Nigerian Journal of Technology (NIJOTECH)
Vol. 41, No. 3, May, 2022, pp.603-612
www.nijotech.com

Print ISSN: 0331-8443
Electronic ISSN: 2467-8821
`http://dx.doi.org/10.4314/njt.v41i3.21`

Comparative Assessment of Biosorption Potential of Non-treated and Acid-treated Activated Carbon Produced from Maize cob for Wastewater Treatment

V. T. Sanyaolu [1, *], O. Fadayini[2] and T. T. Oshin[3]

[1]*Dept. of Biological Science (Environmental Biology Unit), Lagos State University of Science and Technology, Ikorodu – Lagos State, NIGERIA*
[2]*Department of Chemical Engineering, Lagos State University of Science and Technology, Ikorodu – Lagos State, NIGERIA*
[3]*Department of Chemical Science, Lagos State University of Science and Technology, Ikorodu - Lagos State, NIGERIA*

Abstract

Humans and the environment are both concerned about contaminated drinking water. One of the most dangerous constituents in wastewater is heavy metals. The removal of these contaminants from the ecosystem is still a challenge. Some of these heavy metals have been toxic concentrations in human and livestock drinking water. As a result, the goal of this study was to compare the adsorption potential of non-treated and acid-treated activated carbon generated from maize cob in the treatment of wastewater. Fresh maize cobs were air-dried and oven-dried at 255 °C for 9 hours after being cleaned in distilled water. These were crushed, sieved through a 300 µm mesh and carbonized in a muffle furnace to produce powdered activated carbon (PAC). One half of PAC was treated with 780 mL of hydrochloric acid (acid-treated activated carbon - AAC), while the other received no further treatment (non-treated activated carbon - NAC). For surface characteristics and functional groups, the conventional approach was applied to characterize AAC and NAC. Thirty grams of each sample were used in the treatment of metal recycling effluent. Untreated (T1), filtered (T2), NAC treated (T3), and AAC treated (T4) wastewater samples were analysed in three replicates using World Health Organization (WHO) and Lagos State Environmental Protection Agency (LASEPA) standard methods for Physico-chemical parameters. Analysis of data was by ANOVA, while mean separation was by Duncan's Multiple Range Test (DMRT) at ($P \leq .05$). Results showed that T2 had no significant improvement ($P \leq .05$) in all parameters tested. T3 significantly increased pH, conductivity, TS and TSS, gave the highest mean alkalinity, but showed no significant changes in heavy metal contents. T4 significantly improved mean colour, conductivity, nitrate content and DO, reduced mean pH (from 7.4±0 to 2.1±0.1), increased heavy metal concentrations ($P \leq .05$) and increased mean total acidity, but not significantly ($P \geq .05$). Treatments improved parameters in the following order: filtration < NAC < AAC. Thus, acid-activated carbon had a higher adsorbent capability than non-activated carbon due to its wide surface area and low moisture and ash contents.

Keywords: Activated carbon, Industrial wastewater, Metal recycling factory, Physico-chemical parameters, Water quality.

1.0 INTRODUCTION

The increase in the use of potentially toxic elements over the past few decades has unavoidably resulted in the influx of metallic and other toxic substances in the aquatic and terrestrial environment [1, 2]. A major source of these toxic elements is through discharge of untreated wastewater into the environment. Wastewater is a by-product of domestic, industrial, commercial or agricultural activities, whose characteristics may vary depending on the source [3, 4]. Industries produce and use a multitude of synthetic substances, a great many of which are non-biodegradable or degrade extremely slowly. Such recalcitrant substances persist in the environment for prolonged periods and therefore become progressively more concentrated [5]. They accumulate in living tissues throughout the food chain and pose a serious menace to human and public health [6].

Numerous concerted efforts have been made to remediate the release of toxic substances into the environment through wastewater treatment such as oxidation [7]., coagulation [8, 9]., solvent extraction [10], ion exchange [11], membrane separation [12], and reverse osmosis [13].

However, most of these methods for removing contaminants from wastewater are not economically feasible for small and medium-size industries owing to their high operational and maintenance costs, generation of toxic

---

***Corresponding author (Tel:** +234 (0) 8087412679**)**
Email addresses: *vaksanyaolu@yahoo.com* (V. T. Sanyaolu), *olufeday@gmail.com* (*O.* Fadayini.*)*, oshintaiwo2000@yahoo.com (Oshin, T. T.)

sludge and elaborated procedure involved. The use of biosorbents for the removal of toxic pollutants or recovery of valuable resources from aqueous wastewater (biosorption or adsorption) is one of the most recent developments in environmental or bio-resource technology [14-16]. The major advantages of biosorption over conventional treatment methods include its low cost, high efficiency, minimization of chemical and biological sludge, no additional nutrient requirements, ability to regenerate biosorbents and the possibility of metal recovery following adsorption [13, 17-19]. Biosorbents have been reported to treat wastewater pollutants effectively with up 90 % adsorption of pollutants [20, 16]

Biosorbents used in the biosorption process include activated carbon [13], clay [18], Kaolin [19], carbon nanotubes [14], metal nanoparticles [2], Nanocomposites [21], functionalized carbonaceous materials [7], agricultural wastes [10], goethite [11], modified cellulose [12], and native cassava starch hydrogel [15]. These have all emerged as a cost-effective and efficient alternative for wastewater treatment in the last two decades. A large variety of agricultural wastes and by-products have been examined for their capability to remove pollutants from wastewater [1, 22]. Effective biosorption using agricultural waste involves carbonization and activation of these materials.

Carbonization consists of the thermal decomposition of raw materials, eliminating non-carbon species and producing a fixed mass with a rudimentary pore structure [23]. Activated carbon is an odourless, tasteless powder, which absorbs large amounts of chemicals or poison [24-25]. Maize or corn is a common name for cereal grass grown for food or livestock fodder [26-27]. In Nigeria, it is grown in almost all parts of the country. After the maize grain has been harvested, maize cobs, which are produced in large numbers, find very minimal use. These are left in large piles in the homesteads and fields. The abundance of this waste, therefore, makes it readily available for utilization as activated carbon. Odogunyan axis of Ikorodu appears to be a safe haven for poorly regulated metal recycling factories. Here, metal recycling factories released their effluents directly into the environment. This study assessed the biosorption behaviour of activated carbon prepared from maize cob and evaluate its efficiency in the removal of pollutants in wastewater from the metal recycling industry in Odogunyan, Ikorodu, Lagos State.

2.0 METHODOLOGY

2.1 Collection of wastewater sample

Samples of effluent were collected from a metal recycling industry located at Odogunyan, Ikorodu, in Lagos State, Nigeria. Samples were collected at the point of discharge from the major drainage location at coordinates; 06° 68.083 N and 003° 51.135' E. Collected samples were stored in sterilized plastic containers and taken to the Laboratory.

2.2 Collection and Carbonization of Maize Cob to Powdered Activated Carbon

The maize cob used in this study was first washed with distilled water to remove external impurities, then air-dried and oven-dried at 255 °C at a constant weight for 9 h to reduce the moisture content of the fresh cob. These were crushed in a miller to a fine powder and sieved with 300 µm mesh. The sieved maize cob was carbonised in a box muffle furnace at a temperature of 600 °C for 1 h and allowed to cool at room temperature to produce powdered activated carbon (PAC) [23, 27]. Carbonised maize was weighed and divided into two equal weights; one half received no further treatment, henceforth called non-treated activation carbon (NAC), while the other was further treated with acid.

2.3 Acid Treatment of Powdered Activated

Acid treatment of carbonized maize cob was carried out according to the method proposed by Bernard *et al.* (2013). Exactly 820 mL of distilled water was measured into a clean plastic container, to which 780 mL of HCl was added. The solution was then added to the PAC and the mixture was stirred with a glass rod to allow impregnation of the acid into the charcoal. It was kept for 10 minutes to allow proper penetration of the acid. The mixture was then rinsed in distilled water, sieved and dried in the muffle furnace at 400 °C for 15 minutes to return it to the powdery form, henceforth called acid-treated activated carbon (AAC). This was allowed to cool at room temperature.

2.4 Characterization of Activated Carbon

Characterization of surface property and functional groups of NAC and AAC (Plates 1 A and B respectively) was conducted for pore volume, yield, specific surface area and porosity.

2.5 Determination of Surface Properties of Activated Carbon

i. Pore Volume

An electronic weighing scale was used to weigh exactly 2 g of sample into a measuring cylinder, which was then pressed until there was no change in volume. After that, the weighted sample in the graduated cylinder was immersed in boiling water in a beaker. The sample was thoroughly dried and weighed again after the pore had been displaced. The pore volume of samples was determined as described by Aloko and Adebayo (2007) [28]. The pore volume was calculated using the following equation:

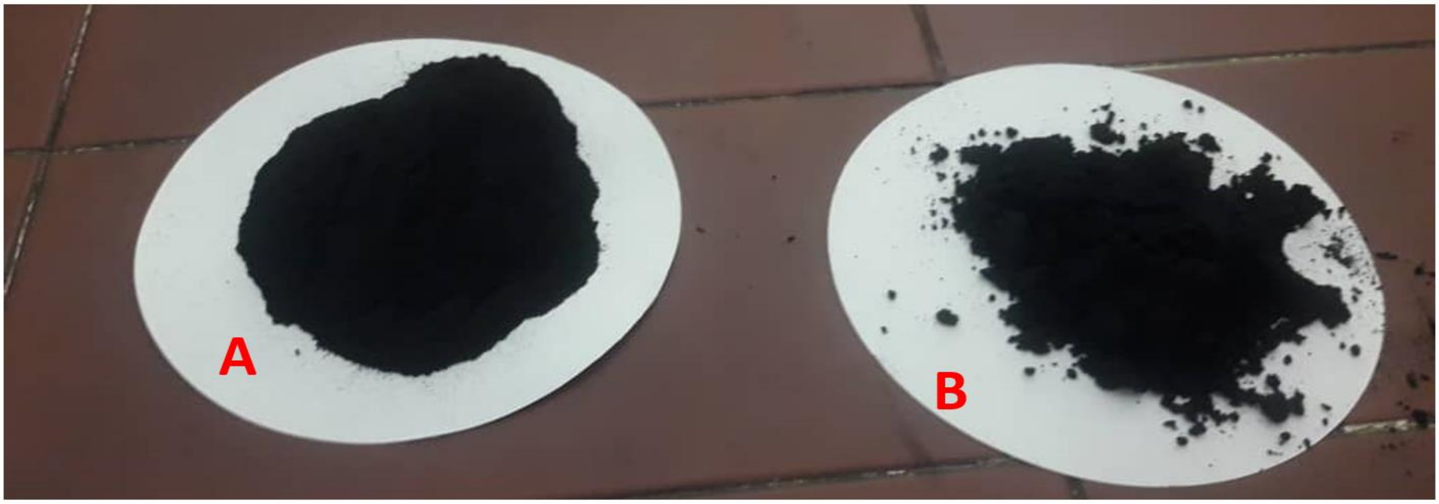


Plate1: Picture showing non-activated carbon (NAC) and acid-treated activated carbon (B).

$$Pore\ volume\ \left(\frac{g}{cm^{-3}}\right) = \frac{WEB + SAV - WOB}{VOW} \quad (1)$$

Where, WEB = weight of empty baker
SAV = sample after volatilizing
WOB = weight of beaker
VOW = volume of water

ii. Surface area

The surface area of the samples was determined by the iodine adsorption method [29]. Sample aliquot solution was prepared by centrifuging 0.5 g of the sample in 25 cm^3 of 0.05 M iodine solution. The blank was titrated with 0.1 M sodium thiosulphate solution after 2 drops of the starch indicator were added to 20 cm^3 of distilled water. The same procedure was applied to the sample aliquot solution of NAC and AAC prepared.

iii. Moisture content

Exactly 2.0 g each of dry samples of NAC and AAC was measured into a crucible that had been previously cleaned, dried and weighed. Each crucible and its sampled contents were dried in an oven at 125°C for 3 hours until a consistent weight was obtained. As reported by Aloko and Adebayo, Ekpete and Horsfall [28-30], the moisture content was determined using the method established by Miroslav and Vladimir [31] as:

$$MC = \frac{(M_1 - M_2)}{M_3} \times 100 \quad (2)$$

Where; MC = moisture content (%), M_1 = initial weight, M_2 = weight after drying specimen (g), M_3 = mass of the container and oven-dried specimen (g).

iv. Ash Content

A known weight of each oven-dried sample (M_5) was placed in a porcelain crucible and ashed in a muffle furnace set at 600 °C for 1h. It was cooled in a desiccator and the final weight (M_4) was determined using an electronic balance. The ash content (%) was calculated as follows:

$$AC = \frac{M_4}{M_5} \times 100 \quad (3)$$

Where; AC = ash content, M_4 = final weight, M_5 = initial weight.

2.6 *Determination of Functional Groups*

Oxygen-containing Functional Groups were determined using the modified Boehm titration method by Ekpete and Horsfall. About 2.0 g of each carbon sample was kept in contact with a 50 mL solution of $NaHCO_3$ (0.1 M), Na_2CO_3 (0.05 M), and NaOH (0.1 M) for the acidic group and 0.1 M HCl for basic groups for more than two days. Subsequently, the aqueous solutions were back-titrated with HCl (0.1 M) for acidic and NaOH (0.1 M) for the basic group. The number and type of acidic sites were calculated by considering that NaOH neutralizes carboxylic, lactonic, and phonetic groups. Na_2CO_3 neutralizes the carboxylic and lactonic groups and the $NaHCO_3$ neutralizes only carboxylic groups. Carboxylic groups were therefore quantified by direct titration with $NaHCO_3$; the difference between the groups titrated with Na_2CO_3 and those titrated with $NaHCO_3$ was assumed to be lactones and the difference between the groups titrated with NaOH and those titrated with Na_2CO_3 was assumed to be phenols. The basic site was determined by titration with HCl. Neutralization points were determined using pH indicators of phenolphthalein solution for titration of a strong base and strong acid, while methyl red solution was used for the titration of a weak base and strong acid.

2.7 Fourier Transformation Infrared Spectrometry (FTIR) Analysis

The Fourier transform infrared (FTIR) analysis of the samples was carried out by FTIR equipment of mark SPECTRUM ONE FTIR incorporated with software (Perkin Elmer Instruments version 3.02.01) for the examination of the spectra. Characterization was according to their structure, chemistry and morphology [31, 32] The functional groups were determined by plotting the transmittance against the wavelength and their frequencies were recorded.

2.8 Biosorption Treatment of Wastewater

Exactly 30 g each of NAC and AAC was added to 2,000 mL of wastewater samples. The mixture was stirred for 1 hour and allowed for 5 mins to settle and then filtered into a conical flask using Whatman grade one filter paper. The filtrate was transferred into a clean sterilized 2.5 L plastic container for analysis. The same procedure was repeated for all samples.

2.9 Experimental Design

The study included four treatments in three replicates as follows; untreated wastewater (T1) filtered wastewater (T2), wastewater treated with non-treated activated carbon (NAC) T3 and wastewater treated with acid-treated activated carbon (AAC) T4. The study was set up using a Completely Randomized Design (CRD).

2.10 Sample Analysis

Analysis of samples was carried out in Wastewater and Sensitivity Laboratory at Lagos State Environmental Protection Agency (LASEPA). All samples were analysed according to Standard Analytical Methods for wastewater examination prescribed by the American Public Health Association [33] and Association of Official Analytical Chemists (AOAC, 2002). Samples were analysed for:

a) Physical parameters including colour, temperature, turbidity, conductivity, total solids (TS), total suspended solids (TSS), total dissolved solids (TDS).
b) Chemical parameters including pH, acidity, alkalinity, DO, BOD, COD, sulphates, nitrate, phosphate and heavy metals (Ca, Cu, Fe, Cr, Mn, Pb, Cd, Ni, and Ag).

2.11 Statistical Analysis

Data were analysed using ANOVA (SPSS, 2015 version) and mean separation was by Duncan's Multiple Range Test (DMRT).

3.0 RESULTS

3.1 Surface Characteristics and Functional Groups of Activated Carbon

Table 1 shows the result of the characterization of the NAC and AAC for pore volume, surface area, yield, moisture content and ash content Result showed that AAC had higher values for surface area, yield, moisture and ash contents, while pore was the same (1.5 g/cm^3) for both. Also, both activated carbons possess 3 different classes of compounds namely: Nitro-compound, Sulfoxide and Alkene, with each compound showing similar characteristics in absorption, bond strength and functional group assignment, except in the range of absorption of alkene, which was between 895 – 874 cm^{-1} in NAC and with strong bonding, while it ranged between 895 – 550 cm^{-1} in AAC and therefore had a weak bond.

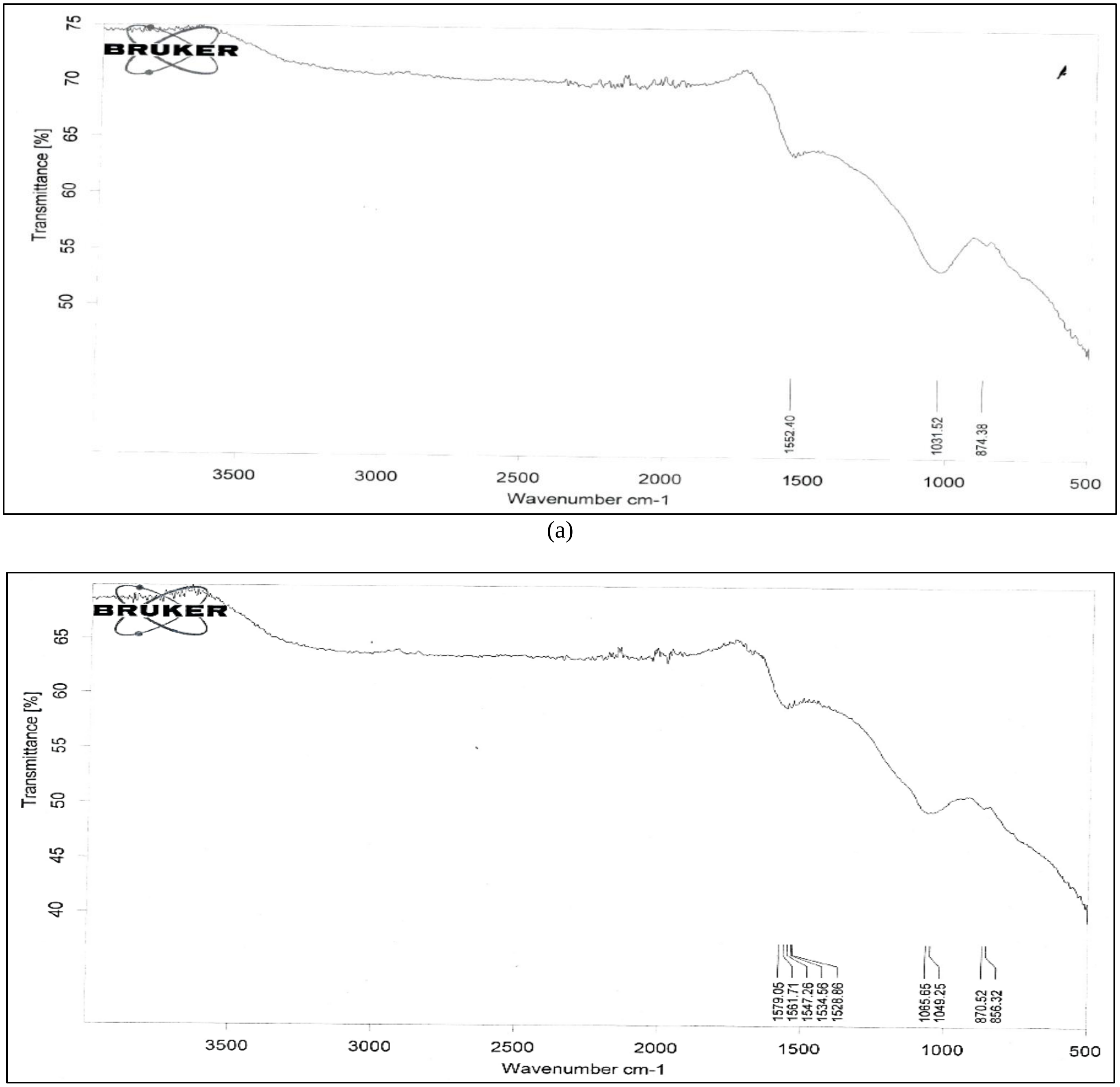
3.2 Fourier Transformation Infrared Spectrometry (FTIR)

Results for analysis of NAC and AAC for chemical and functional groups are shown in Figures 1(a) and 1(b) respectively. In both cases, the wavenumber was found to vary between 4000 and 350 cm^{-1}. However, FTIR spectra for AAC had higher peaks ranging between 50 % and 75 % compared to that for NAC which ranged between 40 % and 65 %.

Table 1: Surface characteristics and functional groups of activated carbon

T	Pore Volume (g/cm^3)	Surface Area (m^2/g)	Yield (%)	Moisture Content (%)	Ash content (%)	Class of compounds	Absorption (cm^{-1})	Bond Intensity	Functional group Assigned
NAC	1.5	31.0	5.0	25.0	5.0	Nitro compound	1550-1500	Strong, Medium	N−O Stretch
						Sulfoxide	1070-1030	Strong, Broad	S=O Stretch
						Alkene	895–874	Strong	C=C Bend
AAC	1.5	35.7	2.5	15.0	0.5	Nitro compound	1550–1500	Strong, Medium	N−O Stretch
						Sulfoxide	1070–1030	Strong, Broad	S=O Stretch
						Alkene	895 – 550	Weak	C=C Bend

T = Treatment; NAC = Non-activated carbon; AC = Activated carbon



(a)

(b)

Figure 1. (a) FTIR Result for acid-treated activated carbon and (b) non-treated activated carbon.

3.3 Effect of Treatments on Physical Parameters of Wastewater

Table 2 shows the results of physical characteristics obtained from the analysis of untreated and treated effluent samples. There were significant differences ($P \leq .05$) in all parameters tested. Treatment with AAC (T4) had significantly lower mean values ($P \leq .05$) in pH, colour and conductivity, while T3 significantly increased mean pH, conductivity, TSS and TS (Table 2). In addition, T3 and T4 were significantly higher ($P \leq .05$) in turbidity compared to T1 and T2.

However, there were no significant differences ($P \geq .05$) between the unfiltered (T1) and filtered (T2) wastewater, except in temperature, where T1 was significantly lower ($P \geq .05$) than all other treatments, but T2 showed a slight improvement compared to T1 in most tested parameters (Table 2)

***Table 2**: Physical parameters of treated and non-treated wastewater*

T	Appearance	pH	Colour (Pt.Co.APH)	Temp (°C)	Conductivity (uS/cm)	Turbidity (NTU)	TSS (mg/l)	TDS (mg/l)	TS (mg/l)
T1	BSP	7.4±0.0^{b}	705.67±15.06^{b}	25.50±0.1^{a}	9.1±0.1^{b}	63.3±6.1^{a}	77.00±6.7^{a}	6557.7±177.0^{a}	6634.67±183.6^{a}
T2	BSP	7.5±0.0^{b}	766.00±34.18^{b}	25.73±0.2^{b}	9.1±0.0^{b}	57.6±11.2^{a}	73.00±4.0^{a}	6399.6±63.1^{a}	6472.67±60.8^{a}
T3	BSP	8.3±0.2^{c}	764.00±116.25^{b}	26.23±0.2^{b}	10.1±0.1^{c}	571.3±10.8^{b}	975.00±332.5^{b}	7494.3±427.7^{b}	8469.33±698.7^{b}
T4	BSP	2.1±0.1^{a}	262.67±16.33^{a}	25.93±0.1^{b}	6.0±0.1^{a}	236.7±170.8^{b}	93.00±20.2^{a}	6977.7±220.3^{ab}	7070.7±238.3^{a}

Mean values along each column having similar superscript are not significantly different ($P \geq .05$ DMRT)

BSP = Bluish with suspended particles; T= treatment; TI = untreated wastewater; T2 = filtered; T3 = NAC treatment; T4 = AAC treatment; TSS = Total suspended solids; TDS = Total dissolved solids; TS =Total solids; Superscripts a, b, c = are classifications in a homogeneous subset, the same alphabet are homogeneous but are different from other subsets with difference alphabet.

***Table 3a:** Mean chemical parameter for different treatments*

T	total acidity (mg/L)	total alkalinity (mg/L)	chloride (mg/L)	nitrate (mg/L)	phosphate (mg/L)	sulphate (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)
T1	50.0 ±5.7^{a}	933.3 ±116.7^{bc}	584.0±148.3^{a}	126.7±22.3^{c}	52.5±1.00^{b}	156.7±26.7^{b}	0.0 ± 0.0^{a}	5,782.3±1847.2^{a}	1,445.6±461.8^{a}
T2	66.7±6.7^{ab}	783.3 ±44.1^{b}	567.3±33.4^{a}	80.0±8.6^{b}	2.7±0.44^{a}	60.0±3.5^{a}	0.0 ± 0.0^{a}	3,513.7±1457.7^{a}	878.4±364.4^{a}
T3	56.7 ±6.7^{a}	1383.3±258.7^{c}	550.6±50.0^{a}	67.4±7.0^{b}	3.2±0.31^{a}	56.3±13.7^{a}	0.0 ± 0.0^{a}	2,625.7±203.6^{a}	656.4±50.9^{a}
T4	86.7±12.0^{b}	185.0±42.5^{a}	500.7±115.5^{a}	8.5±0.8^{a}	2.9±0.15^{a}	45.0±14.5^{a}	4.8 ± 0.6^{b}	2,471.7±353.6^{a}	617.9±88.4^{a}

Mean values along each column having similar superscripts are not significantly different ($P < .05$ DMRT)

T= treatment; TI = untreated wastewater; T2 = filtered; T3 = NAC treatment; T4 = AAC treatment; DO = dissolved oxygen; COD = chemical oxygen demand; BOD = biological oxygen demand.

***Table 3b**: Mean heavy metal concentration (mg/l) for different treatments*

T	Ca	Cu	Fe	Cr	Na	Mn	Pb	Cd	Ni	Ag
T1	0.401±0.07^{b}	0.004±0.01^{a}	0.094±0.03^{a}	0.000±0.00^{a}	0.936±0.29^{a}	0.004±0.00^{a}	0.002±0.00^{a}	0.001±0.00^{a}	0.005±0.00^{a}	0.008±0.01^{a}
T2	0.288±0.13^{ab}	0.001±0.00^{a}	0.066±0.02^{a}	0.002±0.00^{a}	0.836±0.23^{a}	0.000±0.00^{a}	0.002±0.00^{a}	0.001±0.00^{a}	0.009±0.01^{a}	0.000±0.00^{a}
T3	0111±0.01^{a}	0.006±0.01^{a}	0.167±0.08^{a}	0.004±0.01^{a}	0.817±0.22^{a}	0.003±0.00^{a}	0.005±0.01^{a}	0.000±0.00^{a}	0.005±0.00^{a}	0.003±0.00^{a}
T4	0.305±0.13^{ab}	0.205±0.02^{b}	0.949±0.30^{b}	0.652±0.12^{b}	0.893±0.30^{a}	0.057±0.03^{b}	0.003±0.01^{a}	0.000±0.00^{a}	0.421±0.06^{b}	0.000±0.00^{a}

Mean values along each column having similar superscripts are not significantly different ($P < .05$ DMRT)

T = treatments; TI = untreated wastewater; T2 = filtered; T3 = NAC treatment; T4= AAC treatment.

3.4 Chemical Parameters of Treated Effluent

Table 3a shows results for the mean chemical parameter of untreated and treated effluent samples. There were no significant differences ($P \geq .05$) in mean chlorine content, COD and BOD, but the highest mean values were recorded in T1 in all three parameters. T1 was also significantly higher in nitrate, phosphate and sulphate contents with a mean concentration of 126.7±22.3, 52.5±1.00 and 156.7±26.7 mg/l respectively. Acidity recorded the lowest value in T1, whereas T4 was significantly higher ($P \leq .05$) than all treatments except T2. On the other hand, T4 recorded the lowest mean alkalinity, chloride, sulphate, COD and BOD with significantly highest mean values in alkalinity and nitrate. T4 was also significantly higher ($P \leq .05$) in DO with a mean value of 4.8± 0.6mg/l, DO was not present (0.0 ±0.0 mg/l) in T1, T2 and T3. The lowest and highest mean alkalinity were recorded in T4 and T3 respectively (Table 3a).

3.5 Heavy Metals

Table 3b shows the mean concentration of heavy metals in untreated and treated effluent samples. Results showed that there were no significant differences between treatments ($P \geq .05$) in mean concentrations of Na, Pb, Cd and Ag. However, mean concentrations of Cu, Fe, Cr, Mn and Ni were significantly higher ($P \leq .05$) in T4 than in all treatments with values of 0.205±0.02, 0.949±0.30, 0.652±0.12, 0.057±0.03, 0.421±0.06 respectively (Table 3b). The lowest mean Cr and Ni occurred in T1, Cu, Fe, Mn, and Ag occurred in T2, while Ca, Na, Cd occurred in T3.

The lowest mean concentration of Pb occurred in T1 and T2, whereas, the Lowest concentration of Cd occurred in T3 and T4. The lowest mean Ca concentration occurred in T3 which was only significantly lower than that observed in T1 (Table 3b).

4.0 DISCUSSION

One of the most traditional methods of water treatment is filtration. However, because very small particles can pass through membranes used in water filtration, no contaminants are eliminated from the filtered water. In this study, filtered water only showed a slight improvement in most parameters tested, suggesting that filtration alone is not an efficient method of water purification. Activated carbons prepared from cheap agricultural waste have been identified as potential adsorbents for the removal of different pollutants from industrial wastewaters [34]. The large surface area, low amount of moisture and ash, indicates that the particle density is relatively small and that the biomaterial should be an excellent raw material for adsorbents [35]. Acid treatment improves the biosorption potential of activated carbon. In this study, FI-TR spectra for AAC had higher peaks, thus, showing overall improvement in quality and relative purity of AAC compared to the NAC. This further indicates better adsorption property of AAC compared to NAC. This agrees with reports earlier documented on similar studies [35-36].

In this study, the treatment of wastewater with AAC reduced colour significantly compared to other treatments. This result agrees with many other reports that activated carbon from many sources has been used to reduce colour in wastewater [37-39]. However, values obtained for colour were still higher than the Lagos State Environmental Protection (LASEPA) limit of 250 Pt.Co. APHA. Improvement in the colour of wastewater may probably have resulted from acid treatment of the activated carbon. This agrees with the report of Girgis *et al*.[36], who stated that uptake of colour in methylene blue dye was proportional to the average size of micropores, which were larger for the activated carbon with a longer acid soaking time. Treatment with NAC and AAC increased turbidity, TDS, TSS and TS beyond the world health organisation (W.H.O) and LASEPA standard limits [40-41] This may have resulted from an inefficient filtration process. Turbidity affects water by interfering with sunlight penetration. It has been reported that turbidity, visual clarity and TSS of water are interrelated [42]. High concentrations of fine suspended sediment within rivers and streams can lead to mortality of fish [36, 43], constrain the behaviour of fish and birds [44], reduce light penetration into waters and constrain primary productivity [45-46]. Treatment of water with AAC increased acidity and hence, resulted in low pH values. This may have occurred as a direct result of the acid (HCl) treatment of PAC. Treatment with NAC on the other hand increased the alkalinity of water significantly and increased pH. It has been reported that any activated carbon that is not acid-washed usually produce an initial effluent with a pH greater than 7. The rise in pH depends on factors such as the ash content of the starting material [12]. The majority of aquatic creatures prefer a pH range of 6.5-9.0, though some can live in water with pH levels outside of this range. If the pH of water is too high or too low, the aquatic organisms living within it will die. This is because pH can also affect the solubility and toxicity of chemicals and heavy metals in the water [47]. pH affects the availability of plant nutrients and the growth of algae and micro-organisms [48]. Acidity can be reduced by treating the acidified water with lime. Acid-treated activated carbon (AAC) was efficient in reducing the nitrate level of the treated wastewater. This strongly agrees with the work of Morteza *et al.* [49], who concluded that activated carbon sorbent, when used for the treatment of nitrate in water, has more ability to remove nitrate compared to other treatments. This result was also in agreement with Hamidi *et al.* [50], who reported that treatment with chemically activated carbon could remove more than 40 % of ammoniacal nitrogen from a solution.

The level of dissolved oxygen (DO) in wastewater increased significantly after treatment with AAC. This agrees with the result of an earlier study by Egbon *et al.* [20]. Dissolve oxygen level in AAC treated wastewater was slightly higher than the required limit of 4.0 mg/l stated by LASEPA [41]. Although COD and BOD levels were also reduced in all treatments, all were, however, above the permissible limits (120 and 30 respectively) set by the Federal Ministry of Environment. The overly high concentration of COD and BOD may have resulted from high levels of dissolved and suspended solids in the treated water [51]. All heavy metals tested (Ca, Cu, Fe, Cr, Mn, Ni, Cd, Ag) were present in very low concentrations in the wastewater. Treatment of wastewater with AAC was observed to increase the concentration of copper, iron, chromium, manganese and nickel significantly. This result was not in agreement with an earlier report by Bernard *et al*. [52]. An increase in metal concentration may have resulted from external contaminants during the process of acid treatment, which may have introduced some traces of heavy metals into acid-treated activated carbon.

5.0 CONCLUSION

Based on data obtained from this study, the use of filtration alone generally showed a slight improvement in most water parameters tested. Treatment with acid treated activated carbon prepared with maize cob improved wastewater colour and conductivity. It also improved chemical parameters including nitrate, sulphate and DO. However, treatment with acid treated activated carbon increased the acidity of wastewater. It was also not effective in adsorbing heavy metals, as it increased the concentration of Cu. Fe, Cr. Mn and Ni. In treated wastewater, non-treated activated carbon also showed potential in improving the physical and chemical parameters, but was not as effective as acid treated activated carbon.

REFERENCES

[1] T. O. Jimoh, A. T. Buoro and M. Muriana, "Utilization of Blighiasapida (Akee apple) pod in the removal of lead, cadmium and cobalt ions from aqueous solution," *Journal of Environmental*

Chemistry and Ecotoxicology, 4(10), 2012, pp. 178-187.

[2] M. Haghighizadeh, K. Zare, H. Aghaie and M. Monajjemi, "Preparation and Characterization of Chicory Leaf Powder and Its Application as a Nano-Native Plant Sorbent for Removal of Acid Blue 25 from Aqueous Media: Isotherm, Kinetic and Thermodynamic Study of the Adsorption Phenomenon," *Journal Nanostructure in Chemistry*. https://doi.org/10.1007/s40097-019-00330-z, 2020.

[3] V. Emongor, E. Nkegbe, B. Kealotswe, I. Koorapetse, S. Sankwasa and S. Keikanetswe, "Pollution Indicators in Gaborone Industrial Effluent," *Journal of Applied Sciences*, 5(1), 2005, pp. 147-150.

[4] Kaveeshwar, E. D. Revellame, D. D. Gang, E. Zappi and R. Subramaniam, "Pecan Shell Based Activated Carbon for Removal of Iron (II) from Fracking Wastewater: Adsorption Kinetics, Isotherm and Thermodynamic Studies," *Process Safety & Environmental Protection*, https://doi.org/10.1016/j.psep.2017.12.007, pp. 1–50, 2018.

[5] United Nations Department for Technical, "Criteria for and Approaches to Water Quality Management in Developing Countries: United Nations Department of Technical Co-operation for Development (UNDTCD)," *National Resources Water Series*, United Nations New York, 1991.

[6] D. N. Renuga, K. Manjusha and P. Lalitha, "Removal of Hexavalent Chromium from Aqueous Solution using an Eco-friendly Activated Carbon Adsorbent," *Pelagia Research Library, Advance in Applied Science Research*, 1, 2010, pp. 247-254.

[7] L. Y. Jun, N. M. Mubarak, L. S. Yon, C. H. Bing, M. Khalid and E. C. Abdullah, "Comparative Study of Acid Functionalization of Carbon Nanotube via Ultrasonic and Reflux Mechanism," 2018, 6:5889e96. https://doi.org/10.1016/j.jece.2018.09.008, 2018.

[8] S. S. Ghasemi, M. Hadavifar, B. Maleki and E. Mohammadnia, "Adsorption of Mercury ions from Synthetic Aqueous Solution using Polydopamine Decorated SWCNTs," *Journal Water Process Engineering*, 32, 2019, 100965.

[9] L. O. Ekebafe, D. E. Ogbeifun and F. E. Okieimen , "Ekebafe, L.O. Ogbeifun, D.E. and Okieimen F.E (2012a). Removal of Heavy Metals," An Indian Journal Macromolecules, vol. 8, no. 2, pp. 42-47, 2012a.

[10] R. Baby, B. Saifullah and M. Z. Hussein, "Palm Kernel Shell as an Effective Adsorbent for the Treatment of Heavy Metal Contaminated Water," *Scientific Reports*, vol. 9, pp. 1-11, 2019.

[11] B. Dash and S. S. Rath, "A Thorough Understanding of the Adsorption of Ni (II), Cd (II) And Zn (II) on Goethite using Experiments and Molecular Dynamics Simulation," *Separation Purification Technology – Journal. Elsevier*, vol. 240, no. 116649., 2020.

[12] O. Chen, J. Zheng, L. Wen, C. Yang and L. Zhang, "A Multi-Functional-Group Modified Cellulose for Enhanced Heavy Metal Cadmium Adsorption: Performance and Quantum Chemical Mechanism," *Chemosphere*, vol. 224, p. 509–518., 2019.

[13] S. M. Kharrazi, N. Mirghaffari, M. M. Dastgerdi and

M. Soleimani, A Novel Post Modification of Powdered Activated Carbon Prepared from Lignocellulosic Waste Through Thermal Tension Treatment to Enhance the Porosity and Heavy Metals Adsorption, vol. 366, *Powder Technology Elsevier*, 2020.

[14] T. C. Egbosiuba and A. S. Abdulkareem, "Highly Efficient As-Synthesized and Oxidized Multi-Walled Carbon Nanotubes for Copper(II) and Zinc (II) ion Adsorption in a Batch and Fixed-Bed Process," *Journal of Materials Research and Technology*, 2021, pp. 2848-2872.

[15] L. O. Ekebafe, D. E. Ogbeifun and F. E. Okieimen, "Removal of Heavy Metals from Aqueous Media using Native Cassava Starch Hydrogel," *African Journal of Environmental Science and Technology*, 6(7), 2012b, pp. 275-282.

[16] T. C. Egbosiuba, "Incorporation of Zero-Valent Silver and Polyvinyl Acetate on the Surface Matrix of Carbon Nanotubes for the Adsorption of Mercury and Chromium from Industrial Wastewater," *Nigerian Journal of Technology*, 41(1), 2022.

[17] D. Kratochvil and B. Volesky, "Advances in the Biosorption of Heavy Metals," *Reviews Trends in Biotechnology*, 16, 1998, pp. 291-300.

[18] C. V. Lazaratou, D. Panagiotaras, G. Panagopoulos, M. Pospisil and D. Papoulis, "Ca Treated Palygorskite and Halloysite Clay Minerals for Ferrous Iron (Fe+2) Removal from Water Systems,"

Environmental Technology & Innovation, 19, 2020, 100961.

[19] S. Mustapha, J. O. Tijani, M. M. Ndamitso, S. A. Abdulkareem and D. T. Shuaib, "The Role of Kaolin and Kaolin/Zno Nanoadsorbents in Adsorption Studies for Tannery Wastewater Treatment," *Scientific Reports*, pp. 1–22, https://doi.org/10.1038/s41598-020-69808-z., 2020.

[20] E. Egbon, V. Idode, E. Elizabeth and P. Chukwuma, "Treatment of Saloon Waste Water Using Activated Carbon," *Chemical and Process Engineering Research*, 17, 2013, pp. 24-28.

[21] S. Abdul, A. T. Siva, R. Sankara, R. Miditana and K. V. D. Lakshmi, "Efficient and Recyclable Visible Light-Active Nickel–Phosphorus Co-Dopedtion Nanocatalysts for the Abatement of Methylene Blue Dye," *Journal Nanostructure in Chemistry*, https://doi.org/10.1007/s40097-020-00343-z, 2020.

[22] S. Muzaffar and H. Tahir, "Enhanced Synthesis of Silver Nanoparticles by Combination of Plants Extract and Starch for the Removal of Cationic Dye from Simulated Waste Water using Response Surface Methodology. *Journal of Molecular Liquids," Journal of Molecular Liquids*, 252, 2018 p. 368–382.

[23] Z. Hu, M. P. Srinivasan and Y. Ni, Novel Activation process for preparing highly microporous and mesoporous activated carbons,39(6), 877-886, 2001, pp. *Microporous and Mesoporous Activated Carbons*, 39(6): 877-886.

[24] Association of Official Analytical Chemists (AOAC), "Official Method of Analysis. 16th Edition," *Association of Official Analytical, Washington DC*, 2002.

[25] Kentucky water watch, Sulfate and water quality., retrieved from http://www.state.ky.us/nrepc/water/ramp/rmso4.htm)., Accessed May 14, 2021.

[26] P. Muthusamy, S. Murugan and S. Monathi, "Removal of nickel ion from industrial wastewater using maize cobs," *Biological Science*, 1(2), 2012, pp. 7-11.

[27] B. O. Opeolu, O. Bamgbose, T. A. Arowolo and M. T. Adetunji, "Utilization of maize (Zea mays) cob as an adsorbent for lead (II) removal from aqueous solutions and industrial effluents," *African journal of Biotechnology*, 2009, pp. 1567-1573.

[28] D. F. Aloko and G. A. Adebayo, "Production and characterization of activated carbon from agricultural waste (Rice husk and Corn cob)," *Journal of Engineering and Applied Sciences*, 2(2), 2007, pp. 440-444.

[29] F. E. Okieimen, C. O. Okieimen and R. A. Wuana, "Preparation and Characterization of Activated Carbon from Rice Husks," *Journal of the chemical society of Nigeria*, 32(1), 2007, pp. 126-136.

[30] O. A. Ekpete and M. J. Horsfall, "Preparation and characterization of activated carbon derived from fluted pumpkin stem waste (Telfairia occidentalis hook f)," *Research Journal of Chemical Sciences*, 1(3), 2011, p. 10–17.

[31] R. Miroslav and N. B. Vladimir, "Practical environmental analysis," *Royal Society of Chemistry*, UK, 1999.

[32] M. S. Dresselhaus, A. P. Fung, A. M. Rao, S. L. DiVittorio, K. Kuriyama, G. Dresselhaus and M. Endo, "New characterization techniques for activated carbon fibres," *Carbon*, 30, 1992, pp. 1065-1073.

[33] G. Crini and P. P. Badot, Treatment and Purification of Polluted Industrial Water: Membrane Processes, Bioadsorption and Chemical Oxidation, Presses University, Franche-Comté., 2007.

[34] A. P. H. A. (APHA), "Standard Methods for the Examination of Water and Wastewater, 21st edition," *APHA-AWWA-WEF, Washington D.C.*, 2005.

[35] A. A. Abia and J. C. Igwe, "Sorption Kinetics and intra-particular Diffusivities of Cd, Pb, and Zn ions on maize cobs," *African Journal of Biotechnology*, 4(6), 2005, pp. 509-512.

[36] B. S. Girgis, E. Smith, M. M. Louis and A. A. El-Hendaw, "Pilot Production of Activated Carbon from Cotton Stalks using H3PO4," *Journal of Analytical Applied Pyrolysis*, 86, 2009, pp. 180–184.

[37] M. F. Otero, L. F. Rozada, A. I. Calvo and A. Garcıa, "Moran Adsorption on adsorbents from sewage sludge Elimination of organic water pollutants using adsorbents obtained from sewage sludge," *Dyes and Pigments*, 57, 2003, pp. 55–65.

[38] B. Acemioglu, "Adsorption of Congo Red from Aqueous Solution onto Calcium-Rich fly Ash," *Journal of Colloid Interface Science*, 274, 2004, pp. 371-379.

[39] P. Leechart, W. Nakbanpote and P. Thiravetyan, "Application of 'Waste' Wood Shaving Bottom Ash

for Adsorption of Azo Reactive Dye," *Journal of Environmental Management,* 90, 2009, p. 912–920.

[40] World Health Organisation (WHO), "Guidelines for drinking-water quality. 4th edition, p. 631," https://doi.org/10.1016/S1462-0758(00)00006-6., 2017.

[41] Lagos State Environmental Protection Age, "Standard Methods for the Effluents Parameters," *Lagos State Environmental Protection Agency (LASEPA),* Lagos-State, 2016.

[42] E. J. Ballantine, A. O. Hughes and R. J. Davies-Colley, "Mutual Relationships of Suspended Sediment, Turbidity and Visual Clarity in New Zealand Rivers," *in Proceedings of the International Association of Hydrological Sciences* 367, 2014, pp. 265-271.

[43] A. Wenger, M. McCormick, G. Endo, I. McLeod, F. Kroon and G. Jones, "Suspended Sediment Prolongs Larval Development in a Coral Reef Fish," Journal of Experimental Biology, 217, 2014, p. 1122–1128.

[44] R. J. Davies-Colley and D. G. Smith, "Turbidity, Suspended Sediment and Water Clarity: A Review," *Journal of the American Water Resources Association*, 37, 2001, pp. 1085–1101.

[45] P. S. Kumar, J. Narvekar, M. Nuncio, A. Kumar, N. Ramaiah, S. Sardessai, M. Gauns, V. Fernandes and J. Paul, *Current Science*, 98(10), 2010, pp. 1331-1339.

[46] G. L. Perez, L. Lagomarsino and H. E. Zagarese, "Optical Properties of Highly Turbid Shallow Lakes with Contrasting Turbidity Origins: The Ecological and Water Management implications," *Journal of Environmental Management*, 130, 2013, p. 207–220.

[47] Environmental Protective Agency, "Channel Processes: Bedload Transport. In Water: Science & Technology," Accessed 15 march 2018, retrieved from http://water.epa.gov/scitech/datait/tools/warsss/bedload.cfm, 2012.

[48] V. E. Emongor and G. M. Ramolemana, "Treated Sewage Effluent (Water) Potential to be used for Horticultural Production in Botswana, *Physics and Chemistry of the Earth*, Parts A/B/C, (Elsevier 2014)," 29(15-18), , 2014, pp. 1101-1108

[49] K. A. Morteza, H. H. Amir and N. Ehasn, "Evaluation of Nitrate Removal from using from Water using Activated Carbon and Clinoptilolite by Adsorption Method," *Biosciences Biotechnology Research*, 13(2), 2016, pp. 1045-1054.

[50] A. A. Hamidi, N. A. Mohd, S. Z. Mohamed and A. Salina, "Removal of Ammoniacal Nitrogen (N-NH3) from Municipal Solid Waste Leachate by using Activated Carbon and limestone," *Waste Management & Research*, 8, 2004, pp. 167-821.

[51] I. M. Bryant and R. Tetteh-Narh, "Using Slow Sand Filtration System with Activated Charcoal Layer to Treat Salon Waste Water in a Selected Community in Cape Coast, Ghana," *Advanced Chemical Engineering*, 5(4), 2015, pp. 1-8.

[52] E. Bernard, A. Jimoh and J. O. Odigure, "Heavy Metals Removal from Industrial Wastewater by Activated Carbon Prepared from Coconut Shell*," Research Journal of Chemical Sciences*, 3, 2013, pp. 3-9.