**International Journal of Engineering Inventions**
**e**-ISSN: 2278-7461, **p**-ISBN: 2319-6491
Volume 2, Issue 4 (February 2013) PP: 29-34

# On The Efficacy of Activated Carbon Derived From Bamboo in the Adsorption of Water Contaminants

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**Abstract:-** A comparison of adsorption efficiency of the three Granular Activated Carbon (GAC) produced from waste Nigerian Bamboo at different level of activation in a fixed adsorption bed is reported. Bamboo carbonization was done at temperature range of 200-400$^0$c and chemically activated at 400$^0$c with chloride salt at percentage range of 0-20%. The 0, 10 and 20% level activation were selected for water treatment and comparison, based on surface pore area and pore space. There are noticeable differences in adsorptive capacity as well as time interval to attain a fixed level of contaminant removal. The 10% is more effective in adsorption of physical and biological pollutant parameters as compared to 0 and 20%. The raw water passed through the fixed bed was treated effectively with effluent conforming to established standards. The GAC produced from Nigerian bamboo has been established to have maximum adsorptive capacity within 24 hours of use and can reduce effectively most organic and inorganic contaminants found in surface water.

**Keywords:-** Activated carbon, Adsorption, Surface Water, Waste Bamboo.

## I. INTRODUCTION

The most essential need of God's creation is water and must be provide in a pure state for it to be consumed. Clean water becomes a critical issue as the world population increases. Olafedehan and Aribike, (2000), Ademiluyi et al, (2009), noted that recent problems in water treatment originate primarily from the increasing pollution of water sources by organic compounds, most of which are difficult to decompose biologically. These substances resist the self-purification capabilities of rivers as well as degradation in conventional wastewater treatment plant.

To prevent the occurrence of scarcity of potable water in Nigeria, there is a need to improve the techniques behind water purification. Such could be by adopting the use of local agricultural products that will purify the water available to set standards. One of such agricultural products is Bamboo a non- timber forest product. Bamboo is renewable and grows abundantly in the tropics and temperate regions within latitude of 40$^0$s and 40$^0$N, from jungle to high mountainsides (Ralambondrainy, 1983; Liese, 2004; and Ogedengbe, 2010). Nigeria falls into the above- described location and thus, account for the wide variety of bamboo found in the country. Despite the different varieties, the utilization of bamboo in Nigeria is low as compared with some countries like China, India and other part of Asia (Onilude, 2005). Activated charcoal, also called activated carbon or activated coal, is a form of carbon that has been processed to make it extremely porous and thus have a very large surface area available for adsorption or chemical reaction (caron, 2008). Bamboo charcoal is made from bamboo plants with five years or more maturity period by means of pyrolysis (Minigjie, 2004). Fu et al, (2010) confirmed that 1g of bamboo charcoal has approximately 400m$^2$ surface area thus indicating a high adsorptive capacity. Mingjie, (2004) noted that the extra-ordinary microstructure of the bamboo helps to purify water. Similarly drinking water sterilized with chlorine can be treated with bamboo charcoal to adsorb residual chlorine and chlorides. Bamboo clums and waste material from bamboo processed on construction site can be utilized as bamboo activated charcoal. This will not only provide a new way of utilizing bamboo but also reduce constructional waste as well as protecting the environment from being polluted.

In view of the importance of bamboo, this study is aimed at abating environmental nuisance cause by bamboo at construction sites as well as the removal of contaminants likely to be encountered in water. It also aims to compare the adsorptive efficiency of chemically activated granular carbon in the treatment of surface water.

## II. MATERIALS AND METHODS

Sample collection and Preparation

The waste Bamboo (Bambusa vulgaris) used in the present study was collected from the construction site at the back of Agricultural and Environmental Engineering Department, university of Ibadan . The surface water was collected from Awba dam, University of Ibadan and at Abadina stream which is the confluence point for stream flowing from Moniya, NISER, Orogun, Agbowo and Bodija market area of Ibadan. The waste Bamboo was reduced to smaller size and was washed to remove external waste particles. Thereafter, they were soaked in distilled water for 24hrs to remove elements that might have been adsorbed during construction processes.

Bamboo sample were wrapped with aluminum foil and later placed in Gallen kamp muffle furnace to be carbonized (200-400$^0$C) for 2hrs. The charred materials were grinded and 43.0g of 500µm particle size was accurately weighed. Thereafter, 0, 5, 10, 15 and 20% weight of zinc chloride were weighed and dissolved completely in a 250ml beaker with deionized water. The dissolved content was then transferred into a 100ml volumetric flask and the beaker was rinsed subsequently into the volumetric flask. The content in the flask was made up with deionized water to 100ml mark to obtain the required concentration. The dissolution of each weight percentage was done separately for each 43.0g sample from 500µm particle size for an hour at room temperature to obtain a ratio of 0: 100, 5:100, 10:100, 15:100 and 20:100 these corresponding to different impregnation ratio. The impregnated samples were put into a hot air oven at 200$^0$c for 2 hours with aluminum foil as a top cover to prevent escape of zinc chloride while impregnation process is taking place. Aluminum foils were removed from each sample and temperature was increased to 450$^0$c for 4hours to ensure complete reaction of zinc chloride.

Each sample was washed with slightly boiled deionized water to remove zinc chloride, after which they were washed with distilled water to pH of 6-7. They were then placed in the oven at 90$^0$c for 24 hours, and were removed to be cooled at room temperature.

**Characterization of Bamboo Activated Carbon and Adsorption Experiment.**

The Average particle size, Bulk density, Ash content, Moisture content and pH of the GAC were determined according to the methods described by Akpapunam and Markakis, (1981) and Metcalf and Eddy (2003). The water parameters were analyzed according to WHO/EC combined standards.

The Scanning Electron Microscopy (SEM) was used to focus beam of high-energy electrons to generate a variety of signals at the surface of the solid specimens (GAC) and an image reader "image j" was then used to read the pore space and surface area. The fixed bed adsorption experiment was set-up with three rectangular bed filters having height, breadth, length and thickness of 0.16m, 0.18m, 0.18m and 4mm respectively. Ten liter gallon was used as reservoir for raw water samples collected at different points on the stream. The valves were opened slowly such that the feed samples were allowed to flow from the reservoir into the top open of the filter beds by gravity.

The feed (water) sample was retained in each of the filter for 1 hr after which it was allowed to move down along the filtering bed. Filtration was done for 5hours and effluents collected at every hour were subjected to physico-chemical and microbiological analysis. Flow rate was also determined from known volume of water collected for specific time.

## III. RESULTS AND DISCUSSION

**Effect of Different Impregnation ratio on GAC**

Table 1 shows the characteristics of granular activated carbon (GAC) impregnated with different percentages of zinc chloride. It can be deduced that as the impregnation ratio increases, the bulk density, ash and moisture content increase but not in same proportion to impregnation ratios. Table 2 shows the characterization in terms of pH with different impregnation ratio of zinc chloride. The pH value of the bamboo carbon with no $Zncl_2$ was 7.2 but for those impregnated with $Zncl_2$ the pH values fell to the acidic range of 4.1-5.5 before washing. This may be due to the impregnation salt used. After series of washing, the pH values increased to 6.8-7.0. Average particle size of GAC was evaluated to be 29.7µm. Table 2b shows the standard proposed by Zheejlang in china.

The Nigerian bamboos comply with the standard with regards to moisture content, ash content and pH.

**Table 1:** Characterization of bamboo activated carbon with different impregnation ration.

| Impregnation % of $Zncl_2$ | Bulk Density ($g/cm^3$) | Moisture Content (%) | Ash Content (%) |
|---|---|---|---|
| 0 | 0.167 | 2.42 | 2.83 |
| 5 | 0.170 | 2.38 | 2.93 |

| | | | |
|---|---|---|---|
| 10 | 0.177 | 2.41 | 2.67 |
| 15 | 0.182 | 2.42 | 1.84 |
| 20 | 0.191 | 2.43 | 2.40 |

**Table 2:** pH value of GAC at different impregnation ratio

| Impregnation % of $Zncl_2$ | pH value<br>Before Washing | After Washing |
|---|---|---|
| 0 | 7.2 | 7.2 |
| 5 | 5.5 | 7.0 |
| 10 | 5.0 | 6.9 |
| 15 | 4.5 | 6.9 |
| 20 | 4.1 | 6.8 |

Table 2b: Physical and chemical Indexes of Bamboo Charcoal

| Items | Targets | |
|---|---|---|
| | 1st grade | Regulation grade |
| Moisture (%) | ≤8.5 | ≤12.0 |
| Ash (%) | ≤3.0 | ≤4.5 |
| Volatile matter (%) | ≤10.0 | ≤20.0 |
| Fixed carbon (%) | ≥85.0 | ≥75.0 |
| PH value | ≥7.5 | ≥7.0 |
| No-carbonized matter | Eligibility | Eligibility |

Adopted from provincial Standard of Zhejlang P.R. China DB33/T467-2004

Tables 3 and 4 shows the elemental constituents, surface area and pore space when Bamboo GAC was subjected to image J reading and SEM. It can be deduced that as percentage impregnation increases, the pore space and surface area also increase. This was further confirmed from the micrograph shown in plate 1.

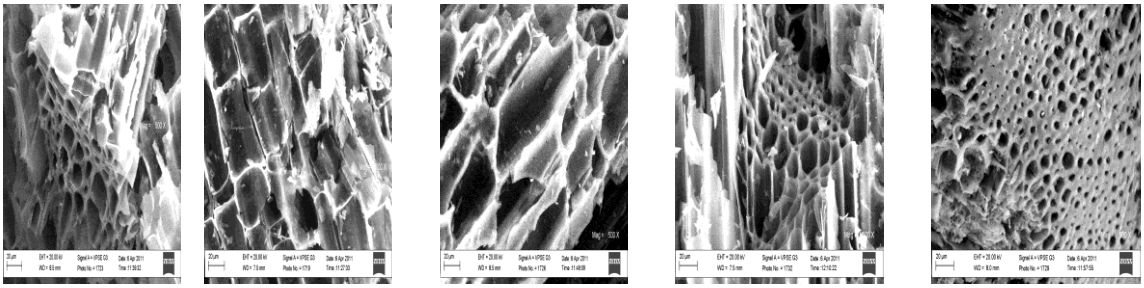
**Table 3**: Elemental composition of GAC at varying $Zncl_2$ Impregnation.

| | Weight (%) | | | | |
|---|---|---|---|---|---|
| Element | 0 | 5 | 10 | 15 | 20 |
| Carbon | 73.85 | 72.62 | 73.78 | 68.20 | 58.21 |
| Oxygen | 22.27 | 15.14 | 14.04 | 18.59 | 25.66 |
| Aluminum | 0.38 | 1.83 | 0.35 | 1.48 | 2.75 |
| Magnesium | 0.00 | 0.00 | 0.00 | 0.09 | 0.09 |
| Silicon | 0.30 | 0.39 | 0.35 | 1.20 | 1.93 |
| Phosphorus | 0.27 | 0.46 | 0.75 | 0.19 | 0.53 |
| Sulfur | 0.20 | 0.38 | 0.00 | 0.00 | 0.15 |
| Chlorine | 0.07 | 2.33 | 2.24 | 1.87 | 2.04 |
| Potassium | 2.35 | 1.09 | 1.64 | 0.24 | 0.13 |

| | | | | | |
|---|---|---|---|---|---|
| Calcium | 0.20 | 0.00 | 0.00 | 0.13 | 0.10 |
| Cobalt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Copper | 0.12 | 0.00 | 0.00 | 0.09 | 0.09 |
| Zinc | 0.00 | 5.75 | 6.86 | 7.62 | 8.12 |

**Table 4:** Pore Space and Surface area of Bamboo Granular activated carbon

| % Impregnation | Average pore area(um) | Average pore width (um) | Average pore length(um) | Surface area (um)2 |
|---|---|---|---|---|
| 0 | 50.45 | 172.30 | 15.0 | 2139772.5 |
| 5 | 53.70 | 180,40 | 16.70 | 2751790.0 |
| 10 | 69.11 | 200.20 | 17.00 | 2869170.5 |
| 15 | 94.40 | 307.15 | 17.95 | 3215676.0 |
| 20 | 104.83 | 354.26 | 18.76 | 3250273.5 |



0% 5% 10% 15% 20%

Plate 1 Micrograph of activated carbon from Nigerian bamboo according to different impregnation ratio of $Zncl_2$

**Bamboo GAC Treatment Effect**

Tables 5a-5c shows the physical, chemical and biological properties of surface water from Abadina stream before and after adsorption process in a fixed bed medium using activated carbon from Nigerian bamboo at different percentage of activation in an hour.

**Table 5a:** Physical properties of Abadina stream before and after adsorption at 1 hour contact time.

| PARAMETERS | Raw | 0% | 10% | 20% |
|---|---|---|---|---|
| Temperature(°C) | 27 | 27 | 27 | 27 |
| pH | 7.4 | 7.5 | 7.3 | 7.6 |
| Colour(Hazen Units) | 6.0 | 2.6 | 2.0 | 2.6 |
| Taste | Objectionable | Unobjectionable | Unobjectionable | Unobjectionable |
| Odour | Objectionable | Unobjectionable | Unobjectionable | Unobjectionable |
| Turbidity(mg/L $SiO_2$) | 12.00 | 2.33 | 2.00 | 2.33 |
| Conductivity (µS) | 1359.7 | 418.0 | 379.3 | 498.7 |
| Total Solids (mg/l) | 3214.7 | 1748.3 | 1752 | 1673.3 |
| Total Dissolved Solids (mg/l) | 578.3 | 260.0 | 256.7 | 313.3 |

The activated carbon product from Nigerian bamboo completely removed taste and odour. The pH of the treated water falls within the range of 6.8-8.4 specified by WHO. The increase in pH may have resulted from the presence of ligands such as carbonate,zinc, aluminum, magnesium in the B.vulgaris which increased the negative charge density on the adsorption surface, and the attraction of metallic ions thus allowing the adsorption onto the cell surface. This was also comfirmed by Rao et al, (2008); Addagalla et al,(2009), and Lim et al, (2010). There was a notable change in colour of

water during adsorption as it reduced from 6HU to 2-2.7HU. This indicate an efficiency of 55-66% for colour removal. Turbidity follows the same tread of treatment as colour with 80-83% removal. The result shows a reduction efficiency of 63-72% for conductivity with 10% $Zncl_2$ impregnation being the most effective. Total solids and Total Dissolved solid has removal efficiency of 45-55% with 20% impregnation being the most effective for Total solid removal.

The Nigerian Bamboo activated carbon can reduced heavy metals like lead, cadmium,nickel and chromium to potable limits specified by WHO. In the current study, the percentage removal of these metals vary from 25 to 91%.

Anions such as chloride(Cl), nitrite ($NO_3$), sulphate ($SO_4$), and phosphate($PO_4$) can be reduced from polluted water with Nigerian bamboo activated carbon to limit specifed by WHO. Zinc was observed to increase as a result of zinc salt used in activation of carbon.

**Table 5b:** Chemical properties of Abadina stream before and after adsorption at 1 hour contact time.

| PARAMETERS | Raw | 0% | 10% | 20% |
|---|---|---|---|---|
| $SO_4^{--}$ | 13.50 | 15.00 | 12.16 | 10.00 |
| $NO_3^{-}$ | 11.50 | 5.33 | 4.16 | 4.00 |
| $Cl^{-}$ | 25.00 | 14.33 | 12.33 | 11.66 |
| $PO_4^{---}$ | 15.00 | 10.00 | 7.16 | 6.00 |
| $Cr^{++}$ | 0.04 | 0.01 | 0.01 | 0.01 |
| $Zn^{++}$ | 0.05 | 0.05 | 0.15 | 0.15 |
| $Ni^{++}$ | 0.02 | 0.01 | 0.00 | 0.00 |
| $Pb^{++}$ | 0.12 | 0.02 | 0.01 | 0.02 |
| $Cd^{++}$ | 0.01 | 0.00 | 0.00 | 0.00 |

All parameters in mg/l

On biological properties the result obtained showed that microbacteria in the class of Total Aerobic count (TAC), Total Coliform count (TCC) and Total Fungal count (TFC) as tested in this study can be reduced drastically to a reasonable limit (36-51% efficiency) but not to the limit specified by WHO for drinking water. Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) are indices of microbe. The GAC also reduced the BOD and COD with efficiency of 96-99% without any pre-treatment. The dissolved oxygen on average increase from 1.43mg/l to 5.06mg/l this further indicate that GAC produced from Nigerian bamboo can purify contaminated water as earlier observed by Ademiluyi et al (2009).

**Table 5c:** Biological properties of Abadina stream before and after adsorption at 1 hour contact time

| PARAMETERS | RAW | 0% | 10% | 20% |
|---|---|---|---|---|
| $BOD_5$ | 468.00 | 15..33 | 11.33 | 12.00 |
| COD | 892.00 | 27.00 | 19.66 | 20.00 |
| DO | 1.43 | 4.50 | 4.46 | 5.06 |
| TAC | $6.06x10^7$ | $3.83x10^4$ | $3.40x10^4$ | $33.33x10^4$ |
| TCC | $6.93x10^5$ | $3.46x10^3$ | $3.36x10^3$ | $3.33x10^3$ |
| TFC | $4.43x10^4$ | $2.46x10^3$ | $2.46x10^3$ | $2.60x10^3$ |

All parameters in mg/l and cfus/ml

Comparing the three activated carbons employed in this study, it can be concluded that 10% $Zncl_2$ is more effective in adsorption of physical and biological pollutant parameters as compared to 0% and 20%, $Zncl_2$ while 20% $Zncl_2$ impregnation adsorbed more of the chemical pollutants. This is in line with the internal structure of the Activated carbon after impregnation with varying levels of $Zncl_2$ as depicted by plate1.

## IV. CONCLUSIONS

The study has revealed that indicative parameters of pollution in some surface water can be reduced to portability level as specified by WHO and Federal Environmental Protection Agency (FEPA) through adsorption with Granular Activated Carbon produced from a species of Nigerian bamboo named "Bambus vulgaris schrad".

The 10% $Zncl_2$ impregnated GAC is more effective in adsorption of physical and biological pollutants while 20% adsorbed more of the chemical pollutants. The GAC from Nigerian bamboo can reduce microbiological pollution, heavy metals and anions to tolerance limits which other forms of activated carbon such as palm kernel shells and coconut shells cannot reduce. It can absorb pollutants continuously for 72 hours with maximum efficiencies within the first 24 hours.

The GAC from Nigerian bamboo proved more effective and useful than just being a clarifier as expected. However, some of the parameters were found to be above the limit specified by WHO for drinking water but align with the limits stated for animal feed and irrigation. The activated carbon produced from Nigerian bamboo can be employed in removal of organic and inorganic contaminants.

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