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# Yield, Characterization and Potential Application of Activated Carbon Produced from Co – pyrolysis of Wood and Plastic Wastes as Adsorbent for Aquaculture Wastewater Treatment

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## ABSTRACT

Pollution from municipal solid wastes and wastewater from different agricultural operations pose detrimental effect to the environment such as wood and plastic wastes as well fish pond effluent. Co – pyrolysis of these solid wastes to produce activated carbon for the treatment of fish pond effluent serves as a means of reducing their negative impact on the environment as well as a viable alternative means of producing energy. Hence, plastic and wood wastes and fish pond effluent were collected for this study. The plastic wastes were washed, dried, shredded using cutlass and hammer milled to a particle size in the range of 1 – 5 cm. The sawdust was oven dried to a moisture content of 10% on dry basis and sieved through a 2mm mesh. In this work, sawdust (80%) and plastic (20%) wastes were co – pyrolysed in a pyrolysing unit. The influence of pyrolysis temperature on the product yields was investigated and part of the produced biocharwas activated using 460ml of nitric acid ($HNO_3$). The collected fish pond effluent was subjected to adsorption using activated and non – activated biochar as the adsorbents at 3g, 4g and 5g dosage levels. Results showed that the yield of biochar reduced with increase in temperature. Biochar produced at 400$^oC$ had the highest carbon content of 77.20%. Also, the fixed carbon, moisture content and ash of the produced biochar increased with increase in temperature while the volatile content decreased with increase in temperature. The results indicated that there were significant differences in the dosage levels of biochar utilized for the treatment in both cases for all the considered parameters except for pH. The removal efficiencies of phosphate and turbidity were the highest for the two absorbents: 89.17%, 71.93% respectively for the activated biochar and 86.36%, 78.25% respectively for the non – activated biochar. However, there was no significant difference between the two treatment options at 5% significance level (α) for all parameters such as pH, turbidity, total Kjeldahl nitrogen, nitrate, nitrite, phosphate, total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and dissolved oxygen (DO) except for total suspended solid (TSS) with probability level less than 0.025.

**Keywords:** Plastic and wood wastes, Fish pond effluent, Activated biochar, Biochemical oxygen demand, Biomass pyrolysis.

## 1. INTRODUCTION

The growth of human population, industrial and agricultural practices is the major causes of pollution (Owa, 2014). Pollution of water resources by fish farms effluent is probably the most common complaint, and this concern has attracted the greatest amount of official attention in various nations (Cobbina *et al*., 2014). The principal sources of aquaculture waste is ultimately the manufactured feeds that are necessary to increase production beyond natural levels (Yeo *et al.*, 2004), and also the use of hormones (antibiotics) with a known impact on the environment (Turcios and Papenbrock, 2014).

Four main components of aquaculture waste water of interest include: nutrients (nitrogen (N) and phosphorus (P)), biochemical oxygen demand (BOD), suspended solids and pathogens.Up to 80% of feed ingested by fish is released to the pond environment as faecal solids and dissolved nutrient and organic matter with just about 20% retain as fish biomass. Nitrogen and phosphorus are the key nutrients generated in aquaculture systems. Increase in concentration of organic matter, nutrients and suspended solids in culture ponds leads to an increase in oxygen demand, eutrophication and turbidity in receiving waters (Cobbina *et al*., 2014).

Efficient techniques for the removal of highly toxic organic compounds, suspended solids and nutrients from water and wastewater have drawn significant interest. A number of methods such as coagulation, filtration with coagulation, precipitation, ozonation, adsorption, ion exchange, reverse osmosis and advanced oxidation processes have been used for the removal of organic pollutants from polluted water and wastewater. These methods have been found to be limited, since they often involve high capital and operational costs. On the other hand, ion exchange and reverse osmosis are more attractive processes because the pollutant values can be recovered along with their removal from the effluents. Reverse osmosis, ion exchange and advanced oxidation processes do not seem to be economically feasible because of their relatively high investment and operational Cost (Rashed, 2013).

Among the possible techniques for water treatments, the adsorption process by solid adsorbents shows potential as one of the most efficient methods for the treatment and removal of organic contaminants in wastewater treatment (Rashed, 2013). Adsorption works on the principle of adhesion. The process of adsorption involvesseparation of a substance from one phase accompanied by its accumulation or concentration at the surface of another. The process can take place in any of thefollowing systems: liquid-gas, liquid-liquid, solid-liquid and solid-gas. The adsorbingphase is the ‘adsorbent’, and the material concentrated or adsorbed at the surface ofadsorbing phase is the ‘adsorbate’ (Vigneswaran *et al*, 2005).

Adsorption has advantages over the other methods because of simple design and can involve low investment in term of both initial cost and land required. The adsorption process is widely used for treatment of industrial wastewater from organic and inorganic

pollutants and meet the great attention from researchers (Rashed, 2013). Since early history, activated carbon was the first widely used adsorbent. Its applicationin the form of carbonized wood (charcoal) has been described as early as 3750 BC in an ancient Egyptian papyrus. The use of activated carbon is perhaps the best broad spectrum technology available at present to control contamination of water by organic pollutants (Vigneswaran *et al*, 2005).
The adsorption properties of carbon-reach materials (e.g. wood charcoal, bone charcoal) have been known for millennia, but only since the beginning of the twentieth century has this material been improved by special activation processes (Worch, 2012). In recent years, the search for low-cost adsorbents that have pollutant –binding capacities has also intensified. Materials locally available such as natural materials, agricultural wastes and industrial wastes can be utilized as low-cost adsorbents (Rashed, 2013). The most common raw materials, presently utilized, for the production of activated carbon are wood, wood charcoal, peat, lignite and lignite coke, hard coal and coke, bituminous coal, petrol coke as well as residual materials, such as coconut shells, lignocellulosic wastes, or plastic residuals (Worch, 2012).

Lignocellulosic wastes are the waste derived from agricultural material, including forest biomass. These materials are abundant in various sawmills and landfills across the nation. Sawmills generate much waste: sawdust, wood off-cuts, wood barks, plain shavings, wood rejects, etc. In the absence of proper disposal methods, these wastes are burnt in the open air, dumped along the bank of streams and rivers or left on any available space to rot. It was estimated that the amount of sawdust generated in Nigeria is about 1.8 million tons per annum while the corresponding figure for wood waste is 5.2 million (Oluoti *et al*., 2014).

Similarly, in Nigeria, there has also been a monumental increase in the yearly generation of plastic waste with minimal percentage of it being recycled. The rate of recycling is not commensurate with the rates at which the wastes are being generated and deposited into the environment. Only 14 kg (14.24%) in 2001 and just 13.06% of 268 kg in 2013 were recycled. Relative proportion of the quantity that may be recycled may be decreasing over time (Aderogba, 2014).

The conversion of these solid wastes into activated carbon requires two major processes, namely: carbonization and activation(Worch, 2012).Carbonization can be achieved through a process known as co – pyrolysis, which involves the thermochemical degradation of two or more feedstock in the complete absence of oxidizing agent (i.e. air), or with such a limited supply that gasification does not occur to an appreciable extent, to produce biochar, bio – oil and non – condensable gases. Generally, co – pyrolysis of plastic with biomass is mostly aimed at improving the quality of bio – oil. Bio – oil from pyrolysis of biomass is usually of high water content, high viscosity, poor ignition characteristics and corrosiveness, as well as high oxygen content, high solids content and chemical instability (Garcia et al., 2014).

Bai *et al*., (2015)co-pyrolysed red oak and HDPE using a laboratory- scale continuous fluidized bed reactor (in the temperature range of 525 – 625°C). The biochar produced was characterised and it was discovered that as compared to pyrolysis of red oak alone, the char produced from co-pyrolysis has higher carbon content and lower hydrogen and oxygen contents. As a result, the high heating value of the char produced from co-pyrolysis was about 10% higher than that obtained from pyrolysis of red oak at the same temperature. However, it was noted that the co-presence of HDPE inhibited char formation from red oak.This work is thus primarily concerned on the need to determine the effectiveness of activated carbon produced from wood and plastic wastes in the treatment of aquatic wastewater.

## 2. EXPERIMENTAL

### 1. Production of activated carbon

Theplastic waste bottles were obtained from dumpsite at Agbowo area of Oyo state, Nigeria. While, sawdust from *Anogeissus leiocarpus* (Ayin tree) was collected from Bodija Isopako in Ibadan metropolis. The plastic wastes were washed, dried, shredded using cutlass and hammer milled to a particle size in the range of 1 – 5 cm. The sawdust collected was stored in a suitable packaging unit to conserve its moisture content. The sawdust was oven dried to a moisture content of 10% on dry basis. It was further sieved through a 2mm mesh.

Plate 1: Plastic waste bottles (high density polyethylene).

Plate 2: Sieved saw dust of *Anogeissus leiocarpus*.

Mixing ratio of 80: 20 was adopted for the mixture of wood and plastic wastes in the co – pyrolysis process, which is in conformity with the work of Bai *et al*., (2015). Temperature was varied in a step of 50°C from 300°C to 400°C as it had been reported by various authors that biochar yield decreases with increase in temperature (Jindo *et al*., 2014, Park et al., 2016, Bai *et al*., 2015, Sarker *et al.*, 2010).

Plate 3: The Pyrolizing unit

A series of experimental process was afterwards initiated to determine the yields of the biochar at different temperatures, as well as its physical and chemical characteristics.

**Determination of the char yield from pyrolysis process**

The weight of the empty flask was determined and recorded as $W_r$. The weight of the flask after it has been cooled to room temperature at the end of the reaction was determined and recorded as $W_{rf}$. The weight of the char ($W_{char}$) produced is expressed as the difference between the weight of flask measured before and after the reaction. The char yield ($Y_{char}$) is obtained as a ratio between the char yield and the oven dry weight of the feedstock.

$W_{char} = W_{rf} - W_r$ Equation 1

$Y_{char} = \frac{W_{char} \times 100}{W_f}$ Equation 2

$W_f$= oven dry weight of the feedstock

**Biochar activation**

The activation of biochar was done according to the method used by Berisha*et al* (2016). For the purpose of this research work, 30g of the produced biochar was weighed and placed in a suitable container. It was then soaked in 460ml of $HNO_3$ and left overnight. After this, the mixture was passed through a muslin cloth and the acid was allowed to drain off. The resulting activated carbon was washed thoroughly under running water to remove residual acid. The washing was done repeatedly until the waste water was clear and clean. The activated carbon was then washed with deionized water to remove any form of residual acid. It was later oven dried at 120°C for 8 hours.

**2. Treatment of fish pond effluent**

Water samples were collected in duplicate using 5 liters' kegs as sampling bottles and small plastic bottles of 50ml from a fish farms located in Akuro, a suburb of Ibadan town. Until analysis, the collected water samples were kept in a cool container and was preserved for various analysis by addition of 1.0 ml of concentrated nitric acid. The collected wastewater was sieved to remove some foreign materials.500ml of wastewater was measured and poured into six plastic bottles individually.The produced biochar was measured as 3g, 4g, 5g and were poured into three different bottles filled with the waste water.The activated biochar was measured as 3g, 4g, 5g and were poured into three different bottles filled with the waste water.The six bottles were properly shaken for a flocculation period of 30 minutes.

Plate 4: Fish pond effluent treated with Non – Activated bio – chars at 3g, 4g and 5g.

Plate 5: Fish pond effluent treated with Activated bio – chars at 3g, 4g and 5g

## 3. RESULTS AND DISCUSSION

**Biochar yield**

The biochar yield was calculated as the proportion of the weight of pyrolysis product to the original material. Table 1 presents the biochar yield at 300 $^{o}$C, 350 $^{o}$C and 400 $^{o}$C under a fixed residence time of 50 minutes respectively with two replicates. It was observed that the biochar yield significantly decreased with increased in temperature. At 300 $^{0}$C, the average yield of biochar is 43.85% while at 350 $^{0}$C the average biochar yield decrease to 34.85%. Also, at 400 $^{o}$C, the biochar yield further decreases to 25.91%. As previously reported by many researchers, who have attributed this decrease in the char yield with increasing temperature, this can either be as a result of the primary decomposition of the wood at higher temperatures or to secondary decomposition of the char produced. This conclusion is consistent with previous studies of cellulose and lignocellulosic materials (Jindo *et al*., 2014). In addition, at lower temperature the co-presence of HDPE inhibited char formation (not properly melted) thus increases the mass of the produced biochar. This is also in agreement with the co-pyrolysis of red oak with HDPE reported by Bai *et al*., (2015).

Table 1: Biochar yield at different temperatures and residence time of 50 minutes

| Residence time (mins.) | Temperature ($^{o}$C) | Weight of feedstock (g) | Weight of biochar (g) | % Yield |
|---|---|---|---|---|
| 50 | 300 | 100 | 43.64 | 43.64 |
| | | 100 | 44.03 | 44.03 |
| | | | Mean | 43.85 |
| | 350 | 100 | 35.00 | 35.00 |
| | | 100 | 34.70 | 34.70 |
| | | | Mean | 34.85 |
| | 400 | 100 | 25.90 | 25.90 |
| | | 100 | 25.92 | 25.92 |
| | | | Mean | 25.91 |

Plate 6: Biochar produced at 400ºC and 50 minutes' residence time.

Plate 7: Biochar produced at 300ºC and residence time of 50 minutes.

**Biochar characteristics**

Table 2 presents the proximate analysis of the biochars derived from the mixture of wood and plastic at different temperatures. The determination of the volatile matter and ash content was conducted according to the American Society for Testing and Materials (ASTM) D1752-84, which is recommended by the International Biochar Initiative (Jindo *et al*., 2014). Biochar obtained at 400°C had the best potential as a carbon-rich material (a suitable criterion for selecting char to be used as activated carbon), it contains 8.04% volatile matter, 8.70% ash and 75.40% fixed carbon.

It is evident from Table 2 that the fixed carbon content of the produced biochar increases with increase in temperature but with consequential reduction in biochar yield. Low-temperature pyrolysis produced higher and an enriched volatile-matter composition than the high-temperature pyrolysis. Which gradually reduces as the pyrolysis temperature increases. The ash and moisture contents of the biochar steadily increases with increase in temperature. This is consistent with the work reported by Jindo *et al*., 2014.

Table 2: Proximate analysis of biochar derived from wood and plastic mixture at different temperature.

| S/N | Temperature ($^0$C) | Biochar Yield (%) | Fixed carbon (%) | Volatile matter (%) | Moisture content (%) | Ash content (%) |
|---|---|---|---|---|---|---|
| **1** | 300 | 43.85 | 64.85 | 21.10 | 6.55 | 7.50 |
| **2** | 350 | 34.85 | 70.10 | 14.49 | 7.28 | 8.13 |
| **3** | 400 | 25.91 | 75.40 | 8.04 | 7.86 | 8.70 |

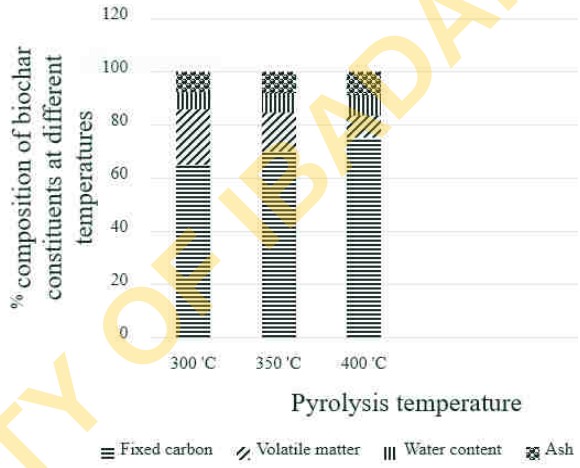


Fig 1: Variation in char content at different temperatures.

Analytical elements, hydrogen: carbon ratio (H:C) and oxygen: carbon (O:C) ratios are useful indicators of the character of biochars (Jindo *et al*., 2014). Data in Table 3 suggest that an increase in the temperature results in a larger loss of H and O compared to that of C. The dehydrogenation of $CH_3$ as a result of thermal induction indicates a change in the biochar recalcitrance. In addition, a biomass material typically comprises of easily decomposed and recalcitrant O fractions; the former is rapidly lost after the initial heating, while the latter is retained in the char of the final product (Jindo *et al*., 2014). Because of the high temperature of the charring process, the H:C and O:C ratios are reduced as a result of dehydration and decarboxylation reactions.

Table 3: Elemental composition of the biochars derived from mixture of wood and plastic feed.

| Temperature (°C) | C (%) | H (%) | O (%) | H:C | O:C |
|---|---|---|---|---|---|
| 300 | 70.95 | 7.40 | 12.60 | 1.2516 | 0.1332 |
| 350 | 73.80 | 7.28 | 11.25 | 1.1830 | 0.1143 |
| 400 | 77.20 | 7.16 | 10.18 | 1.1124 | 0.0989 |

**Treatment of fish pond effluent**

Tables 4 and 5 present the laboratory analysis of the fish pond effluent treated with activated Biochar (A) and Non- activated Biochar (NA) at 3g, 4g and 5g respectively as compared with the raw water sample.

Table 4: Average values of parameters for raw and treated fish pond effluents using activated biochar

| | Parameters | Water samples | | | |
|---|---|---|---|---|---|
| | | RAW | A-3g | A-4g | A-5g |
| 1 | pH | 6.93 | 6.55 | 6.40 | 6.15 |
| 2 | Turbidity (NTU) | 57.00 | 38.00 | 26.50 | 16.00 |
| 3 | TKN | 2.70 | 2.40 | 2.21 | 1.17 |
| 4 | Nitrate | 4.91 | 3.72 | 3.10 | 2.41 |
| 5 | Nitrite | 1.50 | 1.23 | 1.06 | 0.83 |
| 6 | Phosphate | 4.4 | 3.19 | 1.61 | 0.45 |
| 7 | Total suspended solids (mg/l) | 221.00 | 184.50 | 152.50 | 103.50 |
| 8 | Total dissolved solids (mg/l) | 254.00 | 205.50 | 175.50 | 125.00 |
| 9 | Biological oxygen demand (mg/l) | 861.00 | 738.00 | 678.00 | 549.00 |
| 10 | Chemical oxygen demand (mg/l) | 1578.00 | 910.50 | 771.00 | 643.50 |
| 11 | Dissolved oxygen (mg/l) | 2.85 | 3.30 | 4.55 | 5.20 |

Table 5: Average values of parameters for raw and treated fish pond effluents using Non – activated biochar

| | Parameters | Water samples | | | |
|---|---|---|---|---|---|
| | | RAW | NA-3g | NA-4g | NA-5g |
| 1 | pH | 6.93 | 7.10 | 7.14 | 7.20 |
| 2 | Turbidity (NTU) | 57.00 | 31.00 | 25.30 | 12.40 |
| 3 | TKN | 2.70 | 2.25 | 2.00 | 1.15 |
| 4 | Nitrate | 4.91 | 3.51 | 2.41 | 2.10 |
| 5 | Nitrite | 1.50 | 1.29 | 1.11 | 0.75 |
| 6 | Phosphate | 4.4 | 2.75 | 1.20 | 0.60 |
| 7 | Total suspended solids (mg/l) | 221.00 | 164.00 | 127.50 | 85.50 |
| 8 | Total dissolved solids (mg/l) | 254.00 | 183.50 | 134.00 | 106.50 |
| 9 | Biological oxygen demand (mg/l) | 861.00 | 654.00 | 498.00 | 460.50 |
| 10 | Chemical oxygen demand (mg/l) | 1578.00 | 823.50 | 729.75 | 609.00 |
| 11 | Dissolved oxygen (mg/l) | 2.85 | 4.70 | 4.98 | 5.42 |

It was observed that the pH of the activated biochar treated effluent became more acidic, this might be as a result of the acid used in the activation process, while the pH of the non – activated biochar treatment became slightly neutral. Figures 2 and 3 depicted the removal efficiency for all the parameters. The results indicated that the removal efficiencies of all the parameters increase with increase in the utilised dosages of activated biochar. The non – activated biochar treatment is more effective in the removal of organic compounds that were responsible for the turbid nature of wastewater when compared with activated biochar treatment.

The maximum removal efficiency for non – activated biochar treatment was 78.25% while for activated biochar treatment was 71.93%. All the biochar dosages for both activated and non-activated were effective for the removal of phosphate, the removal efficiency increases greatly as the biochar dosage increases from 3g to 5g. The maximum removal efficiency for phosphate was recorded as 89.77% when activated biochar was utilized and 86.36% when non – activated biochar was used. This showed that the activated biochar is more efficient in the removal of phosphate from fish pond effluent. The dissolved oxygen in the treated fish pond effluent increases from 15.78% to 82.46% for activated carbon treatment and 64.91% to 90.18% for non – activated carbon treatment as the dosages increase from 3g to 5g.

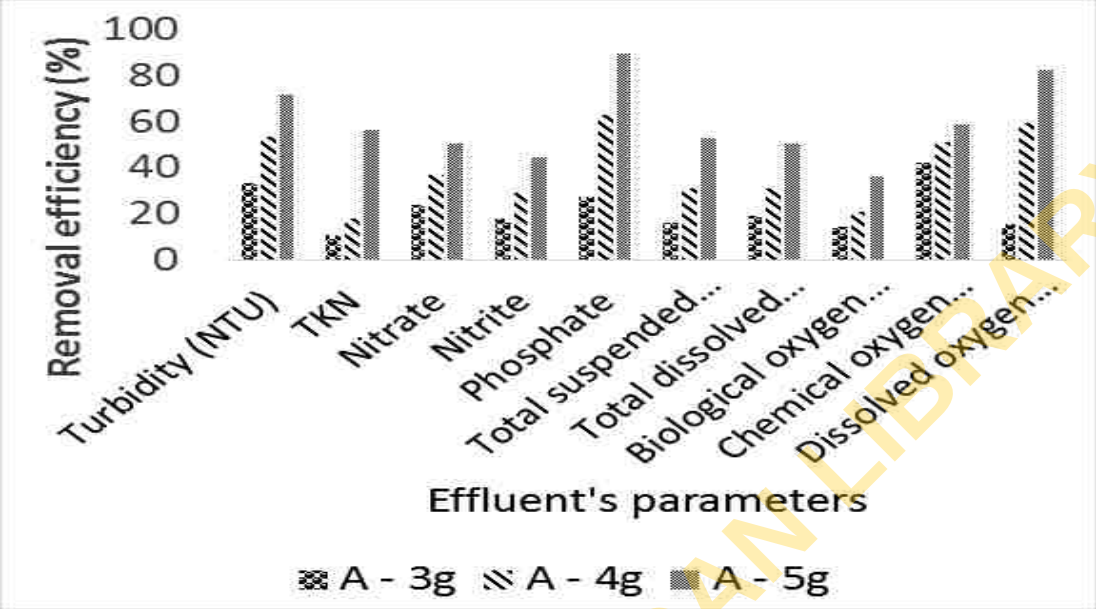


Fig 2: Removal efficiency for the parameters in treated fish pond effluents using activated biochar.

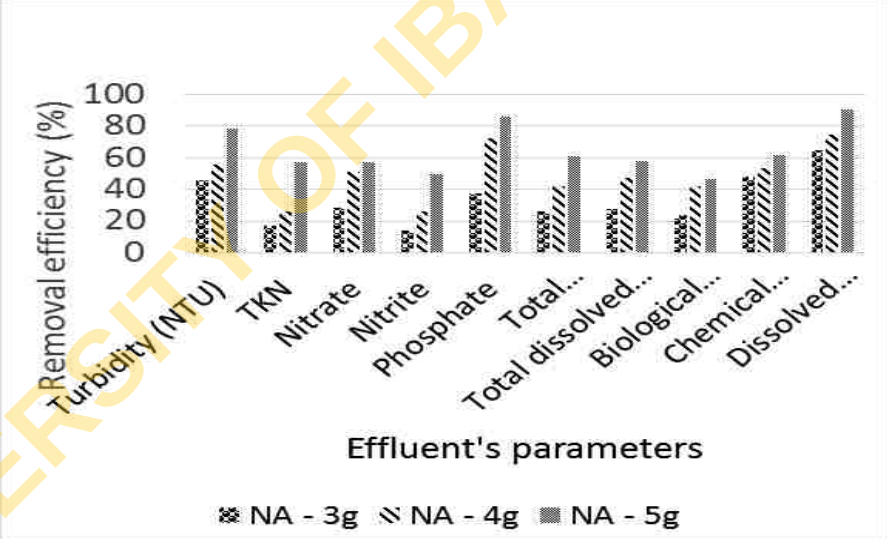


Fig 3: Removal efficiency for the parameters in treated fish pond effluents using Non – activated biochar.

The activated and non – activated biochar treatments were compared statistically using coefficient of variation and two – tailed t – test. The results in Table 6 showed that there was slight variation between the two treatment options for total Kjeldahl mitogen (TKN), nitrite as well as chemical oxygen demand (COD) with coefficient of variation of 4.92%, 0.68% and 5.13%. This showed that the activation process has no effect on the performance of the biochar for fish pond effluent treatment. However, there was a high variation between the two treatments for other parameters such as pH (8.13%), turbidity (11.18%), nitrate (10.08%), phosphate (9.95%), total suspended solid (10.98%), total dissolved solid (12.47%), biochemical oxygen demand (13.93%) and

dissolve oxygen (10.25%). The result of the t – test indicated that there was no significant difference between the two treatment options at 5% significance level (α) for all the considered parameters except for total suspended solid (TSS) with probability level less than 0.025.

Table 6: Comparison between non - activated biochar and activated biochar treatments.

| | Parameters | CV (%) | T - values | Probability (p) |
|---|---|---|---|---|
| 1 | pH | 8.13 | 5.35 | 0.03 |
| 2 | Turbidity (NTU) | 11.18 | 2.34 | 0.14 |
| 3 | TKN | 4.92 | 2.26 | 0.15 |
| 4 | Nitrate | 10.08 | 2.76 | 0.11 |
| 5 | Nitrite | 0.68 | 0.22 | 0.85 |
| 6 | Phosphate | 9.95 | 1.22 | 0.35 |
| 7 | Total suspended solids (mg/l) | 10.98 | 10.34 | 0.01 |
| 8 | Total dissolved solids (mg/l) | 12.47 | 3.82 | 0.06 |
| 9 | Biological oxygen demand (mg/l) | 13.93 | 3.76 | 0.06 |
| 10 | Chemical oxygen demand (mg/l) | 5.13 | 3.29 | 0.08 |
| 11 | Dissolved oxygen (mg/l) | 10.25 | 1.88 | 0.20 |

A = Activated carbon
NA = Non - activated carbon
CV = Coefficient of variation

Tables 7 and 8 depicted the comparison of treated fish pond effluent's parameters with WHO and FEPA standards. The pH of the raw and activated biochar treated effluents are slightly acidic, though the results are still in conformity with both standards. The pH of non – activated biochar treated effluent is however moderately neutral. The turbidity of the raw and the treated effluent range far above the WHO standard and as such further treatment of the effluent is required before it can be discharged to the environment.

Also, nitrate values for both activated and non – activated biochar at the three different dosages all fall considerably below the standard. Initially, the concentration of phosphate in the raw fish pond effluent rises beyond the standard. With dosage increment for both the treatment options, the phosphate concentration was greatly reduced below the set standard. The char can thus be viewed as being efficient for phosphate removal.

Table 7: Comparison of activated biochar treatment parameters with international standards.

| | Parameters | Raw | A – 3g | A – 4g | A – 5g | WHO standard | FEPA standard |
|---|---|---|---|---|---|---|---|
| 1 | pH | 6.93 | 6.55 | 6.40 | 6.15 | 6.5 – 8.5 | 6 -9 |
| 2 | Turbidity (NTU) | 57.00 | 38.00 | 26.50 | 16.00 | 5.0 | – |
| 3 | TKN | 2.70 | 2.40 | 2.21 | 1.17 | | – |
| 4 | Nitrate | 4.91 | 3.72 | 3.10 | 2.41 | 10 | – |
| 5 | Nitrite | 1.50 | 1.23 | 1.06 | 0.83 | | – |
| 6 | Phosphate | 4.4 | 3.19 | 1.61 | 0.45 | 2.5 | – |
| 7 | TSS (mg/l) | 221.00 | 184.50 | 152.50 | 103.50 | 30 | 15 – 30 |
| 8 | TDS (mg/l) | 254.00 | 205.50 | 175.50 | 125.00 | 1000 | 2000 |
| 9 | BOD (mg/l) | 861.00 | 738.00 | 678.00 | 549.00 | 20 | 10 – 50 |
| 10 | COD (mg/l) | 1578.00 | 910.50 | 771.00 | 643.50 | – | 15 – 50 |
| 11 | DO (mg/l) | 2.85 | 3.30 | 4.55 | 5.20 | 4 | 5 – 20 |

The dissolved oxygen as well as total dissolved solid both conformed with the two standards.While there is a huge difference between the result values and those of the standards for biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TDS).

Table 8: Comparison of non - activated biochar treatment parameters with international standards.

| | Parameters | Raw | NA – 3g | NA – 4g | NA – 5g | WHO STANDARD | FEPA STANDARD |
|---|---|---|---|---|---|---|---|
| 1 | pH | 6.93 | 7.10 | 7.14 | 7.20 | 6.5 – 8.5 | 6 -9 |
| 2 | Turbidity (NTU) | 57.00 | 31.00 | 25.30 | 12.40 | 5.0 | – |
| 3 | TKN | 2.70 | 2.25 | 2.00 | 1.15 | | – |
| 4 | Nitrate | 4.91 | 3.51 | 2.41 | 2.10 | 10 | – |
| 5 | Nitrite | 1.50 | 1.29 | 1.11 | 0.75 | | – |
| 6 | Phosphate | 4.4 | 2.75 | 1.20 | 0.60 | 2.5 | – |
| 7 | TSS (mg/l) | 221.00 | 164.00 | 127.50 | 85.50 | 30 | 15 – 30 |
| 8 | TDS (mg/l) | 254.00 | 183.50 | 134.00 | 106.50 | 1000 | 2000 |
| 9 | BOD (mg/l) | 861.00 | 654.00 | 498.00 | 460.50 | 20 | 10 – 50 |
| 10 | COD (mg/l) | 1578.00 | 823.50 | 729.75 | 609.00 | – | 15 – 50 |
| 11 | DO (mg/l) | 2.85 | 4.70 | 4.98 | 5.42 | 4 | 5 – 20 |

## 4. CONCLUSIONS

The treatment of fish pond effluent with activated carbon revealed that the concentration of TDS, phosphate, nitrate and pH all fall within the acceptable limits of FEPA (1991) and WHO (2004) for discharged of wastewater into nearby waterways. However, the huge amount of COD, BOD and TSS needs to be drastically reduced to prevent adverse effect on the environment. Hence, physical separation methods such as clarification and flocculation are essential to reduce the TSS concentration, while biological treatments such as biological filter and activated sludge system should be employed prior to treatment to reduce BOD and COD concentrations.

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