classes of water pollutants. There are disease causing agents such as bacteria, viruses, protozoa and parasitic worms that enter sewage systems and untreated waste. Another category of water pollutants is oxygen- demanding wastes which can be de-composed by oxygen-requiring bacteria. When large populations of decomposing bacteria are converting these wastes, that can deplete the oxygen levels in the water, cause other organisms in the water, such as fish, to die. There is yet another class of pollutants. It is constituted by water-soluble inorganic pollutants in the form of acids, salts and toxic metals. Large quantities of these compounds will make water unfit to drink and will cause the death of aquatic life (Hammer, 1977). Other classes of water pollutants are from non-point source (NPS). Unlike pollution from industrial and sewage treatment plants, non-point source (NPS) pollution comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the run off moves, it picks up and carries natural and anthropogenic

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

pollutants, finally depositing them into lakes, rivers, wetlands, coastal water and ground water systems (USEPA, 2003). Recently, studies conducted in China have shown that NPS is now an important issue in pollution of water environment, and that agricultural NPS poses the greatest risk (Ongley, 2010). With the development of agriculture and the increasing amount of chemical fertilizers and pesticides used in China and other countries, the proportion of NPS pollution would increase annually. To this end, the research on agricultural non-point source pollution modeling was undertaken for improvements in development of technology for controlling such system in China (Shen et al., 2012).

As far as the inorganic and organic contaminants are concerned, the most important with regard to health are heavy metals (arsenic, lead, chromium, mercury, cadmium, etc), turbidity, organo-chlorine and organic phosphorus pesticides, poly-nuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and disinfection by products (WHO, 2004). Each type of raw water has a characteristic pollution pattern, and treatment must be related to the source water quality and the desired end-product standards (WHO, 2003; AWWA, 1990). Since pollution seems inevitable in every society, water must be maintained for human consumption. This need is reflected in the growing market for home water filters which are designed to remove objectionable tastes, odours and organic contaminants from water.

The material in these activated carbon filters is recognized as effective and reliable in removing impurities (Aeppli and Dyer-Smith, 1999). Activated cabon has a tremendous absorbing capacity, for a wide variety of dissolved organics and chlorine and can be custom-tailored to suit specific application (Robert and Mazzoni, 2008). Activated carbon, in granular (GAC) or powered (PAC) form, is commonly incorporated into filters used as home treatment devices. These devices can be fitted to service an entire home at the point of entry or at a single faucet, with the latter termed point of use (POU) devices. Activated carbon is a favored water treatment technique because of its multifunctional nature and the fact that it adds nothing detrimental to the treated water (Desilva, 2000). Activated carbon is the most popular and the cheapest material used in purification of water, and much of it is regenerated (cleaning/desorption) and is used hundreds or even thousands of times. One of the most difficult problems encountered in water purification is that of taste, odour and color control. The usual taste and odour producing substances in water are probably represented by organic matter in an incomplete state of decomposition. However, the use of activated carbon as a means of eliminating tastes and odour has, in many cases, proved to be efficient improvement in purification (Dvorak and Skipton, 2008). Purification ability depends on many things, including type of carbon that is available throughout the entire activation process. The surface of the carbon is in square meters per gram and the pore structure (distribution of micro-, meso-and macro pores). Thus, the current work was designed to examine the comparison of the adsorptive capacity of the raw materials used to make activated carbon filter.

2. MATERIALS AND METHODS

2.1 Raw Materials

Most activated carbons are made from raw materials such as nut shells, wood, coal, coconut shell; bamboo, palm kernel shell and petroleum. The typical surface area for activated carbon is approximately 1,000 square meters per gram (m^2/gm). However, different raw materials produce different types of activated carbon varying in hardness, density, pore and particle sizes, surface areas, extractable ash and pH. These differences in properties make certain carbons preferable over others in different applications. The two principal mechanisms by which activated carbon removes contaminants from water are adsorption and catalytic reduction. Organics are removed by adsorption and residual disinfectants are removed by catalytic reduction. The base materials selected for this work are coconut shell, palm kernel shell and bamboo as wood.

a. Coconut Shell (Cocos Nucifera)

Arecaceae (palm family) is an agricultural crop that is wide spread in the tropics. The species has been cultivated for 400 years. The coconut tree comes from the south-east Asian Peninsula (probably Malaysia), but is cultivated in tropical regions all around the world. Coconut trees commonly grow on tropical beaches. A large plantation of coconut tree can be found in pacific, Indonesia, Philippines, South Asia, East and West Africa and the Caribbean. Based on their stem height, tall and dwarf varieties are distinguished. Presently over 100 varieties are known, about half of them tall. Once tall palms, which can reach stem heights above 20m, are 50-60 years old, their copra yield declines rapidly, and the question of replacement arises. The fruit from the coconut tree consists of the husk, the hard seed coat (ectosperm) which is the shell. The inside of the endosperm has a pleasant, mild and nutty fragrance and a typical taste, with a hint of sweetness. The sour

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

liquid inside the seed is a common refresher in tropical countries.

b. Palm kernel (Elaeis Guineensisn)

The Palm kernel fruit comes from palm tree. Palm tree is a sub tropical evergreen of the proteeaceae family which grows in Hawaii, Nigeria, Malaysia and Australia. It was proved to be suitable for large scale production of activated carbon. The nut from the palm tree has a husk which is red in colour, indicating maturity for use. It is very fatty and edible. The hard seed coat (ectosperm), what is a shell of 2mm to 3mm in thickness, is used for activated carbon.

c. Bamboo (Bambuso Valgeris)

The bamboo is a group of perennial evergreen (except for certain temperate species) plants in the true grass family poaceae, the sub family of this species is made up of bambusoideae, bambuseae and giant bamboos which are the largest members of the family. In bamboo, the intermodal regions of the plant stem are hollow, but the vascular bundles, as seen in cross section, are scattered throughout the stem instead of in a cylindrical arrangement. Secondary, dicotyledonous woody xylem is absent. In its natural form, bamboo as a construction material is traditionally associated with the cultures of East Asia and the South Pacific. The natural hallow form a bamboo makes it an obvious choice for many instruments, particularly wind and percussion. There are numerous types of bamboo flute made all over the world. These carbon-based materials are converted to activated carbon by thermal decomposition in a furnace using controlled atmosphere and heat.

2.2 Anaerobic Furnace

To achieve the aim of the work, a 10kg anaerobic furnace capacity was designed and fabricated at the Covenant University in the Engineering Machine shop for a temperature of 1000^{o}C. The raw materials used are coconut shell, palm kernel shell and bamboo all obtained from the South West of Nigeria. The furnace was designed in such a way that the heat generated would reach the raw material through radiation and conduction. Thermocouple was incorporated into the furnace for the measurement of the temperature. The furnace was test-run for 3 days before the production of the activated carbon materials.

a. Water Samples

A jar of 2 litre of muddy water from the pond in the industrial area of Ota, Ogun – State in the South West of Nigeria was collected in late November, 2011 where effluents from the industrial output were discharged into. This muddy water was analyzed for turbidity, odour, colour, PH, alkalinity and chemical contaminants such as lead, cadmium, manganese, iron, cobalt, mercury, nickel, copper, chromium, Arsenic and Zinc.

2.3 Experimental Methods

The method adopted to activate the carbon in this work was to subject the materials to heating and steam treatment. The result was that the activated carbon created carbon which is highly porous providing a large surface area for adsorption. In a typical experiment of such type a quantity of 6kg of coconut shell was measured and placed in the furnace for 3 hours heating in the absence of oxygen treatment at a temperature of 1000^{o}C and steam. The experiment was repeated with the same quantity of palm kernel and bamboo. The activated carbon each of the materials was ground separately in a mortar with piston. Thereafter, activated coconut shell, palm kernel shell and bamboo were sieved separately using the British auto sieve shaker of different grades mounted together and powered electrically. The activated carbon retained in a 50- mesh sieve (0.297mm) for the three raw materials was used to compare the adsorptive capacity. The collected muddy water from the industrial area was filtered using the method of pour- through (Robert and Mazzoni, 2008). This method entailed the insertion of Whatman filter paper of 110mm diameter into the filtration funnel. The sieved activated carbon of coconut, palm kernel and bamboo were poured into the filter paper in turn. The experiment was repeated three times, and the average result was recorded. The filtrates from both muddy water and activated carbon materials were subjected to atomic absorption spectro-photometric procedure (solar 969 model) for the determination of the metals. The instrument was set at appropriate wave lengths, current, and flame types and then calibrated by the use of standard solutions for each metal (ASTM, 1980).

3. RESULTS AND DISCUSSION

3.1 Effect of Activated Carbon Adsorptive Properties

Activated carbon adsorptive properties are used to remove organics. Generally, adsorption takes place because all molecules exert forces to adhere to each other. Activated carbon adsorbs organic material because the attractive forces between the carbon surface (non-polar) and the contaminant (non-polar) are stronger than the forces keeping the contaminant dissolved in

VOL. 2, NO. 9, Oct 2012 ISSN 2225-7217

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

water (polar). The adsorptive forces are weak and cannot occur unless the organic molecules are close to the carbon's surface. The large surface area of the activated carbon, due to its particle size and pore configuration, allows for the adsorption to take place. Also factors that decrease solubility and/or increase accessibility to the pores improve the performance of the activated carbon filter.

3.2 The comparative result of the activated carbon filters

The developed activated carbon filters from raw materials such as coconut shells, palm kernel shells and bamboo, were used to filter the analyzed muddy water from the pond in the industrial area of Ota in Ogun State, South West Nigeria. The results of the analysis of the muddy raw water was presented in Table 1.The physical properties of the raw muddy water from the pond in the industrial area of Ota, Ogun State, South West Nigeria, confirmed the results of the analysis since, the pond is being affected by the effluents discharged from the industries in that area. The pollutants changed the physical properties and thus the raw muddy water is not suitable for human use. The activities of the industrialists in that area may have been responsible for the high level of elemental compositions.

Table 1: The analysis of the muddy raw water from the industrial area pond of Ota, Ogun State, South-West, Nigeria.

S/N	PHYSICAL PROPERTIES DETERMINED	RESULTS
1	ODOUR	FOUL SMELL
2	COLOUR	SLIGHTLY CLOUDY
3	P^H	9.76
4	CONDUCTIVITY (WS/CM)	2570
5	TDS (MG/L)	1252
6	TURBIDITY (N.T.U.)	19.5
7	SALINITY (%)	4.6
8	IRON (MG/L)	0.05360
9	ZINC MG/L)	0.0465
10	LEAD (MG/L)	0.081701
11	COPPER (MG/L)	0.06361
12	MANGANESE (MG/L)	0.06270
13	NITRATE (MG/L)	33
14	SULPHATE (MG/L)	74
15	CHRONIUM (MG/L)	0.011000
16	ARSENIC (MG/L)	0.281001
17	CADMIUM (MG/L)	0.091001

a. The effects of the physical properties of the filters on purification

Water purification is a process of removing undesirable chemicals, materials and biological contaminants from raw water through the medium of filtration or other purification technology. The goal is to produce water fit for a specific purpose. Most water is purified for human consumption (Drinking Water) but water purification may also be designed for a variety of other purposes, including meeting the requirements of medical, pharmacology, chemical and industrial applications. The purification process of water may reduce the concentration of particulate matter including chemical elements and pathogen parasites, bacteria, algae, virus, and fungi which are dissolved into the water. The quality of purification water depends on the physical properties of the activated carbon filter material used (Table 2). This observation is valid on the basis of the results in Table 3. Therefore, the specific properties of an activated carbon are the results from the raw material used to produce it and the activation process, which boosts its adsorbent qualities. Compare these properties in Table 2; the activated carbon from palm kernel shell seems to have moderate result to be far better adsorbent than the other two materials. Looking at the properties, for example, one observes that the apparent density of the palm kernel shell is higher than that of the two materials Coconut shell and bamboo. Higher apparent density provides greater volume activity and normally indicates better quality activated carbon. Also, in considering the iodine number of the activated carbon materials, one remarks that palm kernel shell shows higher number. Since iodine number is the most fundamental parameter used to characterize activated carbon performance, it is a measure of activity level (higher number indicates higher degree of activation).

VOL. 2, NO. 9, Oct 2012 ISSN 2225-7217

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

Table 2: Variation in the determined properties of the three different types of activated carbon material.

S/N	DETERMINEADSORPTIVE PROPERTIES	ACTIVATED CARBON FROM PALM KERNEL SHELL	ACTIVATED CARBON FROM COCONUT SHELLS	ACTIVATED CARBON FROM BAMBOO
1	HARDNESS	95	89	60
2	ASH CONTENT (%)	5.42	6.38	8.46
3	APPARENT DENSITY (G/CC)	0.65	0.55	0.42
4	POROSITY	0.97	0.85	0.77
5	IODINE VALUE (MG/G)	1270	1254	1240
6	METHYLENE BLUE	82.85	95.56	97.45

Table 3: Comparative results of the three different types of activated carbon filters produced on 50-mesh sieve (0.297mm) each used to filter raw muddy water in tables from the industrial site.

S/N	THEPROPERTIES	MAXI-PERMITTED LEVEL	FILTRATE FROM PALM KERNEL SHELL ACTIVATED CARBON	FILTRATE FROM COCONUT SHELL ACTIVATED CARBON	FILTRATE FROM BAMBOO ACTIVATED CARBON
1	ODOUR	ODOURLESS	ODOURLESS	ODOURLESS	ODOURLESS
2	COLOUR	COLOURLESS	COLOURLESS	COLOURLESS	COLOURLESS
3	P^H	6.5-8.5	6.3	6.9	7.28
4	CONDUCTIVITY (IUS/CM)	1000	560	715	812
5	TDS (MG/L)	500	380	495	565
6	TURBIDITY (NTU)	5	1.25	2.14	2.54
7	SALINITY (%)	1	1.20	1.30	1.45
8	IRON (MG/L)	3.0	0261	0.0353	0.0225
9	ZINC (MG/L)	3.0	0.0261	0.353	0.0225
10	LEAD(MG/L)	0.01	0.0103	0.0123	0.0143
11	COPPER (MG/L)	1.0	0.0102	0.0155	0.0161
12	MANGANESE (MG/L)	0.2	0.0205	0.0205	0.0352
13	NITRATE (MG/L)	50	13.2	33	33
14	SULPHATE (MG/L)	100	60	62	65
15	CHROMIUM	0.5	0.01000	0.00200	0.00200
16	ARSENIC (MG/L)	0.1	0.00601	0.005020	0.007030
17	CADMIUM (MG/L)	0.003	0.007001	0.00801	0.00602

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

The palm kernel gave the highest hardness and porosity followed by coconut shell activated carbon while bamboo activated carbon has the lowest of the properties. Due to the hardness of palm kernel shell, the activated carbon produced from it will have the best absorption strength. Also, the higher the porosity value the better than adsorption rate of the carbon in Strand (2001), thereby making palm kernel shell activated carbon as shown to be the best. Palm kernel shell activated carbon gave the lowest methylene blue as compared to coconut shell and bamboo activated carbon. The higher the ash content of activated carbon, the more reduced the overall activity and its efficiency of reactivation. However, the ash content of the palm kernel shell is lower than that of coconut shell and of bamboo. This also contributes to better absorption of the palm kernel shell than the coconut shell and bamboo.

b. The Effect of The Physical Properties on The Filtrate

The results on the physical properties such as pH, conductivity, TDS, turbidity and salinity showed that palm-kernel shell activated carbon gave the least value compared to coconut shell and bamboo. The results obtained for each type of filtrate fell within the permitted levels according to the (Ahmedna , 1997; WHO, 2007).

c. Chemical Effect of The Filtrate

Analysis of chemical parameters such as iron and zinc revealed bamboo activated carbon as the most efficient, followed by palm kernel and then coconut shell respectively. The test of the chemical parameters such lead, copper, manganese, nitrates and sulphate proved palm kernel shell activated carbon as having the best value followed by coconut shell activated carbon and then bamboo activated carbon.

4. CONCLUSIONS

This study has succeeded in comparing the adsorptive capacity of three raw materials in making activated carbon filter for the purification of polluted potable water for drinking. This has helped to address a major challenge of water purification in the developing nations of the world such as Nigeria where there is shortage of water.

- It has shown that raw materials with high filter content such as palm kernel shell, coconut shell and bamboo can be used to produce activated carbon.
- Activated carbon as a means of purification is a very effective natural product. It is also cheap and the carbon can be recycled and used again. It is the best medium for the purification of water and alcohol.
- The properties of activated carbon allow us to trap poisons, insecticides, bad smells, tastes, heavy metals and undesirable elements in both liquid and gas and there are more potential raw materials for the production of activated carbon to meet local industrial needs.
- In addition to the identified raw materials, palm kernel shells, coconut shells and bamboo, together with other raw materials (such as corncobs, rice hulls and vegetable wastes) can also be used to produce activated carbon.
- In the present work, palm kernel shell activated carbon seems to be more effective than coconut shell and bamboo in the purification of water. The advantages of palm kernel shell over the other materials include high density, low ash content, and its ability to produce activated carbon of high adsorption capacity.
- According to the analysis of the results obtained concerning the properties of each type of activated carbon coupled with the test conducted on the filtrate, palm kernel shell has proven to be the most efficient high quality material that can be used to produce activated carbon. It is closely by followed by coconut shell and bamboo. This study provides a basis for subsequent, larger-scale studies that are necessary to fully evaluate/demonstrate the feasibility and cost-effectiveness of using palm kernel shell activated carbon filter in water treatment plants.

REFERENCES

[1] Shi, C., Wei, J., Jin, Y., Kniel, K.E., and Chiu, P.C. (2012) Removal of viruses and bacteriophages from drinking water using zero-valent iron. *Separ. And Purific. Techn.* 10: 72-78.

[2] Dmikonka, I., Katsiri, A., and Tzia, C. (2007) Application of haccp principles in drinking water Treatment. *Desali.,* 210: 138-145.

[3] Bartrand, T.A., M. Weir, M., and Haas, C.N. (2007) Advancing the quality of drinking water; expert workshop in formulate a research agenda. *Environ. Eng. Sci.,* 24: 863-872.

[4] Nikoladze, E.D., Nits, M., and Kastalsky, A. (1994) Water treatment for public and industrial supply. 14-16.

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

[5] Wells, R.J. (1977) Water quality criteria and standard. *Water. Pollut. Cont.,* 77: 25-30.

[6] Hammer, J.M. (1977) Water quality and pollution waste and water technology 2nd Ed.; John Wiley and Sons, New-York; pp. 143-168.

[7] US, EPA, National management measures for the control of non- point pollution from agriculture, EPA-841-8-03-004, United States Environmental Protection Agency Office of Water, and Washington, DC. 2003.

[8] Ongley, E.D., Zhang, X.L., and Yu, T. (2010) Current status of agricultural and rural non-point source pollution assessment in china. *Environ. Pollut.* 158: 1159-1168.

[9] Shen, Z., Liao, Q., Hong, Q., and Gong, Y. (2012) An overview of research on agricultural non- point source pollution modeling in China. *Separ. and Purific. Techn.,* 84: 104-111.

[10] WHO. (2004) Guidelines for Drinking-Water Quality, 3rd ed.; WHO, Geneva.

[11] WHO. (2003) Guidelines for Drinking-Water Quality, 2nd ed.; WHO, Geneva.

[12] American Water Works Association (AWWA). (1990) Water Quality and Treatment. A Handbook of community water supplies, 4th ed.; McGraw-Hill, Inc., USA.

[13] Aeppli, J., Dyer-Smith, P. (1999) Ozon and Granuler activated filtration, the solution to many problems, Ozonia Limited Duebendorf, Switzerland; pp. 12.

[14] Robert, T.D., and Mazzoni, A.F. (2008) Water filtration TIEE Corporation, U.S.A; pp. 6-15.

[15] Desilva, F. (2000) Activated Carbon filtration water quality products magazine U.S.A.

[16] Dvorak, B.I., and Skipton, S.O. (2008) Drinking water treatment, Activated carbon filtration, University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources, *Binco*., 1; 2-4.

[17] ASTM (1980) American Society for Testing Materials, Annual Brochure of ASTM Standard, Race Street, Philadelphia, U.S.A; pp. 547-549.

[18] Strand G. (2001) Activated carbon for the purification of Alcohol, Sweden.

[19] WHO (2007) Water for pharmaceutical use in quality assurance of pharmaceuticals. A compendium of guidelines and related Materials, 2nd ed.; World Health Organization, Geneva. 2: 170-187.

[20] Ahmedna, M., Johns, M.M., Clarke, S.J., Marshall, W.E., and Rao, R.M. (1997) Potential of agricultural by-product-based activated carbons for use in raw sugar decolourisation, Journ. The Sci. Food and Agric., 75: 117-134.