DIJBAR
www.daagu.org
Volume-3 Issue-1

# KINETIC STUDY OF ADSORPTION OF CONGO RED DYE ON WOOD CHARCOAL OF ADANSONIA DIGITATA (BAOBAB)

Mastan Rao Kotipalli*, Samwel Anderson Mazengo, Emiliani Mwaliga Kikambako and Alfreda Narzis Kinunda

## ABSTRACT

Activated charcoal prepared from Adansonia Digitata (baobab) wood has been used for the removal of congo red dye (CR) from simulated aqueous solutions employing adsorption method. The effect of adsorption was studied by using different parameters such as pH(2-8), contact time(30-120min), initial dye concentration(50-150mg/L) and adsorbent dosage(0.5-2.0g). The extent of adsorption was determined by employing UV-Vis spectrometer. The experimental data was verified by Freundlich model and found to be in agreement. Under the experimental conditions the parameters at the maximum adsorption ability have been determined for the dye and reported.

**Keywords:** adsorption, congo red dye, baobab wood charcoal.

**Citation:** Mastan Rao Kotipalli*, Samwel Anderson Mazengo, Emiliani Mwaliga Kikambako and Alfreda Narzis Kinunda (2021). KINETIC STUDY OF ADSORPTION OF CONGO RED DYE ON WOOD CHARCOAL OF ADANSONIA DIGITATA (BAOBAB). Daagu International Journal of Basic & Applied Research-DIJBAR. Volume3, Issue-1, pp (82-91)

Corresponding Author: Mastan Rao Kotipalli

Email: raonits47@gmail.com

Received: 05/05/2021

Accepted: 07/06/2021

Published: 28/06/2021

OPEN ACCESS

* Department of Chemistry, The University of Dodoma, Dodoma, Tanzania

## 1. INTRODUCTION

Most of the dyes are complex organic molecules. Since dyes are synthetic aromatic compounds they are normally stable and difficult to be degraded (yenikaya, et al., 2010). Several industries release dyes into atmosphere causing harmful effects to the living beings. According to the chemical structure, dyes can be divided into azo dyes, aryl dyes, acridine dyes etc. Azo dyes are widely used in industrial activities (Benkhaya et al., 2020). Dyes are used in production of the essential consumer products of modern life such as textile, leather, cosmetic, foods and beverages, papers and pulp which cause the environmental pollution and threat to the ecological balance (Ulas, et al., 2017). Dyes are used in academic as well as research institutions and normally released into atmosphere after the study is over (Yusuph, 2017).

Synthetic dyes are extensively used for coloring and printing in variety of industry (mohanraj, 2009). The dye based effluent is a considerable source of non-aesthetic pollution. The presence of small amount of dye (below 1 ppm) is also clearly visible. Many researchers found that colorant may cause problems in aquatic ecosystem in several ways (yenikaya, et al., 2010). Worldwide, infectious diseases such as water-borne diseases are harmful to the children under five years old and more people die from unsafe water annually than from all forms of violence (Edogbanya, et al., 2013a). The problem of water pollution has become an issue drawing global attention. Every day, several million tons of sewage, industrial and agricultural waste is discharged into the world's waste water bodies (WWAD, 2006). There are several ways for removal of dyes. Adsorption has been considered as one of the safest and simple methods for the removal of textile dye effluents due to its low cost, easy availability, simplicity of design, high efficiency, ease of operations and ability to treat wide variety of dyes (Ramalakshmi et al., 2012). Activated carbon is a carbonaceous adsorbent with a highly crystalline form and internal pore structure (Kavitha 2019). A wide variety of activated carbon products are available depending upon a starting raw material and activation techniques (Gupta, 2003). Mihayo et al., studied the adsorption effect of methyl red dye on baobab pericarp charcoal and found that adsorption is considerable.

In the present study, adansonia digitata (baobab) wood charcoal is considered for the adsorption of simulated congo red dye solutions. Congo red dye was discovered on 1884 which was used to dye cotton but has been replaced with dyes which are more resistant to light and washing. (Rodriguez, 2018). The baobab tree are mostly found in the equatorial area such as Gabon, Congo, Zaire and the area with marked dry season (Gebauer, et al., 2002) such as Dodoma region in Tanzania. It is a tree of multiple uses and it is observed that all parts of the tree are useful. Generally baobab fruits and seed oil are used for human consumption and the rest of the tree parts are used as traditional medicine (simon, 2015). Baobab belongs to genus: Adansonia and Species: Adansonia digitata. In the present study, congo red is used as a simulated adsorbate and baobab wood charcoal as adsorbent.

## 2. MATERIALS AND METHODS

### 2.1 Preparation of dye solution

Stock solution of dye concentration 1000mg/L was prepared by dissolving 1g of 100% pure congo red dye in 1000mL of distilled water by using standard flasks. Solutions of different concentrations were prepared by dilution method between 20 and 200mg/L using the above stock solution of the dye. All chemicals of 99.9% purity have been used in the present study.

### 2.2. Preparation of adansonia digitata wood biosorbent

Hard wood of adansonia digitata has been collected from a single tree in Dodoma region at Kongwa district. After removing the bark, small chips of the baobab wood are pulverized into powder using grinding machine and then sieved through a pore size of about less than one millimeter. The dried sample was treated with sulfuric acid with constant stirring. Then the sample was kept in hot air oven at 200±50K temperature for twelve hours. The sample was washed with distilled water and soaked in sodium bicarbonate solution and then allowed to stand overnight to remove the residual acid from the pores of carbon. The sample was washed again with distilled water, until the pH of the adsorbent becomes neutral (7±0.2). Then the sample was dried in a hot air over at 100±5℃ for twelve hours. The dried sample was ground to get a powder of particle size about 125-250µm range and stored in an airtight container for further experiments.

### 2.3 Batch mode biosorption studies

A standard calibration plot between the adsorbate concentration and absorbance was drawn for computing the concentrations from batch mode experiments. Batch biosorption equilibrium experiments were conducted in 250mL conical flasks at a constant agitation speed (180rpm). All the experiments were carried out at room temperature ($30^0$C). The concentrations of the dyes both before and after adsorption were determined using Agilent 60 Cary UV-Vis spectrophotometer, USA through monitoring the absorbance for the dye used. All the spectra were recorded for the absorbance of congo red dye at a wave-length of 497nm. In the present study, the effect of initial concentration of the dye, adsorbent dosage, pH of solution and contact time on adsorption has been studied. The effect of initial dye concentration was studied in the concentration range 50-150mg/L. The effect of pH on adsorption process was studied in the pH intervals of 2, 4, 6 and 8. The effect of mass of adsorbent was studied in the range of 0.5gram to 2.0gram at constant dye concentration 100mg/L and optimized conditions. The effect of contact time was studied in the constant dye concentration of 100mg/L and time range from 30 minutes to 120 minutes.

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of initial concentration of dye

The effect of initial dye concentration was studied in the concentration range 50-150mg/L. The extent of adsorption of dye per gram of activated carbon was calculated and reported in Table No:1. A plot is drawn between adsorbate concentration and adsorption ability and shown in Fig.1.
x/w = extent of adsorption (mg/g), $C_i$ = initial concentration of dye (mg/L), $C_f$ = final concentrations of dye (mg/L) , w = dry weight of the activated carbon (g), $C_i$-$C_f$ = x

**TABLE 1:** Data showing initial concentration of dye solution and adsorption ability

| Sl. No. | $C_i$ (ppm) | w (g) | Absorbance | $C_f$ (ppm) | $C_i$-$C_f$ (ppm) | x/w (mg/g) |
|---|---|---|---|---|---|---|
| 1 | 50 | 1.0 | 1.0397 | 39.9148 | 10.0851 | 10.0851 |
| 2 | 100 | 1.0 | 1.9922 | 73.6914 | 26.3085 | 26.3085 |
| 3 | 120 | 1.0 | 2.4159 | 88.71631 | 31.2836 | 31.2836 |
| 4 | 150 | 1.0 | 3.0336 | 110.6206 | 39.3794 | 39.3794 |

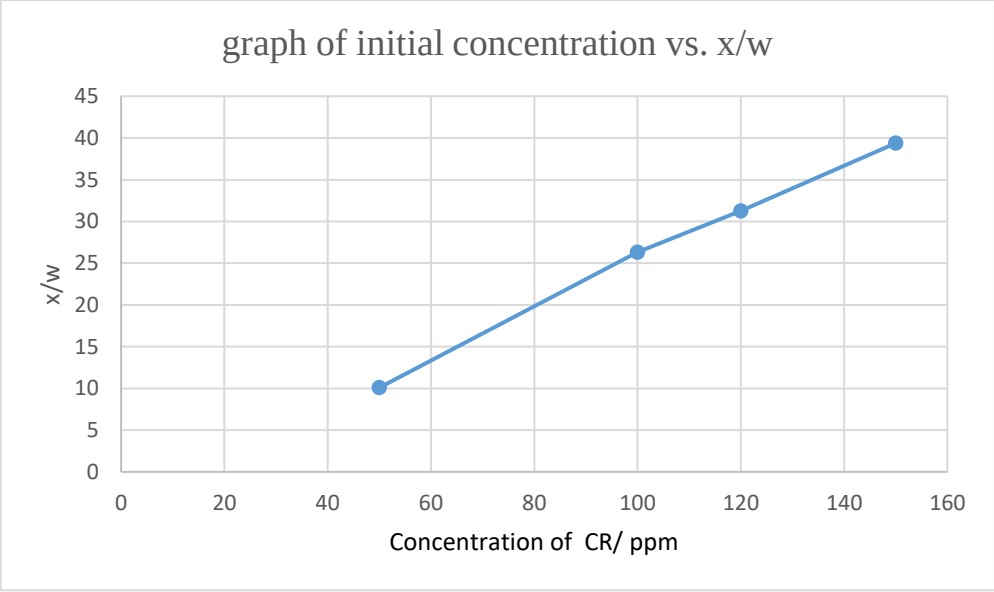



**Figure 1.** Adsorbate concentration vs. Adsorption ability

It is observed from the graph that as the initial concentration of adsorbate increases, adsorption ability increases to a certain extent and thereby the increase is decreased.

This may be due to the saturation of the active sites of the adsorbent upon adsorption of the dye molecules.

### 3.2 Adsorption isotherm

Adsorption isotherm has been studied on the extent of adsorption of CR dye on the adsorbent by using Freundlich adsorption model. According to the Freundlich isotherm model, the amount of adsorption at low concentration varies linearly, at moderate concentration becomes dependent on the Freundlich constant and at higher concentration becomes independent of the adsorbate concentration. From the Fig: 1 above, it is observed that the experimental results obey the Freundlich model satisfactorily. Further it is verified by plotting a logarithmic graph (Fig: 2) and found to be a straight line which is expected of the above results.
x/w – extent of adsorption, $C_i$ – equilibrium concentration of CR dye in aqueous medium.

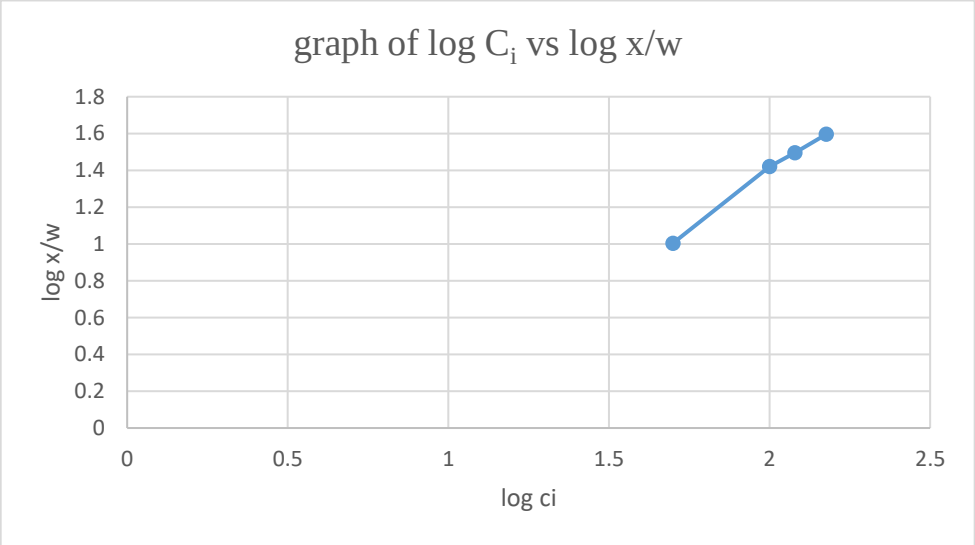



**Figure 2.** Freundlich adsorption isotherm

### 3.3 Effect of adsorbent dosage

The effect of mass of absorbent was studied in the range of 0.5g to 2.0g at constant adsorbate concentration of 100mg/L. The extent of adsorption of dye per gram of activated carbon was calculated and reported in Table No: 2. A plot drawn between adsorbent dosage and adsorption percentage is shown in the Fig.3. It was observed that the extent of adsorption increases with an increase in the mass of adsorbent (activated carbon) from 0.5 -2.0 gram which may be due to the availability of unsaturated surface area (active sites). Further the values of $C_i$-$C_f$ /w are decreasing which can be attributed to the less concentration of dye molecules available per gram of adsorbent. Under the

experimental conditions, a maximum of 44.85% of dye is removed by the adsorbent from the solution under consideration.

**Table 2.** Adsorbent dosage vs. adsorption ability data

| Sl.No. | $C_i$ (ppm) | w (g) | Abs | $C_f$ (ppm) | $C_i$-$C_f$ (ppm) | x/w | % Removal |
|---|---|---|---|---|---|---|---|
| 1 | 100 | 0.5 | 1.9926 | 73.7056 | 26.2943 | 52.5886 | 26.29% |
| 2 | 100 | 1.0 | 1.666 | 62.1241 | 37.8758 | 37.8758 | 37.88% |
| 3 | 100 | 1.2 | 1.5244 | 57.1028 | 42.8971 | 35.7476 | 42.89% |
| 4 | 100 | 1.5 | 1.4694 | 55.1524 | 44.8475 | 29.8983 | 44.85% |

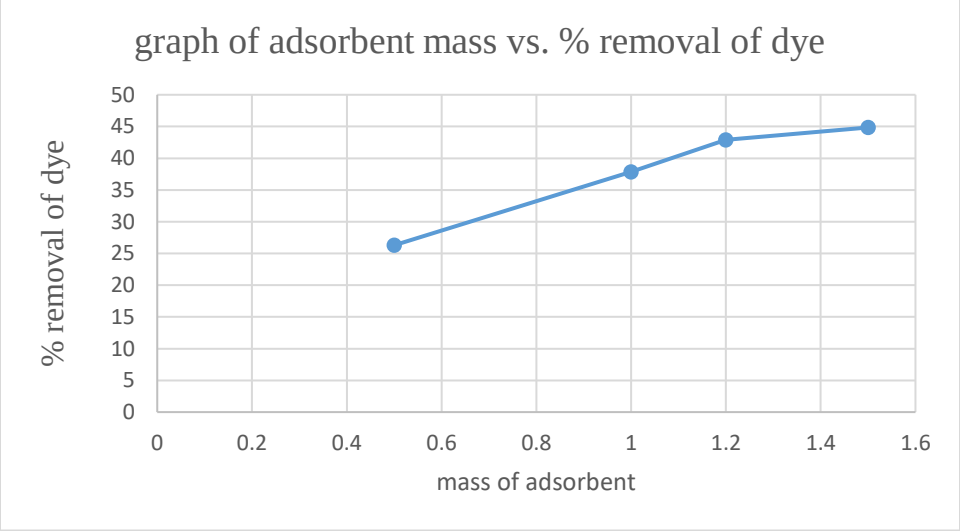



**Figure.3.** Graph between adsorbent dosage and % removal of dye

### 3.4 Effect of pH

The effect of pH was studied at a constant concentration of 100mg/L of adsorbent and pH range 2-8. The pH of different solutions under examination was adjusted using sulphuric acid by employing pH/OPR & EC/TDS/NAC pH Meter. The solutions were allowed to stand under optimized conditions and the spectra were recorded. The extent of adsorption of dye per gram of activated carbon was calculated and reported in table No.3.

x/w = extent of adsorption (mg/g), $C_i$ = initial concentrations (mg/L), $C_f$ = final concentrations of dye (mg/L) , w = dry weight of the activated carbon (g)

The percentage of removal of the dye was calculated as, $q\% = \frac{(Ci-Cf)}{Ci}$.

**TABLE 3.** Data showing the variation of absorbance with change in pH at a constant mass of adsorbent.

| Sl.No. | $C_i$/ppm | w (g) | pH | abs | $C_f$ | $C_i$-$C_f$ | x/w | % Removal |
|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 1.51 | 2.18 | 0.8258 | 32.3297 | 67.6702 | 44.8147 | 67.67% |
| 2 | 100 | 1.51 | 4.41 | 1.4909 | 55.9148 | 44.0851 | 29.1954 | 44.09% |
| 3 | 100 | 1.50 | 6.22 | 1.9989 | 73.9290 | 26.0709 | 17.3806 | 17.38% |
| 4 | 100 | 1.51 | 8.45 | 2.3612 | 86.7766 | 13.2234 | 8.75722 | 8.76% |

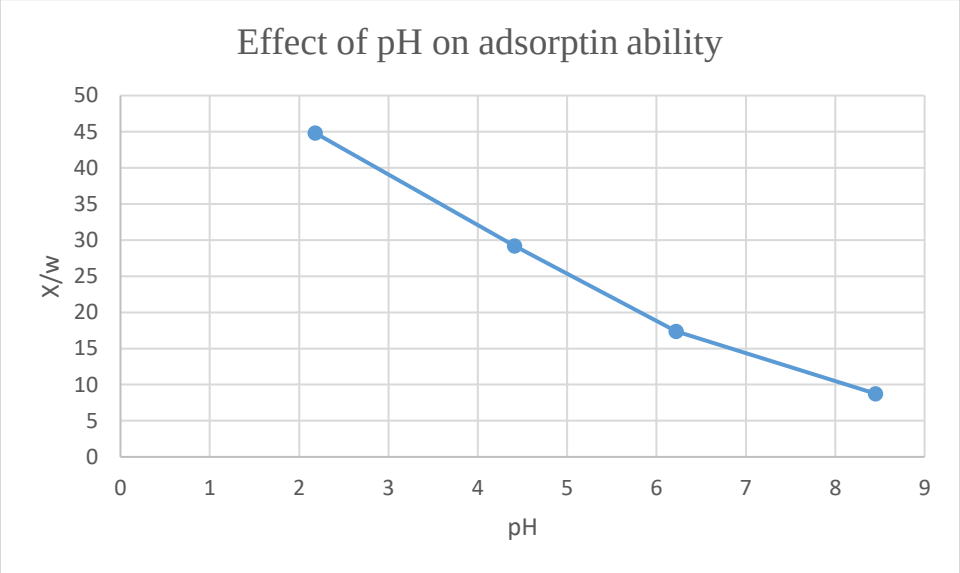



**Figure.4**. Effect of pH on the adsorption ability

The adsorbate shows a maximum adsorption at pH 2.18 with maximum percentage of adsorption of 67.67%, because it works efficiently on the acidic medium than in a basic medium. Congo red is an anionic azo dye; hence at lower pH it shows higher adsorption due to the positively charged surface of the adsorbent.

### 3.5 Effect of contact time

The effect of contact time was studied at a constant concentration of 100mg/L and time range from 30 minutes to 120 minutes. The extent of adsorption of dye per gram of activated carbon was calculated and reported in Table no: 4 below.
The percentage of color removal in the dye solution after adsorption was calculated as $q\% = \frac{(Ci-Cf)}{Ci}$.

**TABLE 4.** Contact time vs. adsorption ability data

| Sl. No. | $C_i$/ppm | w/g | | Time(min) | abs | $C_f$ | $C_i$-$C_f$ | x/w | % Removal |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 1.1 | | 30 | 1.584 | 59.2305 | 40.7695 | 37.0631 | 40.77% |
| 2 | 100 | 1.0 | | 60 | 1.115 | 42.6170 | 57.3829 | 57.3829 | 57.38% |
| 3 | 100 | 1.1 | | 90 | 0.401 | 17.2659 | 82.7340 | 75.2127 | 82.73% |
| 4 | 100 | 1.0 | | 120 | 0.218 | 10.7978 | 89.2021 | 89.2021 | 89.20% |

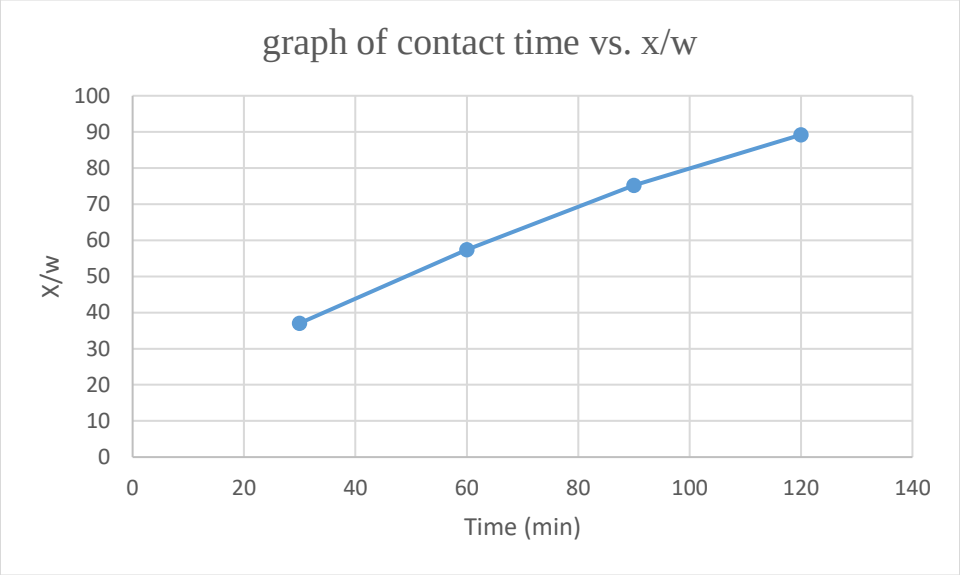



**Figure.5.** Effect of contact time on the adsorption ability

The removal of congo red dye by activated carbon as a function of time was observed. Initially, the adsorption of dye is considerable and increasing during the time interval of 50 to 150 minutes. It is predicted that the adsorption of congo red dye will be adsorbed more on baobab charcoal under extended experimental conditions. The adsorption efficiency was found to be 89.2% which is found to be maximum under the experimental conditions.

## 4. CONCLUSION

The data obtained from the adsorption studies showed that the maximum removal efficiency was found to be 67.67% at a temperature of 303K, at solution pH of 2.18, initial dye concentration of 100mg/L and biosorbent dosage of 1.5g. A contact time of 120min was sufficient for the maximum removal of congo red dye from aqueous solution using baobab wood charcoal under the above optimized conditions.. The experimental data of biosorption of the dye on the baobab wood charcoal biosorbent

fits well with the Freundlich adsorption model. This indicates that the biosorption of the dye on the baobab charcoal is favorable. It is observed that the adsorption of congo red dye can be further increased upon allowing it for longer period under different experimental conditions. Further investigation of the adsorption characteristics like surface area of the adsorbent and surface characteristics etc., are suggested to understand the adsorption mechanism.

## REFERENCES

1. **Anna chladova and kathleen prinz (2019),** Genetic diversity and structure of baobab (adansonia digitata L.) in southeastern kenya, Royal Society Open Science, 6 (9) 190854.
2. **Benkhaya, S., & Elharfi A. (2020),** A review on classification, recent sythesis and applications of textile dyes. Inorganic Chemistry Communication 115(2020) 107891.
3. **David Mihayo L and Mastan Rao K(2020),** Kinetic study of adsorption of methyl red dye on Adansonia Digitata(baobab) pericarp charcoal, DAAGU International Journal of Basic and Applied Research, Volume-2, Issue-2, pp 42-50.
4. **Edogbanya P.R.O, Ocholi O.J and Y Apeji (2013a),** A review on the use of plant seed as biocoagulants in purification of water, Continental J.of Biological Sciences 6(2) pp26-32 http://www.wiloludjournal.com.
5. **Gebauer J, El-sidding K and Elbert (2002),** G Baobab (adansonia digitata): a review on multipurpose tree, Gartenbauwissenschaft, 7(4) 155-160.
6. **Gupta, V. K., I. Ali, and Dinesh Mohan (2003)**, Equilibrium uptake and sorption dynamics for the removal of a basic dye (basic red) using low-cost adsorbents, Journal of colloid and interface science, 265 (2) 257-264.
7. **Kavitha, D** and **C. Namasivayam (2007**), "Experimental and kinetic studies on methylene blue adsorption by coir pith carbon. "bio resource Technology, 98 (1) (2007) 14-21.
8. **Mohanraj Rangaswamy (2009),** Adsorption of crystal violet dye from aqueous solution using Eicinus Communis pericarp carbon as an adsorbent, E-Journal of Chemistry, 6(4) 1109-1116.
9. **Omprakash Sahu and Nagender Singh(1918),** Significance of biosorption process on textile industry waste water Book, Impact and Prospects of Green Chemistry for Textile technology(pp 367-416).
10. **Ramalakshmi S and Muthucheliam K (2012),** Comparatives studies on removal of fast green dyes from aqeous solution by activated carbon prepared from Gloriosa superba waste and alternaria raphani fungal biomass, Journal of Environmental Science and Technology (5) 222-231, https://scialert.net/abstract/?doi=jest.2012.222.231.
11. **Rodriguez, E. (2018**), *Congo red* . Retrieved Jan 12, 2021, from Britannica: http://www.britannica.com
12. **Singh Nagender(2019),** Imparct and prospect of green chemistry for textile technology Book Review.
13. **Sircar S and Rao B.M (1996),** Activated carbon for gas separation and storage, Carbon, 34(1) pp1-12.
14. **Simon J (2015),** Bobab: the tree of life- An Enthnopharmacological review, The Journal of the American Botanical council, (108) pp42-53.
15. **Ulas Calisir and Kiline Namlik(2017),** Biosorption for dyes removal from industrial waste water Int.J.Adv.Res.5(8),707-714, http://dx.doi.org/10.21474/IJAR01/5110.

16. **Yenikaya Cengiz. and Atar Emrah(2010)**, Biosorption study of anionic dye from aqoues solution using bacillus amyloliquefaciens, Wiley online library, (10) pp233-241 https://doi.org/10.1002/elsc.200900108
17. **Yusuf, A. A., & Karacali, A. (2017),** Biosorption methods and biosorbent for dye removal from industrial waste water.

## ACKNOWLEDGEMENT

The authors are thankful to the authorities of University of Dodoma, Dodoma, Tanzania for providing laboratory facilities.