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# Removal of Colour from Textile Wastewater by Mango Seed Endocarp Activated Carbon

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## ABSTRACT

Activated Carbons were produced from seed endocarp of a local variety of mango (*Magnifera indica)* by chemical activation with Zinc Chloride ($ZnCl_2$) before and after carbonization. Various impregnation ratios (1:2, 1:3, 1:4, 1:5 and 1:6) of $ZnCl_2$ to prepared mango seed endocarp by weight were considered in the production of the activated carbons. The produced activated carbons were characterised and subjected to preliminary batch adsorption studies for the removal of colour from textile wastewater to obtain the best impregnation ratio. The best impregnation ratio was further evaluated through batch studies for the purpose of determining optimum conditions for the removal of colour from textile wastewater. Adsorbent dose, initial colour concentration, contact time, stirring rate, pH and temperature were used as variables. The results obtained revealed that mango seed endocarp activated carbon (MSEAC) produced using impregnation ratio of 1:4 was the best among the impregnation ratios investigated. The optimum carbon dose, stirring rate, temperature and pH were respectively 0.8 g, 90 rpm, 30$^o$C and 7. Colour removal increased with decrease in initial colour concentration. 100% removal was achieved at initial colour concentrations below 399 Pt-Co units, hence 399 Pt-Co units was chosen as the optimum initial colour concentration. With respect to time, MSEAC achieved 86.3% removal of colour in 40 min and therefore 40 min was chosen as the optimum contact time. It was recommended that MSEAC can be used to effectively remove colour from textile wastewater at the optimum conditions determined in this research, thus, converting the waste to wealth.

**Key words:** *Mango Seed Endocarp, Activated Carbon, Colour, Textile Wastewater*

## 1. INTRODUCTION

Textile industries discharge a large quantity of highly coloured wastewater effluent on lands or rivers without any treatment because the conventional treatment methods are very expensive. The removal of colour from effluents is significant to reduction of toxicity in water bodies. (Verma and Mishra, 2010)

Dyeing industry effluents constitute one of the most problematic wastewaters to be treated not only for their high chemical and biological oxygen demands (BOD), suspended solids content and toxic compounds but also for colour. Moreover, the human eye can detect concentration of 0.005 mg/L of dye in water and therefore, presence of dye exceeding this limit would not be permitted on the aesthetic grounds (Pearce *et al.*, 1994) or because of toxicity to the aquatic environment.

In countries with poor economic base, the high cost of importing water treatment chemicals reduce consistently, good drinking water quality. Activated carbon (also called activated charcoal or activated coal is a form of carbon that has been processed to make it extremely porous with large surface area available for adsorption or chemical reactions) has been widely used worldwide as an effective filtration (adsorption) material for removing colour, biological and chemical contaminants from waste water and drinking water. Currently, Nigeria uses Commercial activated carbon for urban water treatment and imports the commercial carbon at high cost. The high cost of importing commercial activated carbon puts a significant burden on the water treatment budget since foreign currency is ever adding value relative to the naira.

In recent years, there has been research focusing on the use of appropriate, low-cost technology for the treatment of water and waste water in the developing world because the conventional activated carbon used in adsorption is usually expensive (Mckay 1981; 1982). Many attempts on the use of agricultural wastes/by-products as adsorbents for water treatment have been made.

Previous studies has shown that activated carbon prepared from local agro forestry waste residues such as cow bone, *Terminalia catappa* (umbella three fruit), maize cob, mango seed shells and palm kernel shell (Ogedengbe and Olawale, 1983,Ochonogor et al., 1999, Akpen et al., 2011) can achieve high removal of contaminants from wastewater. However, the use of mango seed endocarp as adsorbent has not been reported, although the potential for its use has been recognised by some researchers (Ajmal et al., 1998; Kumar and Kumaran, 2005; Elizalde-Gonzalez and Hernandez-Montoya, 2007).

The discharge of dye-bearing wastewater into natural streams and rivers from textile, paper, carpet, leather, distillery and printing industries pose severe pollution problems (Gurses et al., 2006).Various processes tried so far for the removal of colour from water are aerobic and anaerobic microbial degradation, chemical oxidation, membrane separation, dilution, electrochemical treatment, adsorption etc. However, most of these methods have high operational and maintenance cost, low removal efficiencies, lack of selectivity and other limitations. Adsorption by AC is of interest because of the large surface area they offer for pollutants removal. This research therefore investigated the optimum conditions for

the removal of colour from textile wastewater by mango seed endocarp activated carbon (MSEAC).

## 2. MATERIALS AND METHODS

The wastes shells of a local variety of mango were collected from Mangar district of Bokkos LGA of Plateau State, Nigeria where the potential raw material is in abundance. 50 kg of the mango shells were washed several times with water to remove any dirt attached to its surface, then air-dried and later pilled-off to remove the seed. The mango seeds were air dried ready for carbonization and activation.

Ten carbons were produced at different impregnation ratios through two processes; i.e five carbons by carbonization before activation (CBA) and another five carbons by activation before carbonization (ABC) to study the effect of impregnation ratio.

Carbonization before activation (CBA) was achieved by carbonizing the air- dried mango seed at 500$^{o}$C for 2 hours in a muffle furnace and allowing to cool at room temperature for three hours before chemical activation of the same material using zinc chloride salt ($ZnCl_2$) as activating agent. To study the effect of impregnation ratio, 200 g, 300 g, 400 g, 500 g and 600 g of the carbonized was were set apart. 100 g of the $ZnCl_2$ was diluted in 100 ml of distilled water each. The diluted solution of 100 g of $ZnCl_2$ each, were mixed with the carbonized materials respectively to obtain impregnation ratios of 1:2, 1:3, 1:4, 1:5 and 1:6.

Activation before carbonization (ABC) was achieved by chemically activating the prepared mango seeds with $ZnCl_2$ before carbonization. The effect of impregnation ratio was investigated just as in the case of carbonization before activation.

Textile wastewater used in the batch studies was obtained from Angel Spinning Textile Industry, Kano. Samples were collected from the wash water drain that discharges into the surrounding drainage system outside the industry's yard. Preliminary batch adsorption studies was carried out on all the ten samples using the textile waste water to determine the best impregnation ratio to be used for further studies for the removal of colour. Thus, adsorption studies using adsorbent dose, initial concentration, contact time, stirring rate, pH and temperature as variables were conducted on the better carbon produced. The adsorption efficiency of the test carbon for colour removal was used as criterion for determining optimum conditions.

To investigate the effect of adsorbent dose, 100 ml of waste water, of pH 7.6 and initial adsorbate concentration of 512 Pt-Co Units were placed in beakers and mixed using a flocculator (ESF 12/10 model) in 500 ml beakers. Specified adsorbent (MSEAC) doses of 100 mg, 200 mg, 400 mg, 600 mg, 800 mg, 1000 mg and 1200 mg were added to each beaker respectively and stirred at 90 rpm using electrically operated paddles for 10 minutes. These corresponded to 1 g/l, 2 g/l, 4 g/l, 6 g/l, 8 g/l, 10 g/l and 12 g/l respectively. After the stirring period, the beakers were removed slowly from flocculator and contents allowed to settle for 5 minutes and were filtered through no 42 filter paper. The filtrates were separately analysed for residual concentrations of colour using a spectrophotometer (DR 2000 model).

The effect of contact time on adsorption was studied at the optimum dose, (0.8 g) initial adsorbate concentration (512 Pt-Co Units). 100 ml of the wastewater was placed in 7 beakers at room temperature; pH was maintained at 7.6. 0.8 g of the activated carbon (size 150 µm -850 µm) were measured and placed in each of the beakers respectively. The samples were placed in the flocculator and were agitated at a speed of 90 rpm. The beakers were retrieved from the flocculator after 10 min, 20 min, 30 min, 40 min, 50 min, 60 min and 70 min respectively. The content in each beaker was allowed to settle for 5 minutes afterward filtered through No.42 filter paper. The filtrates were separately analysed in the spectrophotometer to determine the residual colour concentrations.

Stirring rate effect on the adsorption of colour from waste was carried out at the optimum adsorbent dose (0.8 g) and contact time 40 min. Other test conditions were the same as in the case of the effect of adsorbent dose. 100 ml of the wastewater was placed in 6 beakers at room temperature; pH was maintained at 7.6. 0.8 g of the activated carbon (size 150 µm -850 µm) was measured and placed in each of the beakers and the sample placed in the flocculator and agitated at speeds of 30 rpm, 60 rpm, 90 rpm, 120 rpm, 150 rpm, and 180 rpm respectively. The beakers were retrieved from the flocculator after 40 min each and analysed as before.

The effect of initial adsorbate concentration was investigated by adjusting initial concentration of the adsorbate via random dilution of the test sample with distilled water to achieved 215 Pt-Co, 302 Pt-Co, 399 Pt-Co, 427 Pt-Co, Pt-Co, 512 Pt-Co, and 550 Pt-Co. 100 ml each of the diluted wastewater was placed in 7 beakers at room temperature; pH was maintained at 7.6. 0.8 g of the activated carbon (size 150 µm - 850 µm) was measured and placed in each of the beakers respectively. The samples were placed in the flocculator and were agitated at a speed of 90 rpm. The beakers were retrieved from the flocculator after 40 min and analysed for residual colour concentration.

To study the effect of temperature on the removal of colour from waste water, 100 ml samples of the wastewater having optimum initial concentration were placed in nine 500 ml beakers. The optimum adsorbent dose of MSEAC was added to each beaker and agitated at optimum contact time, stirring rate, and initial adsorbate concentration. The temperature of the experiment was randomly varied from 20$^{o}$C, 25$^{o}$C, 30$^{o}$C, 35$^{o}$C, 40$^{o}$C, 45$^{o}$C, 50$^{o}$C, 55$^{o}$C and 60$^{o}$C while all other test conditions remained the same as in the case of adsorbent dose.

The effect of pH was investigated at the optimum adsorbent dose, contact time, stirring rate, initial adsorbate concentration and temperature. 100 mL of the wastewater was placed in 5 beakers; pH was varied from 2, 4, 7, 8, and 10 by adding NaOH to each beaker. 0.8 g of the activated carbon was measured and placed in each of the beakers. The

samples were then placed in the flocculator and agitated at a speed of 90 rpm for 40 min. The residual concentration of colour was again determined as in the case of adsorbent dose.

## 3. RESULTS AND DISCUSSIONS

**Effect of Impregnation Ratio:**

The effect of impregnation ratio on the removal of colour from textile wastewater is depicted in Tables 1 and 2. It was observed both CBA and ABC variations of activated carbon imparted colour to the waste water given that the colour remaining after treatment was higher than the initial colour concentration. It is also obvious from the Tables that CBA is a better adsorbent for the removal of colour from textile wastewater compared to ABC. The highest percentage removal of colour (98.24%) was achieved by CBA 1:4, therefore it was used as the test carbon for colour removal in determining the optimum conditions.

**Table 1: Results of Preliminary Adsorption Experiment on Sample ABC (300 µm Size)**

| S/NO. | Sample | Colour Remaining Pt-Co Units | Colour Removed Pt-Co Units | % Colour Removal |
|---|---|---|---|---|
| | ABC Particle size 300 µm | | | |
| 1 | ABC1:2 | 550 | -38 | -7.42 |
| 2 | ABC 1:3 | 28 | 484 | 94.53 |
| 3 | ABC 1:4 | 227 | 285 | 55.66 |
| 4 | ABC 1:5 | 338 | 174 | 33.98 |
| 5 | ABC 1:6 | 414 | 98 | 19.14 |

**Table 2: Results of Preliminary Adsorption Experiment on Sample CBA (300 µm Size)**

| S/NO. | Sample | Colour Remaining Pt-Co Units | Colour Removed Pt-Co Units | % Colour Removal |
|---|---|---|---|---|
| | CBA Particle size 300 µm | | | |
| 1 | CBA 1:2 | 291 | 221 | 43.16 |
| 2 | CBA1:3 | 24 | 488 | 95.31 |
| 3 | CBA1:4 | 9 | 503 | 98.24 |
| 4 | CBA1:5 | 10 | 502 | 98.05 |
| 5 | CBA1:6 | 213 | 299 | 58.4 |

**Effect of Adsorbent Dose**

The adsorption of colour as function of adsorbent dose at constant initial colour concentration of 512 Pt-Co for CBA 1:4 carbon was presented in Fig.1. The Figure suggested that increase in the quantity of adsorbent results in a corresponding increase in the amount of colour removed which is as a result of increase in surface area and hence more sites were available for adsorption of colour. Similar results have been reported by other investigators (Namasivayam and Yamuna, 1994; Akpen et al., 2011). Also 0.8 g of CBA 1:4 was enough to achieved 83% removal of colour from textile waste water. Thus, 0.8 g of CBA 1:4 was chosen as the optimum carbon dose for further investigation.

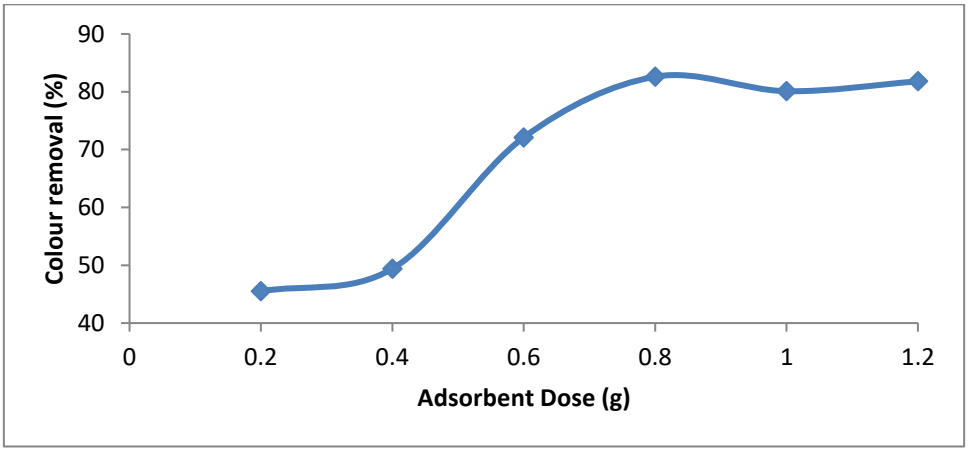


**Fig. 1: Colour Removed by CBA (1:4) as a Function of Adsorbent Dose**

### Effect of Contact Time

The effect of contact time on the removal of colour by CBA 1:4 was depicted in Fig.2. Contact time of 40 minutes was sufficient to achieve 86.3% colour removal by MSEAC. The percentage removal remained constant at 86.3% at contacts time above 40 minutes; therefore it was chosen as the optimum contact time for further investigation. In general, the removal efficiency increased with time and attained equilibrium in 40 minutes.

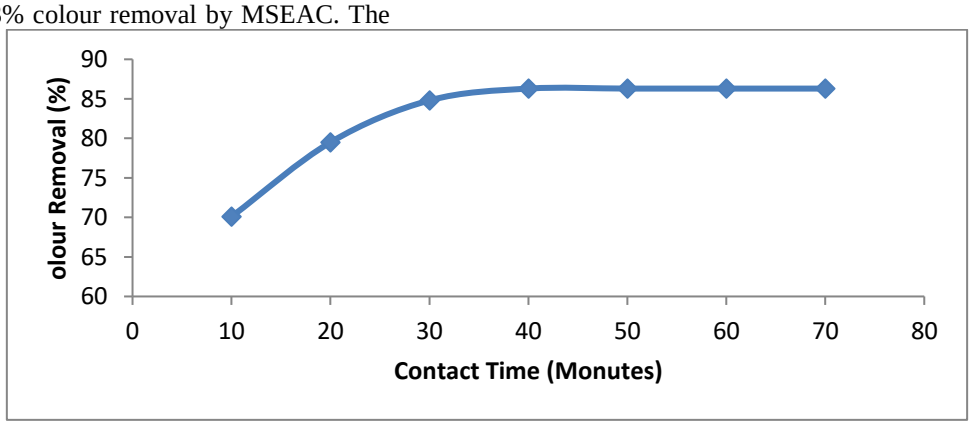


**Fig. 2: Colour Removed by CBA (1:4) as a Function of Contact Time**

### Effect of Speed (Stirring Rate)

The influence of speed on the efficiency of colour removal was shown in Fig. 3. The figure suggested that colour removal increased as speed increased to some extent. At speed of 90 rpm, 86% colour removal was attained. There was drop in percentage colour removal after applying speed above 90 rpm; hence 90 rpm was chosen as the optimum speed for further studies.

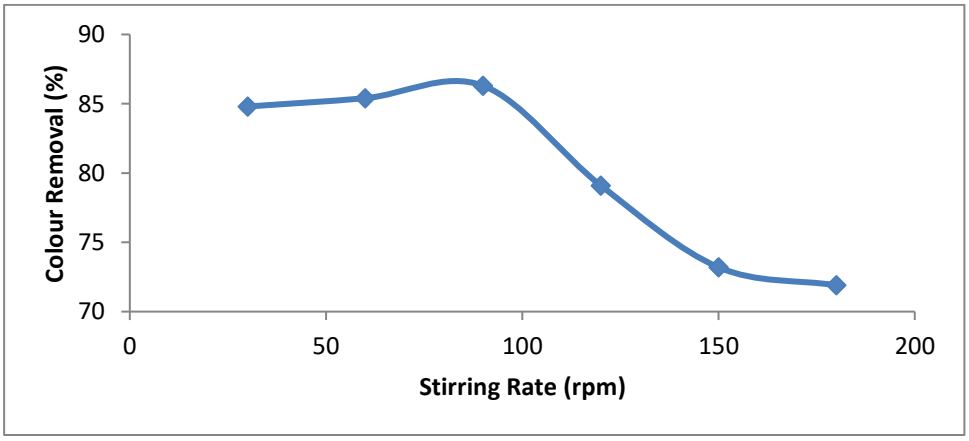


**Fig. 3: Colour Removed by CBA (1:4) as a Function of Speed**

**Effect of Initial Concentration**

Investigation on the effect of the initial adsorbate concentration was conducted by varying the colour concentration from 215 Pt-Co units to 550 Pt-Co units. Fig 4, indicated that MSEAC showed decrease in percentage removal of colour as the initial colour concentration was increased from 215 Pt-Co units to 550 Pt-Co units. This was probably due to the fact that for a fixed carbon dose the total available adsorption sites remained unchanged, thereby adsorbing almost the same amount of colour that resulted in a decreased percentage of removal corresponding to an increased initial colour concentration. Hence, for this particular textile wastewater, 399 Pt-Co was chosen as the optimum initial colour concentration for further investigation.

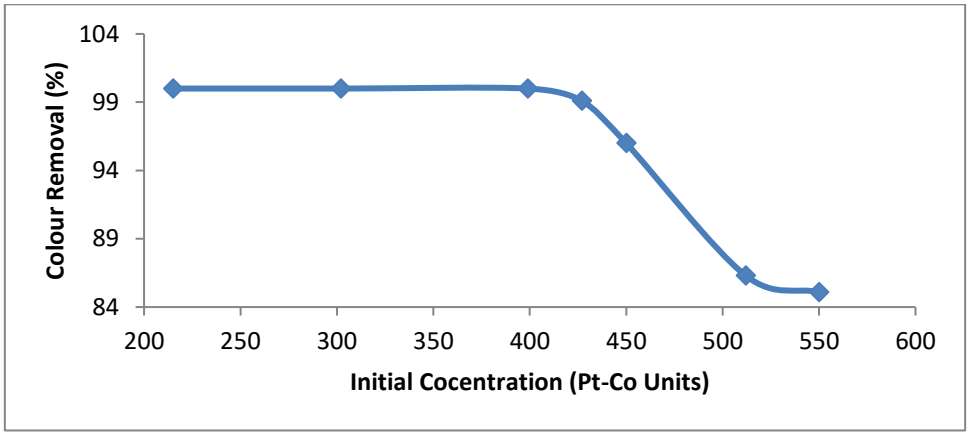


**Fig. 4: Colour Removed by CBA (1:4) as Function of Initial Concentration**

**Effect of Temperature**

The percentage removal of colour by MSEAC reduced as temperature increases (see Fig. 5). The highest percentage removal of 98% was achieved at 30°C. At temperatures higher than 30°C, the percentage removal decreased. Adsorption reactions were normally exothermic, thus, the extent of adsorption generally increased with decreasing temperature. Therefore 30°C was chosen as the optimum temperature required for further studies.

**Effect of pH**

Figure 7, showed the result of the effect of pH on the removal of colour by the MSEAC. 100% removal was achieved at pH 7 which felled within the range of recommended pH value for commercial activated carbons. It was reported by Okiemmen *et al.* (2007); that for most adsorption applications, carbons with pH 6-8 are acceptable. Therefore, pH 7 was recommended as the optimum pH value for further studies. The optimum conditions for adsorption of colour from textile wastewater for CBA 1:4 are summarized in Table 5.

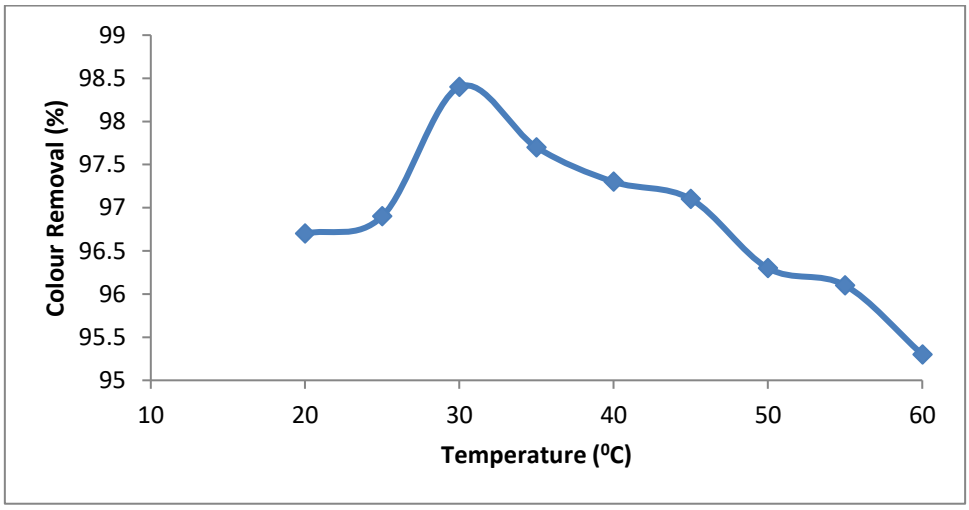


**Figure 5: Colour Removed by CBA (1:4) as Function of Temperature**

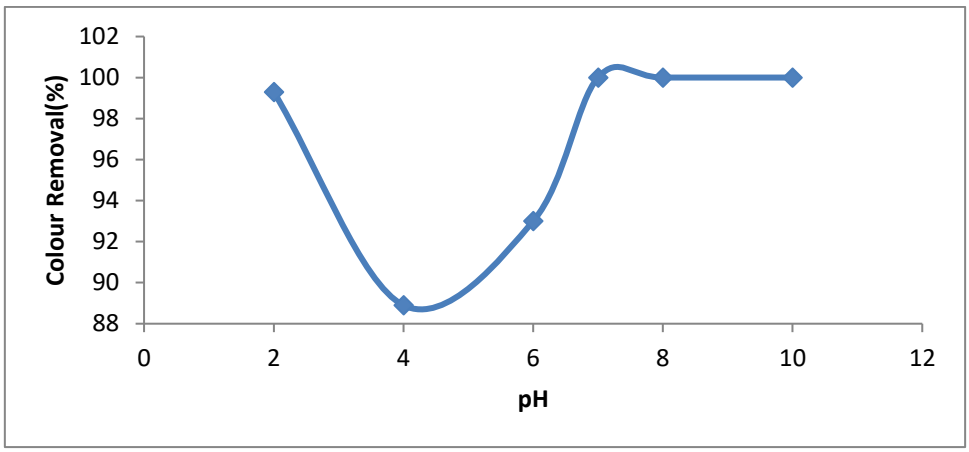


**Fig. 7: Colour Removed by CBA (1:4) as a Function of pH**

**Table 5 Optimum Conditions for Adsorption of Colour from Textile Wastewater**

| Variables | Optimum Condition |
|---|---|
| Adsorbent dose (g) | 0.8 |
| Initial Colour Concentration (Pt-Co unit) | 399 |
| Initial pH | 7 |
| Contact time (minutes) | 40 |
| Stirring rate (rpm) | 90 |
| Temperature $^{o}$C | 30 |

## 4. CONCLUSION

Activated carbons were produced using the endocarp of the seed of local variety of mango (Mangoro), referred to as MSEAC in this study by impregnating it with $ZnCl_2$. Different impregnation ratios 1:2, 1:3, 1:4, 1:5 and 1:6 were investigated to determine the effect of preparation procedure. Activation was done before and after .In all 10 samples were produced; 5 ABC, while 5 CBA. The performances of the produced activated carbons were evaluated through laboratory preliminary batch studies for the purpose of obtaining an optimum impregnation ratio. The results obtained from preliminary batch studies revealed that MSEAC produced using impregnation ratio of 1:4 (for CBA) was the best adsorbent compared to other impregnation ratios investigated as it gave the highest percentage of colour removed in the preliminary test.

The selected mango seed activated carbon; CBA 1:4 was used to study the effect of operating variables such as pH, carbon dose, contact time, stirring rate, initial concentration, temperature and particle size using single stage batch study for the purpose of determining the optimum conditions for the removal of colour from textile wastewater. The results indicated that; 83% colour removal was achieved at 0.8 g carbon dose, optimum carbon dose of 0.8 g was recommended for further studies. Contact time of 40 minutes was required to achieve 86% colour removal, therefore 40 minutes was chosen as the optimum contact time for further investigation. 86% colour removal was achieved at stirring rate of 90 rpm, and was recommended as the optimum stirring rate for further investigation.

Studies to determine optimum initial concentration reveals that 98% colour removal was achieved at initial concentration of 399 Pt-Co units for the textile wastewater, therefore 399 Pt-Co units was chosen as the optimum initial concentration. Optimum temperature of 30$^{o}$C was required to achieve 98% removal. While pH range of 7-10 was adopted as the optimum for the range of pH values investigated in this study. It was recommended that MSEAC can be used to effectively remove colour from textile wastewater at the optimum conditions determined in this research, thus, converting the waste to wealth

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