CAULIFLOWER LEAVES AS A LOW-COST BIOMASS ADSORBENT FOR THE REMOVAL OF BASIC FUCHSIN FROM AQUEOUS SOLUTIONS: EQUILIBRIUM AND PARAMETRIC STUDIES

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A Research Study

Presented to the Faculty
Of the Chemical Engineering Department
School of Engineering and Architecture
Saint Louis University

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In Partial Fulfillment
Of the Requirements for the Degree
Bachelor of Science in Chemical Engineering

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by:

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ABSTRACT

In this study, Cauliflower Leaves was utilized as an adsorbent to remove Basic Fuchsin from aqueous solutions. The experiments were conducted to investigate the effects of several parameters on the adsorption of Basic Fuchsin in dried Cauliflower Leaves. Utilizing batch-wise adsorption, the conditions were studied concerning the amount of adsorbent, initial dye concentration, and contact time. An adsorbent dosage of 1 gram and a contact time of 30 minutes were found to be the optimum conditions. Equilibrium adsorption isotherms were also studied using Langmuir and Freundlich isotherm models. The isotherm data obtained could be best described by the Freundlich isotherm with a correlation coefficient of 0.9912. The adsorption mechanism was also studied by determining which order best fits the adsorption. The data obtained showed that the adsorption obeys pseudo-second-order kinetic model. The maximum biosorption capacity (q_{max}) was found to be 0.3276 mg/ gram adsorbent.

Keywords: Cauliflower leaves, Basic Fuchsin, dye removal, dye, Isotherms, Kinetic model

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CHAPTER I

INTRODUCTION

Background of the Study

Water pollution is considered to be one of the most undesirable problems in the world (Aljeboree et al., 2014). In 2012, more than 8.4 million people died due to water, air, and land pollution (GAHP, 2014). At present, water stress affects four billion people worldwide making it is considered as a major challenge to be solved (Mekonnen et al., 2016). Brought about by the increase of water demand due to population growth, income increase, and industrialization (UNDP, 2016), the prevention of contamination of water resources because of various pollutants is of vital need.

One of the main contributors to water contamination is the textile industry. Large volumes of water, approximately 200 liters per kg of textile produced, are being used in the textile industry. This results to a generation of considerable amount of wastewater (Paraschiv, 2015). The release of wastewater from industrial plants that contain dyes and pigments is unavoidable (Zhang, 2010). These dyes have adverse effects to the biological community. Most of these compounds can form toxic products having acute or chronic effect on the ecosystem (Reis da Silva et al, 2010). Aside from their toxicity, the intense color of the dyes contribute to the turbidity of any water system causing the hindrance of the adsorption of sunlight thus reducing the photosynthetic activity in the aquatic biota (Tabassum et al., 2015).

Dyes are widely used in textile, paper, plastics, rubber, cosmetics, leather, food, and pharmaceutical industries. Usually, these dyes are of synthetic origin which have complex aromatic structures making them difficult to biodegrade (Hameed, 2009). Annually, 700 000 tons of synthetic dyes are produced worldwide and 10 000 kinds of dyes are used in these industries (Zollinger, 1999; Chequer et al., 2013).

Dyes are colored substances which have affinity to substrates where they are applied (Pereira and Alves, 2012). Dyes are soluble and may undergo application process which can destroy the crystal structure of the substrate. This process can be by the process of adsorption, mechanical retention, or by chemical bonds which may either be ionic bond or covalent bond (Nwokonkwo, 2013). Dyes differ from paints such that dyes are adsorbed into the pores of the materials while paints build up in the surface of the material. Dyes also absorb light in visible spectrum ranging from 400nm to 700nm.

Dyes can be classified into two major types based on their source. One is natural dyes which are made from organic materials such as plant, animal, and mineral matter. The other one is synthetic dyes which may be made from petroleum compounds (Singh and Bharati, 2014). Moreover, dyes can also be divided into two based on their pH: basic dyes which stain acidic substrate; and acidic dyes which stain basic substrate (Kuhlman, 2008). The water-soluble dyes are categorized under the basic dye group. Basic dyes are found to be the brightest kind of soluble dyes.

Dyes which are synthetic and basic in nature are one of the problems of the textile industry because they are not only difficult to biodegrade but are also in need of glacial acetic acid to become water-soluble. Glacial acetic acid can be corrosive to the health. An example of these synthetic and basic dyes is Basic Fuchsin. This is a triaminophenyl dye which is a mixture of rosaniline and pararosalinine (El-Sheek and Abou-El-Souod, 2016). The UV-visible adsorption spectrum shows an intense peak at λmax = 546 nm (Gajbe, 2007). The structure of Basic Fuchsin is shown below:

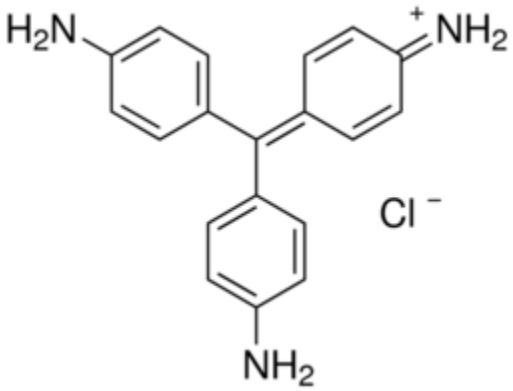

Figure 1.1 Structure of Basic Fuchsin

Basic Fuchsin, also called basic red 9, is widely available. Because of its availability, textile industries often use this kind of dye (Nandi B. and Patel S., 2013).

Moreover, Basic Fuchsin is toxic, carcinogenic, and mutagenic. These characteristics can cause potential dangers to human health and aquatic life. It was reported that 3 out of 45 workers in a manufacturing industry involving this dye acquired bladder tumor. Basic Fuchsin is difficult to remove by using

conventional method since it is resistant to aerobic digestion and is stable to light and oxidizing agents (Duro et. al., 2015).

Aside from the conventional methods, there are physical and chemical processes for the treatment of effluent of textile industry but these processes are costly and inefficient. To address this problem, researches on using biological methods are present and were proven effective. However, a problem with this method is that the biological matters need to be cultured which entails a considerable amount of time to finish the process (El-Sheek and Abou-El-Souod, 2016). Alternative adsorbent for dyes which is both cost effective and easily prepared can be a breakthrough of this problem.

Solid waste management includes the anticipation of making useless wastes into useful ones. The Philippines has been facing environmental problems like lack of solid waste management, improper waste disposal, and notably unceasing increase in waste materials generation. These are more likely occurring in urban places around the country. Focusing on Cordillera which is the foremost vegetable producer of the country, and more particularly on Baguio City, vegetable wastes are observed to be abundant especially on public markets and trading posts. One of these abundant vegetable wastes are Focusing on Cordillera which is the foremost vegetable producer of the country, and more particularly on Baguio City, vegetable wastes are observed to be abundant especially on public markets and trading posts. For this study, Cauliflower Leaves make it appealing to be developed into a novel product for their uselessness and abundance as waste material.

Cauliflower leaves are agricultural wastes which has no other known uses aside from them being used as organic fertilizer. Cauliflower leaves have been proven to have a significant number of pores and have a coarse and asymmetrical surface (Ahmad et. al., 2016). These characteristics are the prerequisite for an effective adsorbent. In addition, on the surface of the the cauliflower leaves, alcohols, carboxylic acid, ester and ethers are present (Ahmad et. al., 2016).

Theoretical and Conceptual Framework

Adsorption is defined as the deposition of chemical species at the interface between the liquid solution and solid phase. The chemical species that gets adhered at the interface is known as the adsorbate and the material whose surface where the deposition occurs is known as the adsorbent.

In physicochemical wastewater treatment, adsorption is the most used method. In this process, the wastewater is mixed with the porous material (powder or granules such as activated carbon and clay) or the wastewater is allowed to flow through a filter bed of granular materials. Pollutants dissolved in the wastewater are adsorbed and adhered onto the surface of the porous material or filter through the said method. (Zongping Wang, Miaomiao Xue, Kai Huang and Zizheng Liu, 2011).

In general, physical adsorption involves only relatively weak intermolecular forces such as Van der Waals force and electrostatic attraction. The Van der Waals forces' contribution is always present while the electrostatic attractions'

contribution is significant only when adsorbents such as zeolites, which have ionic structures, are used. On the other hand, case of chemisorption involves the formation of a chemical bond which holds the adsorbate molecules or atoms to the surface of the adsorbent.

Adsorption isotherms are significant for the analysis of data where the relationship between the capacity of adsorbent and the amount of adsorbate is described with its pressure (if gas) or concentration (if liquids) at a constant temperature. Several isotherm models are used to help understand the mechanism of adsorption. Langmuir and Freundlich models are the most widely used isotherm models to describe adsorption (Yagub, et al., 2014).

The Langmuir isotherm model applies in adsorption occurring as monolayer coverage where atoms or molecules are singly and closely packed in an energetically equivalent homogeneous site of adsorbent surface.

The Langmuir adsorption isotherm is given by the linearized equation

$$\frac{1}{q_e} = \frac{1}{C_e K_a q_m} + \frac{1}{q_m}$$

where q_e, which represents the extent of adsorption at equilibrium,is the mass of adsorbate adsorbed per unit mass of the adsorbent (mg g^{-1}), C_e is the dye concentration (mg g^{-1}), K_a is the Langmuir adsorption constant related to the energy of adsorption (L mg^{-1}), and q_m is the maximum adsorption capacity (mg g^{-1}). However, this model is valid only for systems at low pressures and high temperatures.

The Freundlich isotherm model is an empirical equation used to represent relationship describing the amount of adsorbed solute from the liquid per unit

mass of adsorbent with pressure assuming that different sites with several adsorption energies are involved. Freundlich adsorption isotherm can be given as:

$$q_e = K_f C_e^{\frac{1}{n}}$$

Transforming to logarithmic form of the equation above becomes,

$$\log q_e = \log K_f + \frac{1}{n} \log C_e$$

where n and K_f are the Freundlich constants which are the adsorption intensity and capacity of adsorption, respectively. This model becomes independent with pressure as increase in pressure continues.

In order to effectively use the raw material as a potential adsorbent, the fundamental factors to be considered are contact time and concentration. These factors contribute to the controlling mechanism of adsorption processes such as mass transfer and chemical reaction. Pseudo-first order (PFO) (Lagergren) and pseudo-second order (PSO) (Ho and McKay) equations are fitted to model the kinetics of Basic Fuchsin onto dried cauliflower leaves.

According to Lagergren, the PFO equation can be expressed as:

$$\log(q_e - q_t) = \log(q_e) - \frac{k_1}{2.303t}$$

where q_t is the the amount adsorbed at any time t (mg g^{-1}), and k_1 is the rate constant of PFO adsorption process (min^{-1}).

According to Ho and McKay, the PSO equation is given as:

$$\frac{1}{q_t} = \frac{1}{k_2 q_e^{\,2}} + \frac{1}{q_e} t$$

where k_2 is the rate constant of PSO adsorption process (g-mg^{-1} min).

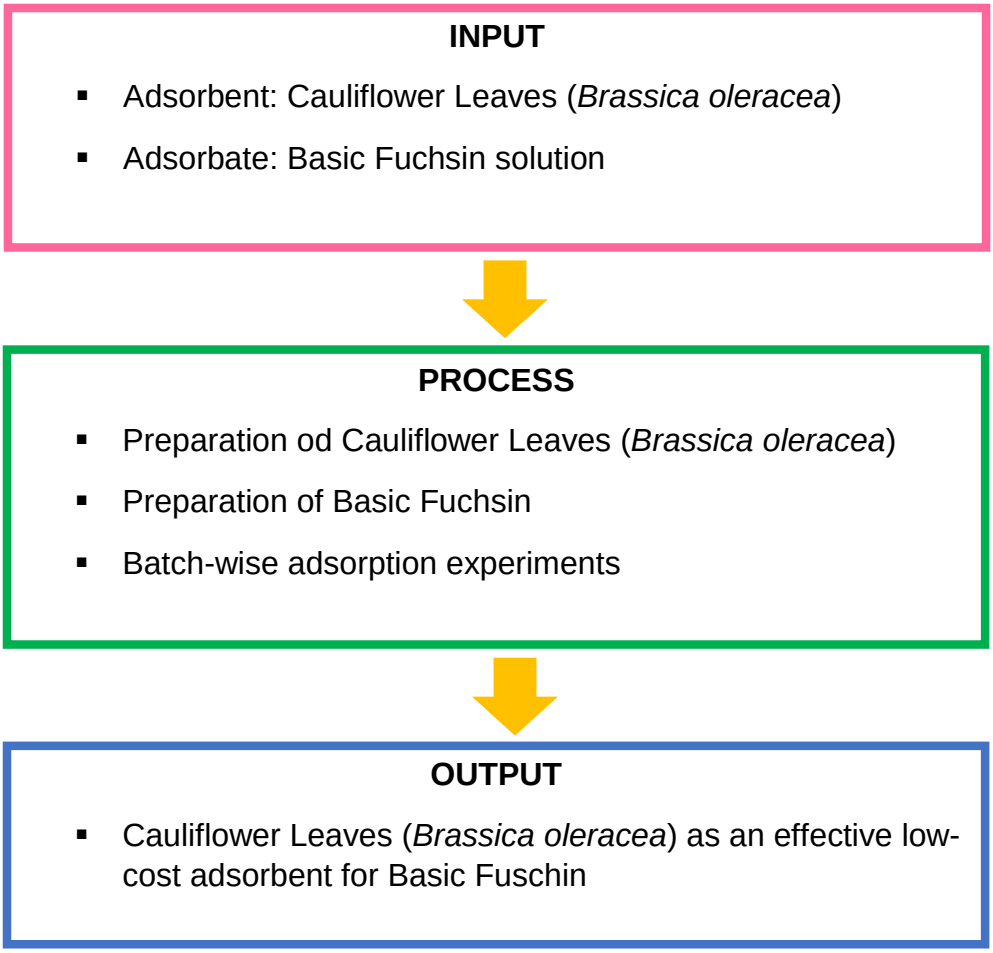

Figure 1.2 Research Paradigm of the proposed (*Cauliflower Leaves as a Low-Cost Biomass Adsorbent for the Removal of Basic Fuchsin from Aqueous Solutions: Equilibrium and Parametric*)

Scope and Delimitation

The study focused on the potential of cauliflower leaves as a low-cost biomass adsorbent for the removal of Basic Fuchsin from aqueous solutions focusing on the study of equilibrium isotherms and adsorption kinetic parameters. The adsorbate used in this study was Basic Fuchsin dye while the adsorbent was dried cauliflower leaves. The study was given a duration of six (6) months. Studies on the effect of varying pH for the percent removal were not performed due to the sustainability of the dye which can result to the inaccuracies of the pH meter readings.

Constraints of the Study

The raw material used is considered as a waste therefore no ordinance has been violated. The study does not include the discussion of the extent of toxicity of the dye and the raw material.

In all experiments, DO 136-14 (Guidelines for the Implementation of Globally Harmonized System (GHS) in Chemical Safety Program in a Workplace) was observed. Thus, under Section IV-3, there were necessary control measures including personal protective equipment provided (DOLE).

Moreover, in the discharge of the tested solutions, DAO 35 (Revised Effluent Regulations of 1990 Section IV) was strictly followed. According to DAO 35, industrial and other effluent when discharged into the bodies of water shall not contain toxic substances. In addition, discharge shall not cause abnormal discoloration in the receiving water outside the mixing zone (DENR-EMB).

Statement of the Problem

The study is intended to determine the effectiveness of dried Cauliflower Leaves as adsorbent of Basic Fuchsin from aqueous solutions. Moreover, the study seeks to answer the following questions:

1. What is the adsorbent dosage that will yield optimum percentage removal of the dye?
2. What is the effect on the percentage removal of the dye if its initial concentration in the aqueous solution is varied but the dosage of the adsorbent is held constant?
3. What is the effect on the percentage removal of the dye if the contact time between the dye aqueous solution and the adsorbent is varied but the dosage of the adsorbent is remained constant?
4. Which Isotherm best fits the adsorption of Basic Fuchsin into the dried Cauliflower Leaves?
5. What type of kinetics does the adsorption of Basic Fuchsin into the dried Cauliflower Leaves follow?

CHAPTER II

RESEARCH DESIGN AND METHODOLOGY

Research Design

An experimental method was employed as a research design in this study because of the need for quantitative analysis. The potential of the adsorbent in dye removal was studied using qualitative analysis. Quantitative study was employed with the aim of examining the relationships of various parameters. This approach included the investigation of the effects of operating parameters such as the amount of dried cauliflower leaves adsorbent, the initial concentration of the dye solution, and the contact time. Spectrophotometric method was employed to determine the percentage removal of basic fuchsin as a result of the variations of the independent variables. The adsorption kinetics and adsorption equilibrium were also studied in this research.

The operating parameters were studied in order to establish and determine the most effective parameter (adsorbent dosage and initial dye concentration), the rate of adsorption, and the controlling parameters involved in removal of dye. The parameters were studied to check the potential of dried cauliflower leaves as a low-cost adsorbent for the removal of basic fuchsin in aqueous solutions.

Data Gathering Tools

Apart from the data that were obtained from the experiment itself, additional information was also gathered from published works and researches related to this study. Information such as adsorption, adsorption procedures, adsorption equilibrium and kinetics, Basic Fuchsin, and dyes in wastewater was collected. Internet sources were also utilized, assuring that data obtained from them were highly dependable.

Data Gathering Procedures

A. Preparation of Dried Cauliflower Leaves Adsorbent

Cauliflower leaves (*Brassica Oleracea)* were collected from vendors of Baguio City market. The fresh cauliflower leaves were prepared based from the method reported by Ansari et al. The cauliflower leaves were washed with tap water to remove dirt and adhering impurities. After washing, the leaves were sun dried to remove excess water. The washed leaves were dried at 80^0 C.

The dried cauliflower leaves were reduced in size using mortar and pestle. The leaves were screened using U.S.A. Standard Sieve Series with a uniform particle size. The screened leaves were washed with distilled water to remove impurities and were dried in an oven at 105^0 C. The dried cauliflower leaves were kept in a desiccator for further use. There were no more physical and chemical treatments involved prior to the execution of batch adsorption experiments.

B. Preparation of Adsorbate Solutions

A 1000 ppm Basic Fuchsin stock solution was prepared by dissolving 1000 mg of Basic Fuchsin with enough distilled water into an Erlenmeyer flask. The resulting solution was transferred into a 1-L volumetric flask and was diluted with distilled water to a volume of one (1) liter.

Solutions to be used with different concentrations were prepared by diluting definite amount of dye stock solution with appropriate amount of distilled water. The absorbance of each prepared dye solution was read in a spectrophotometer at a wavelength equal to 546 nanometers.

Varying concentrations of dye solutions (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15 ppm) were prepared. The absorbance versus dye concentration was plotted to produce a calibration curve.

C. Batch-wise Adsorption studies for Basic Fuchsin

Unless it is the parameter to be tested, the pH of the Basic Fuchsin dye solution was constant and was not altered. Also, 7 ppm was the concentration utilized in most tests. This was determined optimum during the pre-experiments. At 7 ppm, the percentage removal of the dye is at its peak and this can be seen in Figure B.6. Also, the agitation was done manually. Agitation has low to no effect on the percentage removal of dye from the solution (Weng 2009).

1. Potential of Adsorbent

A 7 ppm dye solution was prepared by diluting the stock dye solution with appropriate amount of distilled water. The prepared

solution was mixed with dried cauliflower leaves adsorbent (0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00 and 4.25 grams) and was shaken for 10 seconds every 3 minutes until 30 minutes were elapsed. The color of the solution was observed afterwards.

Environmental conditions and other variables can affect the effectiveness of the adsorption process. Such variables are contact time, initial dye concentration, and adsorbent dosage.

The percent dye removal, considered as the amount of adsorption, was highly dependent on the initial dye concentration. It also depends on the relation between the available sites on the adsorbent surface and the initial concentration of the dye solution (Yagub et al., 2014).

The initial concentration of the adsorbate is an important factor to be considered because the rate of adsorption is a function of the initial concentration of the adsorbate (Chowdhury, 2011).

The effect of adsorbent dosage and initial adsorbate concentration will therefore be investigated in the study.

2. Effect of the Amount of Adsorbent

Basic Fuchsin dye solution of 7 ppm was prepared and transferred into 250 ml Erlenmeyer flasks. Different amount of dried cauliflower leaves adsorbent stated above were added to each flask. The flasks were shaken for 10 seconds every 3 minutes until 30 minutes is reached. Afterwards, the absorbance of the resulting

mixture was transferred in a cuvette. The absorbance was measured using a spectrophotometer at λ=546 nm.

3. Effect of the Initial Concentration of Dye Solution

Basic Fuchsin dye with different concentrations (1, 3, 5, 7 , 9, 11, 13 and 15 ppm) were prepared by diluting proper amount of stock dye solution using distilled water and were transferred in a 250 ml Erlenmeyer flask. A 1 gram of dried cauliflower leaves adsorbent was added to each flask. The flasks were shaken for 10 seconds every 3 minutes until 30 minutes was achieved, the treated solution was transferred in a cuvette and their absorbance was measured in a spectrophotometer at λ=546 nm.

4. Effect of the Contact time

Fifty milliliters of the basic Fuchsin dye solution was prepared with a fixed concentration of 7 ppm and was transferred to a 250 mL Erlenmeyer flask. A 1 gram of dried cauliflower leaves adsorbent was added to each flask. The mixtures were shaken for 10 seconds every 3 minutes until 60 minutes was attained. The absorbance at λ=546 nm of the treated solution in each flask was measured in different contact time (10, 20, 30, 40, 50 and 60 minutes)

5. Determination of Adsorption Isotherm Constants

Basic Fuchsin dye solution with varying concentrations were prepared and transferred in 250 mL Erlenmeyer flasks. A 1 gram of

dried cauliflower leaves adsorbent was added to the flasks. The mixture was allowed to reach equilibrium and the absorbance of the resulting solutions were measured at λ=546 nm.

6. Determination of Adsorption Kinetics Constants

A 7 ppm of Basic Fuchsin dye solution was mixed with 1 gram of dried cauliflower adsorbent. The solutions were shaken periodically. The absorbance at λ=546 nm of the treated solutions were measured at different residence time (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 1080, 1440 and 2880 minutes).

Treatment of Data

After the experimentation and the data collection, the data was subjected to computational and statistical analysis.

The absorbance of Basic Fuchsin solution treated with dried Cauliflower leaves as adsorbent was measured by spectrophotometer in order to determine the final concentrations. The final concentration of the treated Basic Fuchsin solutions was computed by using the equations formulated by the calibration curve.

In order to determine the effectiveness of the cauliflower leaves adsorbent in the removal of Basic Fuchsin in aqueous solution, the percentage dye removal was calculated by utilizing the computed final concentrations. The equation

below was used to calculate the percentage removal of dye from aqueous solutions.

$$\%\text{Dye Removal} = \frac{\text{Initial concentration-Final concentration}}{\text{Initial concentration}} \times 100$$

One of the most significant characteristics of an adsorbent was the amount of adsorbate it can acquire, which was usually calculated from the adsorption isotherms. The adsorption isotherms were constant-temperature equilibrium relationship between the quantity of adsorbate per unit of adsorbent (q_e) and its equilibrium concentration (C_e).

The Langmuir and Freundlich isotherms were applied in this study. The linearized forms and the variables that were plotted from the two isotherms are shown in the table below:

Table 2.1 Linear Forms and Variables to be Plotted of the Isotherms to be used

Isotherm	Linearized Form	Variables to be Plotted
Langmuir	$\frac{1}{q_e} = \frac{1}{C_e K_a q_m} + \frac{1}{q_m}$	$\frac{1}{q_e}\ vs\ \frac{1}{C_e}$
Freundlich	$log\ q_e = logK_f + \frac{1}{n} logC_e$	$logq_e\ vs\ logC_e$

C_e represents the equilibrium concentration of the dye solution and wascalculated using the equation formulated by the calibration curve. Additionally, q_e represents the adsorption capacity which was obtained by utilizing the following formula:

$$q_e, \frac{\text{mg}}{\text{g}} = \frac{(\text{Initial concentration-Equilibrium concentration}) \text{x Vs}}{\text{Mass of adsorbent}}$$

For the Langmuir model, the slope and intercept of the plot between $1/q_e$ and $1/C_e$ will give q_m (mg/g) and K_a (L/mg) respectively.

On the other hand, the Freundlich isotherm constants Kf (mg/g) and 1/n were determined from the plot of log q_e versus log C_e.

The pseudo-first order kinetic model and pseudo-second order kinetic model were established by utilizing and plotting the different variables based on their linearized forms. The linearized forms and the variables that were plotted from each model used are as follows:

Table 2.2 Linear Forms and Variables to be Plotted of the Kinetic Models to be used

Kinetic Model	Linearized Form	Variables to be plotted
Pseudo-First Order (Lagergren)	$\log(q_e - q_t) = logq_e - \frac{k_t}{2.303}t$	$\log(q_e - q_t)\ vs\ t$
Pseudo-Second Order (Ho and Mckay)	$\frac{t}{q_t} = \frac{1}{k_2 {q_e}^2} + \frac{1}{q_e}t$	$\frac{t}{q_t}\ vs\ t$

Where:

k = kinetic constant of the pseudo-first order adsorption, min^{-1}

q_e = amount of adsorbed dye at equilibrium, mg/g

q_t = amount of adsorbed dye at a given time, t, mg/g

t = time, min

CHAPTER III

PRESENTATION, ANALYSIS AND INTERPRETATION OF RESULTS

Effect of Varying the Amount of Dried Cauliflower Leaves

For an adsorption process, adsorbent dosage is an important process parameter to determine the capacity of an absorbent for a given amount of adsorbate at varying conditions. The effect of adsorbent dosage gives an idea for the ability of a dye adsorption to be adsorbed with the smallest amount of adsorbent, so as to recognize the capability of a dye from an economical point of view. (Salleh et.al, 2011)

Generally the percentage dye removal increases with increasing adsorbent dosage, where the number of adsorption sites at the adsorption surface will increase by increasing the amount of the adsorbent. Table 3.1 shows the gathered data on the study of the effect of adsorbent dosage on the percentage dye removal. Figure 3.1 shows the removal of Basic Fuchsin by dried cauliflower leaves at different amounts (0.25-2.00g/50ml) for a given dye concentration of 7 ppm.

Table 3.1 Percentage Basic Fuchsin Dye Removal with Varying Amounts of Dried Cauliflower Leaves

Mass of Dried Cauliflower Leaves (grams)	Average Percentage Removal of Basic Fuchsin Dye
0.25	74.0509
0.50	79.3459
0.75	83.4522
1.00	84.4248
1.25	84.7850
1.50	84.4608
1.75	84.6049
2.00	84.5688
2.25	84.5328
2.50	84.1366
2.75	82.5877
3.00	81.0388
3.25	78.1932
3.50	76.4282
3.75	73.4385
4.00	72.6821
4.25	71.6015

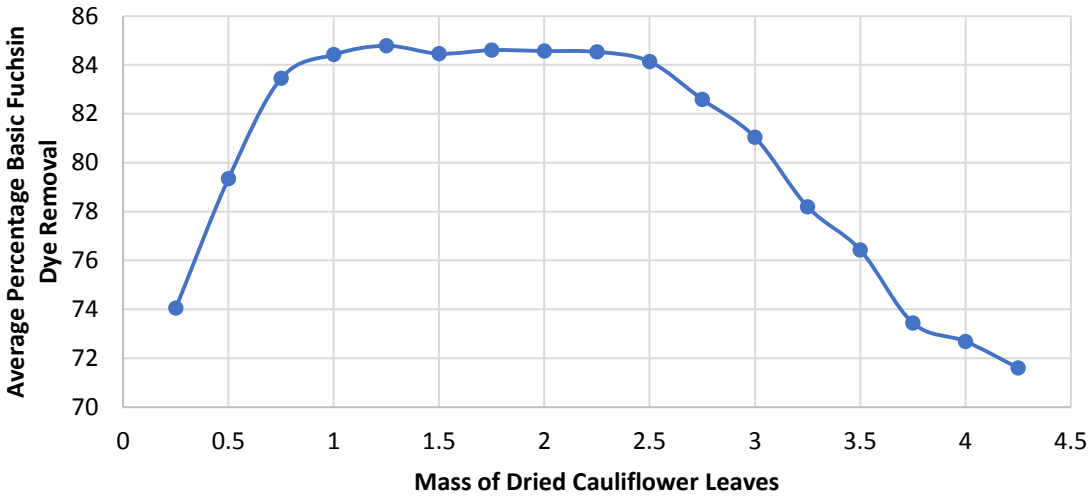

Figure 3.1 Effect of the Amount of Dried Cauliflower Leaves on the Percentage Removal of Basic Fuchsin Dye

It was found from the Figure 3.1 that increasing the dried cauliflower leaves dosage from 0.25 to 1.25 g led to increasing Basic Fuchsin removal percentage from 74.05% to 84.78%. This may be due to the availability of more adsorption sites as well as greater availability of specific surfaces of the adsorbent.

Further addition to the adsorbent dosage from 1.25 to 2.25 g did not significantly influence the Basic Fuchsin removal. This phenomenon can be attributed to greater surface area and the availability of more adsorption sites by further increasing the adsorbent surface. The percent removal at this state becomes almost insignificant due a quick exhaustion of the adsorption sites. (Yu et.al, 2002)

It was also shown in the figure that from the amount of adsorbent dosage of 2.5 to 4.5 g, the percentage removal of Basic Fuchsin dye decreases from 81.04 to 71.60%. It is understood that the number of available adsorption sites already decreases by increasing the dried cauliflower dosage and it, therefore, results in a decreasing amount of adsorbed dye. At this point, it is evident that the capacity of the adsorbent gets exhausted and then the uptake rate at which the adsorbate is transported from the exterior to the interior sites of the adsorbent surface. (Yu et.al,2002)

Effect of Varying the Initial Basic Fuchsin Concentration

In every research that involves the principle of adsorption. Concentration is one of the important parameters to be tested. Concentration affects the availability of vacant surface sites on the adsorbent at a certain period and amount of dye. All vacant sites are occupied. Thus, there is a need to know the effect of the initial concentration of dye to see the adsorption capability of the adsorbent (Bonerjee, 2013).

Below is the Table containing the results of the experiment about the effect of the initial concentration of Basic Fuchsin Dye and a graph showing percentage removal vs. initial concentration of Basic Fuchsin dye. The analysis was done with a varying initial concentration but the constant weight of adsorbent, 1 gram, and constant contact time at 30 minutes.

Table 3.2 Percentage Removal of Basic Fuchsin Dye for Different Initial Concentrations

Final Basic Fuchsin Concentration (ppm)	Average Percentage Removal of Basic Fuchsin Dye
0.6011	91.4127
0.7020	89.9719
0.8280	88.1709
0.8835	87.3784
1.0298	85.2892
1.1911	82.9839
1.2289	82.4436
1.4206	79.7061

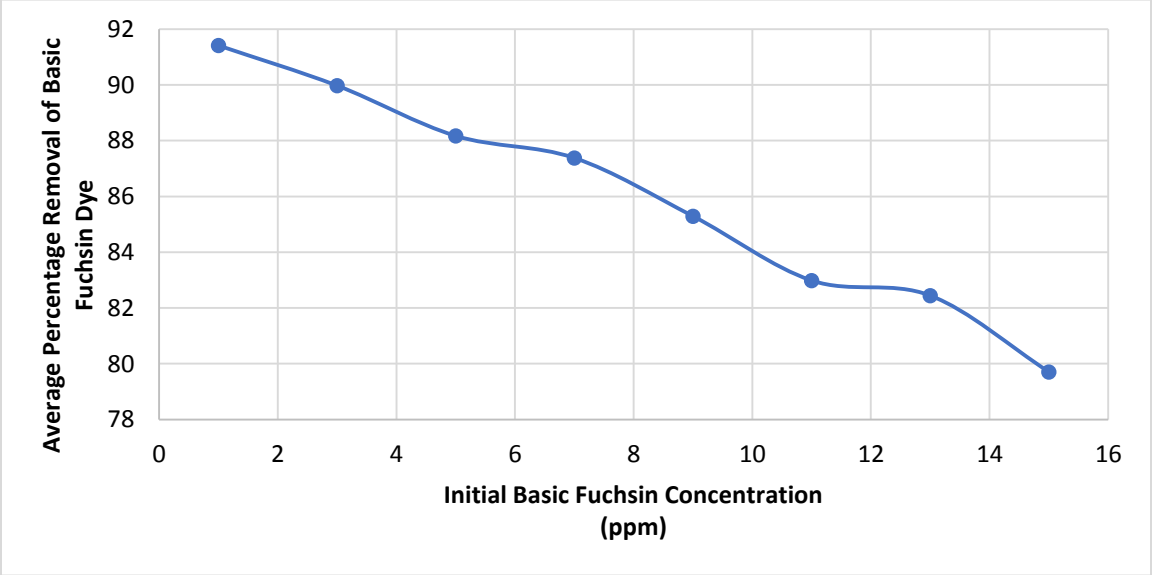

Figure 3.2 Effect of Varying Initial Basic Fuchsin Dye Concentration on the Percentage Removal of Dye

Table 3.2 shows the initial concentration of Basic Fuchsin dye used which ranges from 0.6 -1.42 ppm and has an approximate interval of 0.1 ppm. The percentage removal was also shown, and this varies from 91.42 - 79.7 %. The percentage removal is decreasing as the initial concentration of Basic Fuchsin increases. This is due to the occupation of the vacant sites on the surface of the adsorbent. As concentration increases, the number of dye molecules that are attached to the vacant sites of the adsorbent increases limiting the amount of dye adsorb (Makinde, O. E., 2015). The available vacant sites in the adsorbent are constant because the amount of it is limited to 1 gram. Therefore, as the number of molecules increases, increasing concentration, the percentage removal decreases due to the limited amount of adsorbent. The decreased percentage removal of the dye as the concentration increases may be attributed to this lack of available active sites required for further uptake after attaining the equilibrium

(Liang et al., 2010). The percentage removal is exponentially varying (Emmanuel, K. A., 2009).

Effect of Contact Time

Contact time must also be considered to be able to use the cauliflower leaves as a potential absorbent efficiently. Contact time is one of the essential parameters to test for before considering the biosorbent into practical application. One of the desirable characteristics of a good biosorbent is a rapid sorption time. The influence of contact time on the removal of basic fuchsin by the cauliflower leaves is shown in Figure 3.3. It can be seen that cauliflower leaves are efficient to adsorb basic fuchsin dye. The adsorption process of the dye rapidly attains equilibrium. It only takes 30-40 minutes for the cauliflower leaves to achieve equilibrium with percentage removal of above 80%. The mechanism of dye adsorption in the adsorbent is based on four steps: (a) transfer of the dye particles from the bulk solution to the surface of the adsorbent, (b) encountering the boundary layer effect on the surface of the leaves, (c) diffusion of the molecules from boundary layer film onto adsorbent surface, (d) intraparticle diffusion to the porous interior of the leaves. (Elgeundi,1991 and Malik 2003). The boundary layer resistance will affect the rate of adsorption and increasing the degree of agitation will reduce this resistance and increase the mobility of the system thus decreasing the needed time to reach equilibrium (Elgeundi, 1991).

Table 3.3 Percentage Removal of Basic Fuchsin Dye for Different Contact Time

Contact Time (minutes)	Average Percentage Removal of Basic Fuchsin Dye
10	44.7662
20	67.3511
30	82.3716
40	85.9016
50	88.0268
60	88.7472

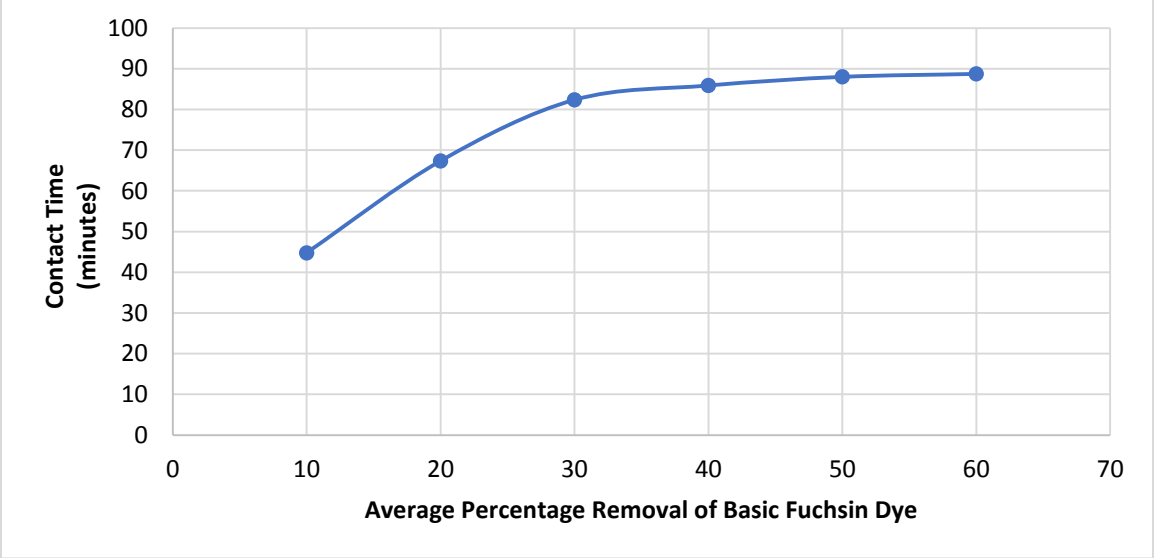

Figure 3.3 Effect of Varying Contact Time on the Percentage Removal of Dye

It can be observed in Figure 3.3 that the percentage removal of the dye on the cauliflower leaves varies linearly before it reaches equilibrium. Beyond this time, the percentage removal gradually diminished and it attained equilibrium where no increase can be observed significantly. The increase in the percentage removal with an increase in contact time can be attributed to the availability of adsorption sites on the adsorption surface. The gradual decrease observed on the percentage removal after equilibrium time could be attributed to the removal or desorption of dye molecules from the binding site of the adsorbent surface due

to the repulsive forces between dye molecules at adjacent sites on the adsorbent's surface (Iscen, 2008).

Adsorption Isotherms

Adsorption isotherms are also needed to optimize the use of the adsorbent. These isotherms describe how solute relates to the adsorbent in the solution. In order to know what the most suitable dosage requirement is and to quantify the adsorption capacity of the adsorbent, it is essential to know what adsorption isotherm fits well in the system. This includes testing experimental data to different multilayer adsorption isotherms.

Langmuir Isotherm

Table 3.4.a. Experimental Adsorption Equilibrium Data for Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves

Initial concentration (ppm)	Mass of adsorbent (g)	Equilibrium Concentration, Ce (ppm)	Adsorption Capacity, qe (mg/g)
1	1.002	0.6717	0.0163
2	1.001	0.9138	0.0543
3	1.002	1.1407	0.0928
4	1.000	1.2466	0.1377
5	1.001	1.3752	0.1811
6	0.999	1.4660	0.2269
7	1.000	1.4811	0.2759
8	1.002	1.5113	0.3238
9	1.001	1.6172	0.3688
10	1.003	1.6626	0.4156

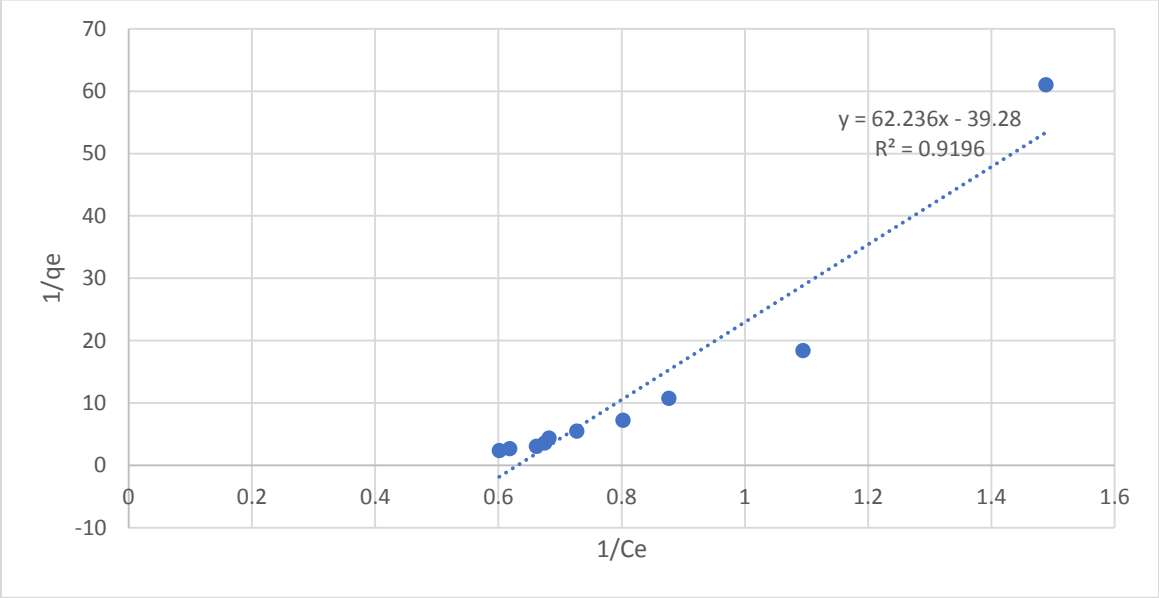

Figure 3.4.a. Plot of Experimental Data from the Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves fit to the Linearized Langmuir Equation

Freundlich Isotherm

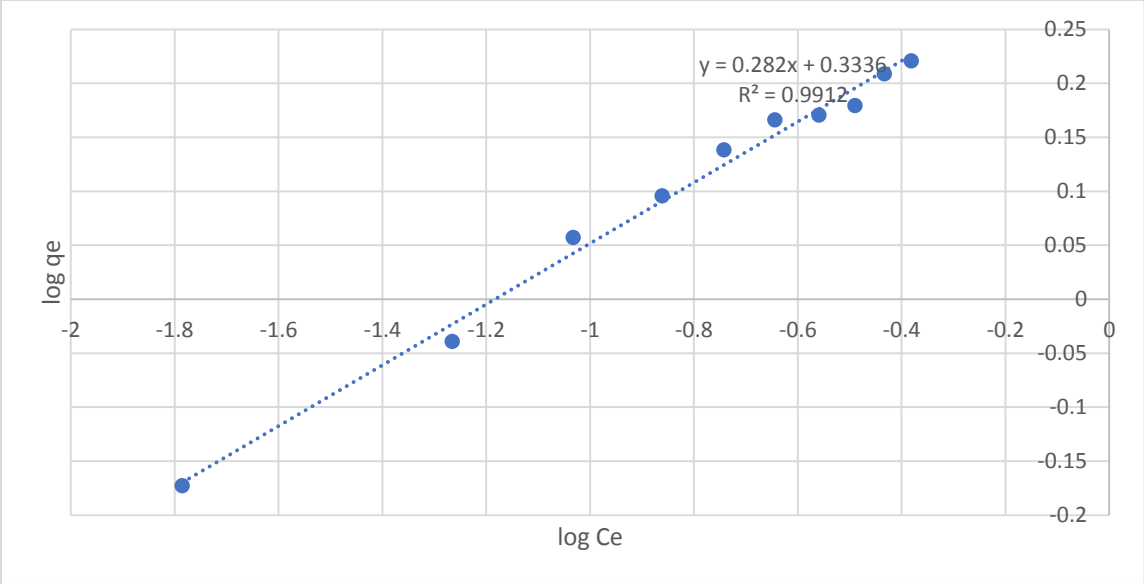

Figure 3.4.b. Plot of Experimental Data from the Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves fit to the Linearized Freundlich Equation

The data obtained from the batch-wise adsorption experiments shows that it fits to the linearized Langmuir equation, as seen on Figure 3.4.a. The adsorption of basic fuchsin in the cauliflower leaves showed a correlation coefficient value of 0.9196. This suggest that the adsorption mechanism of cauliflower leaves occur on a monomolecular adsorption on energetically homogeneous surfaces. However, correlation between the data obtained to the Freundlich linearized isotherm model shows better correlation coefficient value of 0.9912. This would mean that the adsorption mechanism of cauliflower leaves occur heterogeneous surfaces and there is interaction between the basic fuchsin dye adsorbed that gives infinite surface coverage.

Other Isotherm models were also tested but these models resulted to low correlation coefficients meaning the data would not fit on these isotherms. Appendix A.8 show the results on these isotherms

Sine it better fits the Freundlich isotherm, it is better to understand the mechanism by looking at other parameters. The other parameters obtained from Freundlich isotherm model are summarized below.

Table 3.4.b Isotherm Constants and Correlation Coefficients for the Adsorption of Basic Fuchsin Dye on Cauliflower Leaves.

Parameter	Value
Kf (mg-g-1)(L-mg-1)1/n	2.15576
n	3.54609
R^2	0.9912

The heterogeneity factor value is 3.54609 and this indicates that the adsorption is a physical process in nature since it is greater than 1.

Adsorption Kinetics

In this study, two kinetic models were tested namely, pseudo-fist order kinetics and pseudo-second order kinetics to obtain the rate constants. The kinetic models are given as follows:

Pseudo-first Order Kinetics by Lagergren:

$$\log(q_e - q_t) = \log q_e - \frac{k_t}{2.303} t$$

Pseudo-second Order Kinetics by Ho and McKay

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^{\,2}} + \frac{1}{q_e} t$$

First Order Kinetics

Table 3.5a shows the result regarding the experiment done for the modelling of the kinetics. Plots of the linearized pseudo-first order and pseudo-second order kinetic equation using the experimental data from the Table 3.5a were obtained and analyzed subsequently. Figure 3.5a, on the other hand, shows how the experimental data obtained from the adsorption of the Basic Fuchsin dye onto the dried cauliflower leaves fit to the pseudo-first order model. The curve constructed yield a correlation coefficient of 0.9678.

Table 3.5.a. Adsorption Kinetics Data for Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves

Time (min)	Concentration After Time Noted (ppm)	Milligrams of Basic Fuchsin Dye Adsorbed	q_t (mg/g)
10	4.8623	0.1069	0.1069
20	4.1362	0.1432	0.1431
30	2.5477	0.2226	0.2226
40	1.9198	0.2540	0.2539
50	1.6551	0.2672	0.2672
60	1.4735	0.2763	0.2763
70	1.3903	0.2805	0.2805
80	1.2769	0.2862	0.2861
90	1.1710	0.2915	0.2915
100	1.0877	0.2956	0.2956
110	0.9970	0.3002	0.3001
120	0.9894	0.3005	0.3005
130	0.9818	0.3009	0.3008
140	0.9743	0.3013	0.3013
150	0.9440	0.3028	0.3027
1080	0.5053	0.3247	0.3246
1440	0.4902	0.3255	0.3254
2880	0.4826	0.3259	0.3257

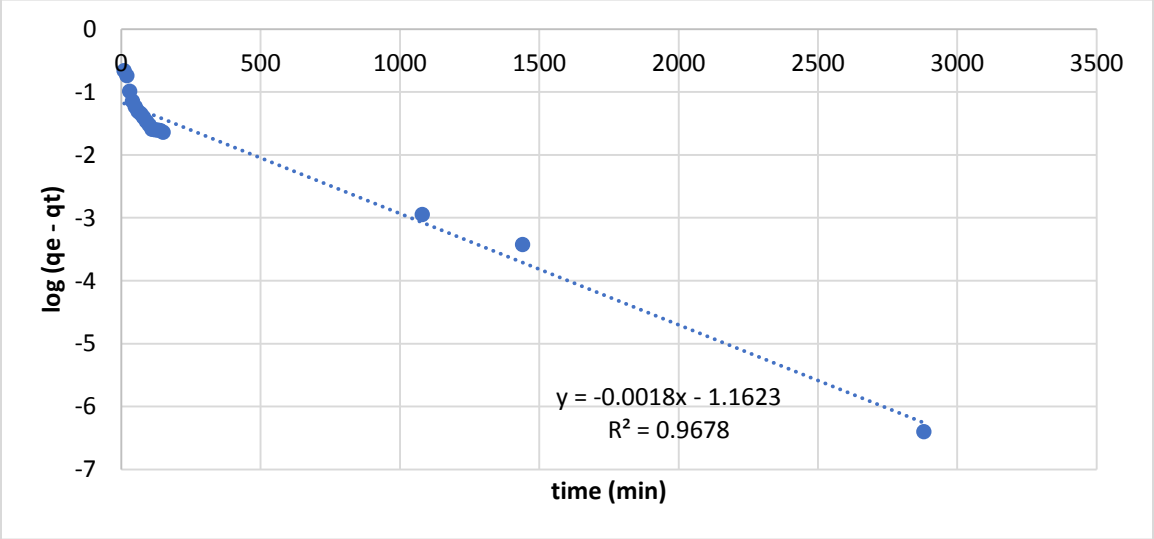

Figure 3.5.a. Test for Goodness of Fit to the Pseudo-First-Order Kinetic Model (Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves)

Second Order Kinetics

On the other hand, Figure 3.5b shows how the experimental data collected fit to the pseudo-second order model. The correlation coefficient value obtained from the curve constaructed was equal to unity (1). This means that the adsorption of Basic Fuchsin dye onto the dried cauliflower leaves can be observed more accurately by pseudo-second order kinetic model than the pseudo-first order kinetic model. This finding suggested that chemisorptions may be the rate-limiting step of the adsorption system, according to Chowdhury and Das (2011).

Table 3.5.b. Adsorption of Kinetics Data for Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves

Time (minutes)	Concentration After Time Noted (ppm)	Milligrams of Basic Fuchsin Dye Adsorbed	q_t (mg/g)
10	4.8623	0.1069	0.1069
20	4.1362	0.1432	0.1431
30	2.5477	0.2226	0.2226
40	1.9198	0.2540	0.2539
50	1.6551	0.2672	0.2672
60	1.4735	0.2763	0.2763
70	1.3903	0.2805	0.2805
80	1.2769	0.2862	0.2861
90	1.1710	0.2915	0.2915
100	1.0877	0.2956	0.2956
110	0.9970	0.3002	0.3001
120	0.9894	0.3005	0.3005
130	0.9818	0.3009	0.3008
140	0.9743	0.3013	0.3013
150	0.9440	0.3028	0.3027
1080	0.5053	0.3247	0.3246
1440	0.4902	0.3255	0.3254
2880	0.4826	0.3259	0.3257

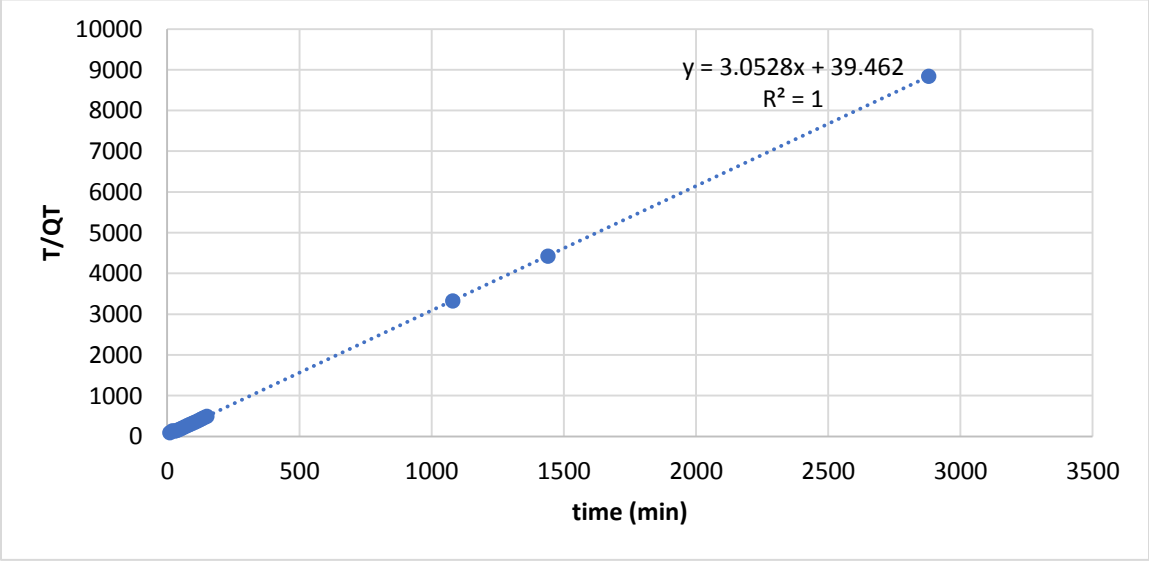

Figure 3.5.b. Test for Goodness of Fit to the Pseudo-Second-Order Kinetic Model (Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves)

Kinetic modelling of the adsorption of Basic Fuchsin dye onto Cauliflower Leaves determines the right order for the adsorption capacity of the adsorbent. Presented on Table 3.5.c. the data involving the Lagergren pseudo-first Order Kinetic model and Ho and McKay pseudo-second Order Kinetic model. The experimental capacity ($q_{e,\ exp)}$ is 0.3257 mg of dye adsorb per g of adsorbent. For the pseudo-first order the calculated capacity ($q_{e,\ cal}$) is equal to .0688 mg of dye adsorb per g of adsorbent. While on the pseudo-second order the calculated capacity ($q_{e,\ cal}$) is equal to 0.3276 mg of dye adsorb per g of adsorbent which is closer to the experimental value proving that it best fits the adsorption of Basic Fuchsin dye Cauliflower leaves. The rate of each kinetic model is also presented below.

Table 3.5.c. Kinetic Parameters for Adsorption of Basic Fuchsin dye on Cauliflower leaves

	Lagergren pseudo-first Order Kinetic model			**Ho and McKay pseudo-second Order Kinetic model**		
$q_{e,\ exp}$ (mg/g)	**$q_{e,\ cal}$ (mg/g)**	**k_1 (min^{-1})**	**R^2**	**$q_{e,\ cal}$ (mg/g)**	**k_2(g/mg-min)**	**R^2**
0.3257	0.0688	$7.8159x10^{-4}$	0.9678	0.3276	0.2361	1.0000

CHAPTER IV

CONCLUSION AND RECOMMENDATIONS

Conclusions

This study revealed that cauliflower leaves biomass adsorbents can be used to remove basic fuchsin dye in aqueous solutions using batch wise experiments. To answer the problems raised in this research, the following conclusions were formulated based on the data obtained and the results of the experiments:

1. The study showed that with the amount of the adsorbent ranging from 0.25 grams to 1.25 grams, the percentage removal of Basic Fuchsin dye increases. However, increasing the amount of Cauliflower Leaves beyond 1.25 grams results to a decreased percentage removal of Basic Fuchsin dye.

2. The increase in initial concentration will yield in lower percentage removal of the basic fuchsin due to the decrease of available adsorption sites.

3. The optimum conditions for the adsorption of basic fuchsin dye in the cauliflower leaves are an adsorbent dosage of 1 gram with a contact time of 30 minutes.

4. The adsorption of basic fuchsin on cauliflower leaves can be best described by Freundlich isotherm with a correlation factor of 0.9912.
5. The adsorption of basic fuchsin on the leaves were found to follow second-order kinetics model.

Recommendations

The dried cauliflower leaves are recommended as a low-cost biomass adsorbent for the removal of basic fuchsin dye from aqueous solutions. In addition, the researchers recommend further works to:

1. Make desorption studies to explain the mechanism of the recovery and regeneration of the adsorbent and the adsorbate.
2. Include the study on the effects of varying pH and temperature as this study kept the pH and temperature of the solution constant.
3. Have additional research on the mechanism of modified/activated cauliflower leaves and its application for industrial scale

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APPENDICES

A. LIST OF EQUIPMENT AND APPARATUS USED

1. Aluminum Foil – used to contain dried Cauliflower leaves during weighing.
2. Aluminum Tray- container of leaves during the drying process.
3. Analytical Balance- apparatus used to measure the mass of dried Cauliflower leaves used in the adsorption process.
4. Beaker- used to temporary hold liquid during the p.
5. Cork- used to cover the Erlenmeyer to avoid contamination.
6. Cuvette – container of the soulution during Spectrophotometry.
7. Erlenmeyer Flask- used to hold the dye and leaves during the adsorption process.
8. Filter Paper- used to separate the solid particles from the solution to avoid interference during the spectrophotometry.
9. Medicine Dropper- used to transfer the solution from the Erlenmeyer to the cuvette.
10. Oven- equipment used to dry the Cauliflower leaves.
11. Pipetol- complimentary apparatus of pipette.
12. Pipette- used to measure and transfer solution.
13. Reagent Bottle- container for the stock solution.
14. Sieve Series- used to separate fine Cauliflower
15. Spectrophotometer - equipment used to measure used absorbance of the solution. Governed by the principle of Beer's law.

16. Stirrer- used to mixed the solution for better adsorption.
17. Stopwatch- used to measure the time during adsorption process.
18. Volumetric Flasks (1000mL)- used to dilute the stock solution to desired concentration.
19. Wash Bottle- used to contain deionized water.
20. Waste bottle-container of waste solution.

B. LIST OF TABLES AND FIGURES ACCOMPANYING THE RESULTS OBTAINED

1. Calibration Curve

Table B.1 Absorbance Reading at Different Basic Fuchsin Dye Concentrations

Concentration	Absorbance
1	0.014
2	0.217
3	0.391
4	0.544
5	0.616
6	0.758
7	0.978
8	1.069
9	1.235
10	1.263
11	1.465
12	1.488
13	1.688
14	1.789
15	1.942

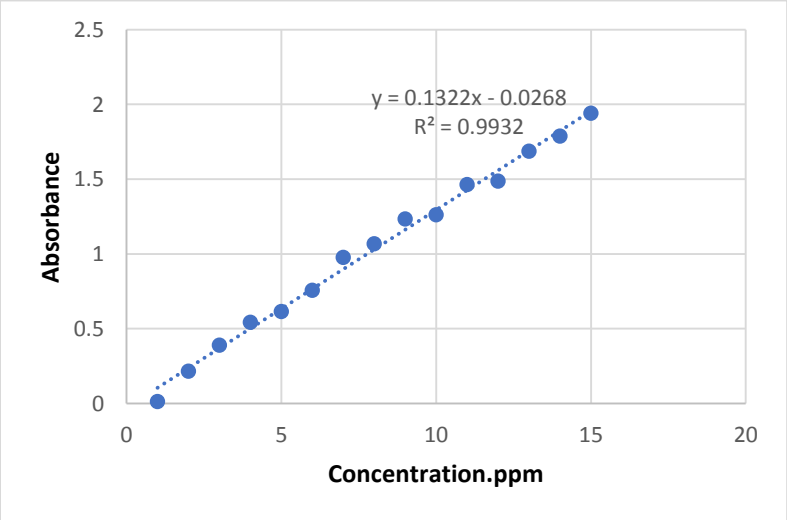

Figure B.1 Calibration Curve for Basic Fuchsin

2. Effect of Adsorbent Dosage

Table B.2 Absorbance Readings after Adsorption of Basic Fuchsin with Varying Adsorbent Dosage.

Mass of Adsorbent	Initial Concentration (ppm)	Final Concentration			Average	% Removal
		Trial 1	Trial 2	Trial 3		
0.25	7.00	1.7912	1.7156	1.9425	1.8164	74.0509
0.50	7.00	1.3601	1.5567	1.4206	1.4458	79.3459
0.75	7.00	1.0726	1.2088	1.1936	1.1583	83.4522
1.00	7.00	1.0651	1.0348	1.1710	1.0903	84.4248
1.25	7.00	1.0575	1.0045	1.1331	1.0651	84.7850
1.50	7.00	1.0575	0.9894	1.2163	1.0877	84.4608
1.75	7.00	1.0651	0.9440	1.2239	1.0777	84.6049
2.00	7.00	1.0802	0.9440	1.2163	1.0802	84.5688
2.25	7.00	1.0877	0.9289	1.2315	1.0827	84.5328
2.50	7.00	1.0953	0.9743	1.2617	1.1104	84.1366
2.75	7.00	1.0877	0.9818	1.5870	1.2189	82.5877
3.00	7.00	1.1331	1.0121	1.8366	1.3273	81.0388
3.25	7.00	1.2315	1.1029	2.2451	1.5265	78.1932
3.50	7.00	1.2769	1.2163	2.4569	1.6500	76.4282
3.75	7.00	1.3298	1.2315	3.0166	1.8593	73.4385
4.00	7.00	1.3601	1.3071	3.0696	1.9123	72.6821
4.25	7.00	1.4206	1.3601	3.1831	1.9879	71.6015

3. Effect of Concentration

Table B.3 Absorbance Readings after Adsorption of Basic Fuchsin with Varying Concentration.

Initial Concentration	Mass of Adsorbent	Final Concentration			Average	% Removal
		Trial 1	Trial 2	Trial 3		
1	1.00	0.6490	0.5431	0.6112	0.6011	39.8891
3	1.00	0.7474	0.6868	0.6717	0.7020	76.6011
5	1.00	0.8533	0.8003	0.8306	0.8280	83.4392
7	1.00	0.7852	0.9667	0.8986	0.8835	87.3784
9	1.00	0.8003	1.2163	1.0726	1.0298	88.5583
11	1.00	1.0121	1.3903	1.1710	1.1911	89.1716
13	1.00	1.0575	1.4206	1.2088	1.2289	90.5466
15	1.00	1.3298	1.4962	1.4357	1.4206	90.5295

4. Effect of Contact Time

Table B.4.a Absorbance Readings after Adsorption of Basic Fuchsin with Varying Contact Time (fresh leaves).

Time (minutes)	Final Concentration			Average	% Removal
	Trial 1	Trial 2	Trial 3		
10	3.9017	3.8411	3.8563	3.8664	44.7662
20	2.2073	2.3812	2.2678	2.2854	67.3511
30	1.2163	1.2466	1.2390	1.2340	82.3716
40	0.9818	1.0272	0.9516	0.9869	85.9016
50	0.8306	0.8684	0.8154	0.8381	88.0268
60	0.8003	0.7776	0.7852	0.7877	88.7472

Table B.4.b Absorbance Readings after Adsorption of Basic Fuchsin with Varying Contact Time (rotting leaves).

Time minutes	Final Concentration Trial 1	Trial 2	Trial 3	Average	% Removal
10	5.8532	5.9440	5.9894	5.9288	15.3014
20	3.6747	3.5310	3.5839	3.5965	48.6204
30	2.4947	2.4190	2.9183	2.6106	62.7044
40	2.0937	2.1618	2.0635	2.1064	69.9085
50	1.8593	1.8744	1.9652	1.8996	72.8621
60	1.7685	1.7534	1.7912	1.7710	74.6992

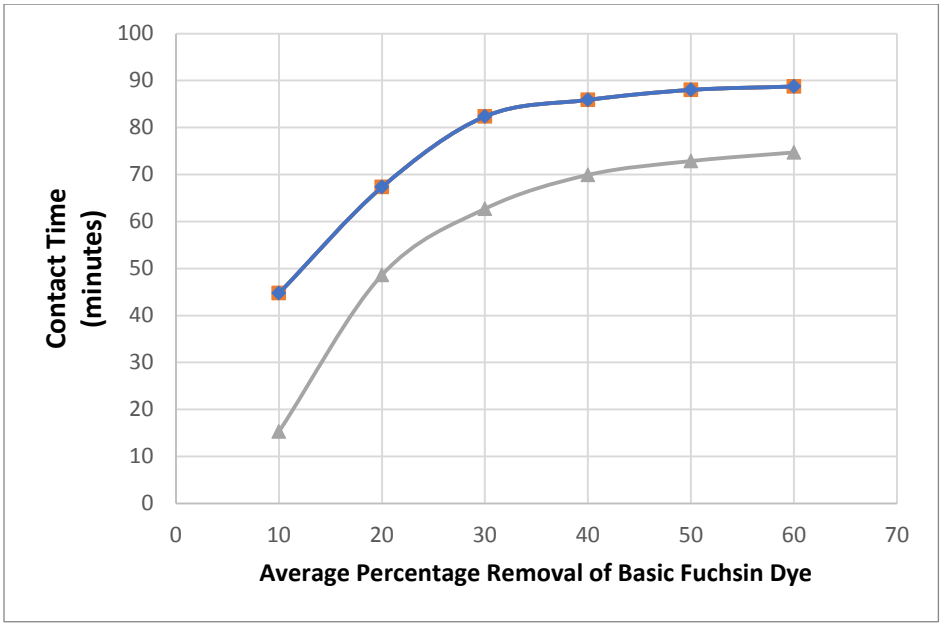

Figure B.4 Effect of Varying Contact Time on the Percentage Removal of Dye using fresh leaves compared to dried leaves.

5. Adsorption Isotherm

Table B.5.a Langmuir Isotherm Model

Concentration	Absorbance	Equilibrium Concentration,Ce	Mass of adsorbent	Mass of dye adsobed	Adsorption Capacity, qe	1/ce	1/qe
1	0.062	0.6717	1.002	0.0164	0.0164	1.4887	61.0435
2	0.094	0.9138	1.001	0.0543	0.0543	1.0944	18.4307
3	0.124	1.1407	1.002	0.0930	0.0928	0.8767	10.778
4	0.138	1.2466	1	0.1377	0.1377	0.8022	7.2637
5	0.155	1.3752	1.001	0.1812	0.1811	0.7272	5.5230
6	0.167	1.4660	0.999	0.2267	0.2269	0.6821	4.4067
7	0.169	1.4811	1	0.2759	0.2759	0.6752	3.6239
8	0.173	1.5113	1.002	0.3244	0.3238	0.6617	3.0885
9	0.187	1.6172	1.001	0.3691	0.3688	0.6183	2.7117
10	0.193	1.6626	1.003	0.4169	0.4156	0.6015	2.4060

Table B.5.b Freundlich Isotherm Model

Cocncentration	Absorbance	Equilibrium concentration, Ce	Mass of adsorbent	Mass of dye adsobed	Adsorption Capacity, qe	log qe	log ce
1	0.062	0.6717	1.002	0.0164	0.0164	-1.7856	-0.1728
2	0.094	0.9138	1.001	0.0543	0.0543	-1.2655	-0.0392
3	0.124	1.1407	1.002	0.0930	0.0928	-1.0326	0.0572
4	0.138	1.2466	1	0.1377	0.1377	-0.8612	0.0957
5	0.155	1.3752	1.001	0.1812	0.1811	-0.7422	0.1384
6	0.167	1.4660	0.999	0.2267	0.2269	-0.6441	0.1661
7	0.169	1.4811	1	0.2759	0.2759	-0.5592	0.1706
8	0.173	1.5113	1.002	0.3244	0.3238	-0.4897	0.1794
9	0.187	1.6172	1.001	0.3691	0.3688	-0.4333	0.2088
10	0.193	1.6626	1.003	0.4169	0.4156	-0.3813	0.2208

6. Adsorption Kinetics

a. Correlation with Pseudo-First-Order Kinetic Model

Table B.6.a. Correlation of Experimental Data from the Adsorption of Basic Fuchsin onto Dried Cauliflower Leaves with the Pseudo-First-Order Kinetic Model

Time (min)	Mass of adsor bent	Absor bance	Final Concentration	Mass of dye adsorbed	qt	log(qc-qt)
10	1.0002	0.6160	4.8623	0.1069	0.1069	-0.6598
20	1.0003	0.5200	4.1362	0.1432	0.1431	-0.7385
30	1.0002	0.3100	2.5477	0.2226	0.2226	-0.9865
40	1.0003	0.2270	1.9198	0.2540	0.2539	-1.1438
50	1.0002	0.1920	1.6551	0.2672	0.2672	-1.2325
60	1.0002	0.1680	1.4735	0.2763	0.2763	-1.3056
70	0.9999	0.1570	1.3903	0.2805	0.2805	-1.3446
80	1.0003	0.1420	1.2769	0.2862	0.2861	-1.4016
90	1.0000	0.1280	1.1710	0.2915	0.2915	-1.4649
100	1.0001	0.1170	1.0877	0.2956	0.2956	-1.5206
110	1.0003	0.1050	0.9970	0.3002	0.3001	-1.5904
120	1.0002	0.1040	0.9894	0.3005	0.3005	-1.5974
130	1.0003	0.1030	0.9818	0.3009	0.3008	-1.6034
140	1.0001	0.1020	0.9743	0.3013	0.3013	-1.6111
150	1.0003	0.0980	0.9440	0.3028	0.3027	-1.6377
1080	1.0004	0.0400	0.5053	0.3247	0.3246	-2.9452
1440	1.0000	0.0380	0.4902	0.3255	0.3255	-3.6050
2880	1.0004	0.0370	0.4826	0.3259	0.3257	-6.3961

b. Correlation with Pseudo-second-order Kinetic Model

Table B.6.b. Correlation of Experimental Data from the Adsorption of Basic Fuchsin onto Dried Cauliflower Leaves with the Pseudo-Second-Order Kinetic Model

Time (min)	Mass of adsorbent	Absorbance	Final Concent-ration	Mass of dye adsorbed	qt	t/qt
10	1.0002	0.6160	4.8623	0.1069	0.1069	93.5785
20	1.0003	0.5200	4.1362	0.1432	0.1431	139.7144
30	1.0002	0.3100	2.5477	0.2226	0.2226	134.7874
40	1.0003	0.2270	1.9198	0.2540	0.2539	157.5219
50	1.0002	0.1920	1.6551	0.2672	0.2672	187.1305
60	1.0002	0.1680	1.4735	0.2763	0.2763	217.1800
70	0.9999	0.1570	1.3903	0.2805	0.2805	249.5435
80	1.0003	0.1420	1.2769	0.2862	0.2861	279.6504
90	1.0000	0.1280	1.1710	0.2915	0.2915	308.7983
100	1.0001	0.1170	1.0877	0.2956	0.2956	338.3143
110	1.0003	0.1050	0.9970	0.3002	0.3001	366.5918
120	1.0002	0.1040	0.9894	0.3005	0.3005	399.3751
130	1.0003	0.1030	0.9818	0.3009	0.3008	432.1558
140	1.0001	0.1020	0.9743	0.3013	0.3013	464.7213
150	1.0003	0.0980	0.9440	0.3028	0.3027	495.5271
1080	1.0004	0.0400	0.5053	0.3247	0.3246	3327.1165
1440	1.0000	0.0380	0.4902	0.3255	0.3255	4424.0762
2880	1.0004	0.0370	0.4826	0.3259	0.3257	8841.4182

7. Pre-Experiment Results

Table B.7 Pre-Experimentation Absorbance Reading at Different Basic Fuchsin Dye Concentrations

Concentration	Absorbance
1	0.157
3	0.485
5	0.804
7	1.145
9	1.382
11	1.701
13	1.95
15	2.154

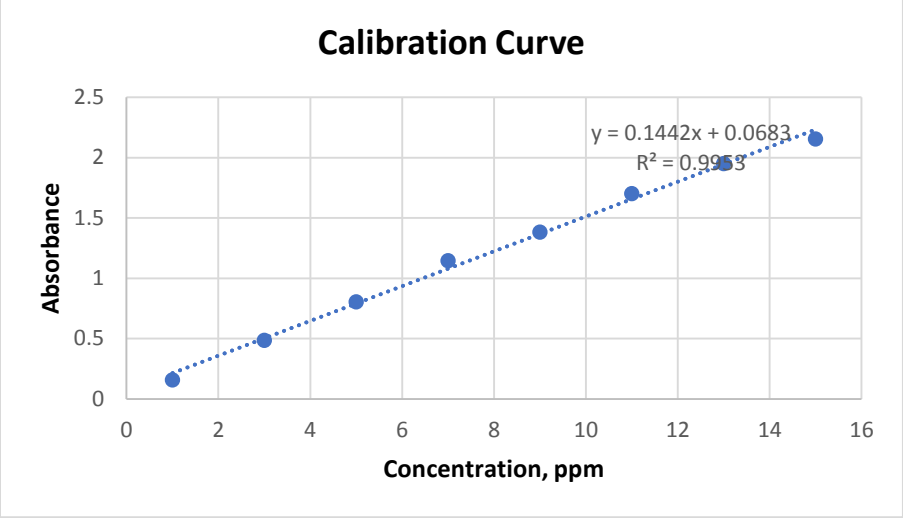

Figure B.5 Pre-Experimentation Calibration Curve for Basic Fuchsin

Table B.8 Pre-Experimentation Results

Initial Concentration	Final Adsorbance	Final Concentration	Percent Removal
1.0000	0.1280	0.4140	58.5992
3.0000	0.1580	0.6221	79.2649
5.0000	0.1750	0.7399	85.2011
7.0000	0.2050	0.9480	86.4573
9.0000	0.2580	1.3155	85.3830
11.0000	0.2920	1.5513	85.8971
13.0000	0.3330	1.8356	85.8797
15.0000	0.3770	2.1408	85.7282

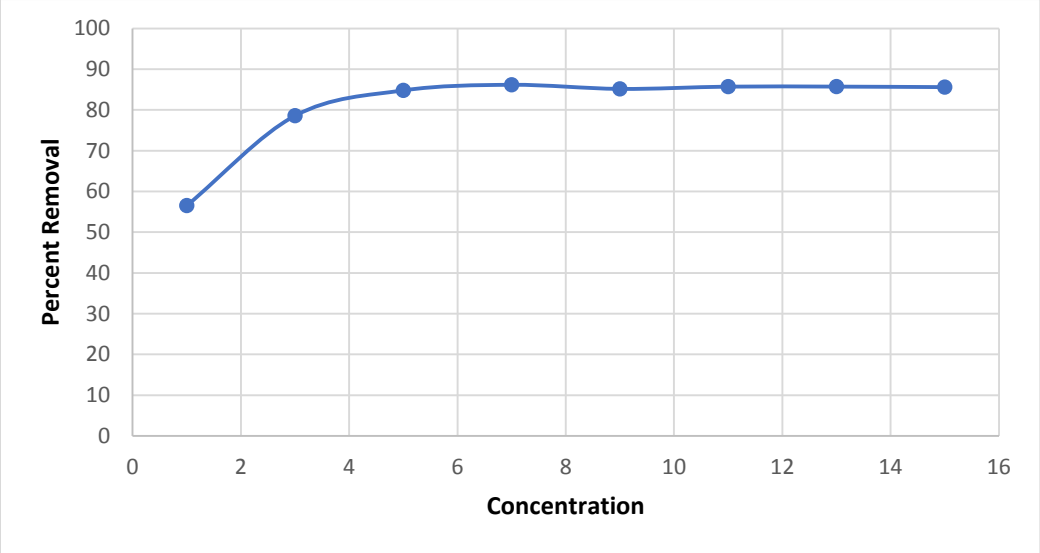

Figure B.6 Pre-Experimentation Results

8. Other Isotherms Used

Ho and Mckay

Table B.9.a Ho and Mckay Isotherm Model

Concentration	Absorbance	Equilibrium Concentration,Ce	Mass of adsorbent	Mass of dye adsobed	Adsorption Capacity, qe	ln ce	qe
1	0.055	0.6187	1.002	0.01906	0.0190	-.4800	0.0190
2	0.105	0.9969	1.001	0.05015	0.0501	-.0030	0.0501
3	0.132	1.2012	1.002	0.0899	0.0897	0.1833	0.0897
4	0.155	1.3751	1	0.1312	0.1312	0.3185	0.1312
5	0.16	1.4130	1.001	0.1793	0.1791	0.3457	0.1791
6	0.167	1.4659	0.9999	0.2267	0.2267	0.3825	0.2267
7	0.169	1.4810	1	0.2759	0.2759	0.3927	0.2759
8	0.173	1.5113	1.002	0.3244	0.3237	0.4130	0.3237
9	0.187	1.6172	1.001	0.3691	0.3687	0.4807	0.3687
10	0.193	1.6626	1.003	0.4168	0.4156	0.5084	0.4156

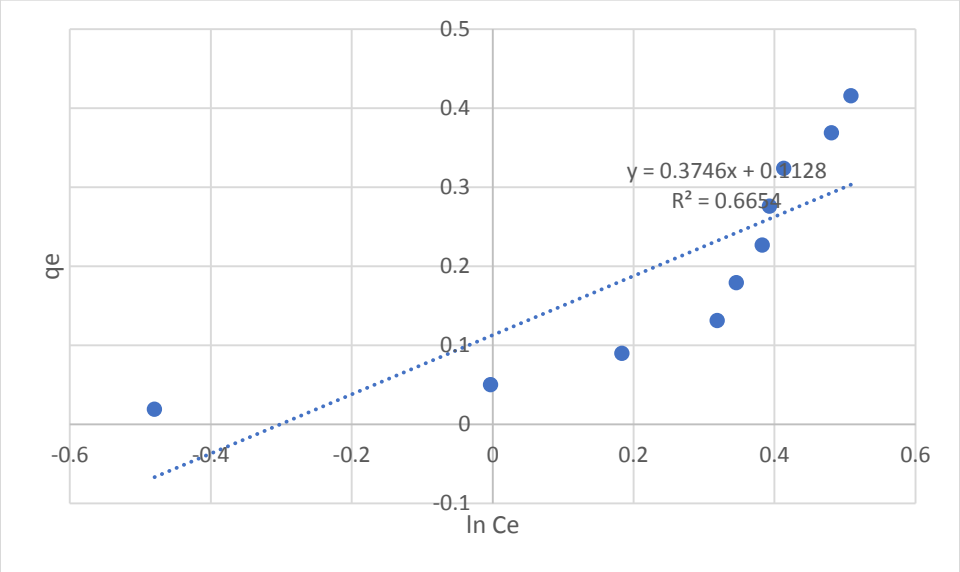

Figure B.7.a. Plot of Experimental Data from the Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves fit to the Linearized Ho & Mckay Isotherm

Harkins Jura

Table B.9.b Harkins Jura Isotherm Model

Concentration	Absorbance	Equilibrium Concentration,Ce	Mass of adsorbent	Mass of dye adsobed	Adsorption Capacity, qe	log ce	1/qe^2
1	0.055	0.6187	1.002	0.01906	0.0190	-.2085	2763.10
2	0.105	0.9969	1.001	0.05015	0.0501	-.0013	398.385
3	0.132	1.2012	1.002	0.0899	0.0897	0.0796	124.118
4	0.155	1.3751	1	0.1312	0.1312	0.1384	58.0583
5	0.16	1.4130	1.001	0.1793	0.1791	0.1501	31.1507
6	0.167	1.4659	0.9999	0.2267	0.2267	0.1661	19.4537
7	0.169	1.4810	1	0.2759	0.2759	0.1706	13.1327
8	0.173	1.5113	1.002	0.3244	0.3237	0.1794	9.5386
9	0.187	1.6172	1.001	0.3691	0.3687	0.2088	7.3535
10	0.193	1.6626	1.003	0.4168	0.4156	0.2208	5.7890

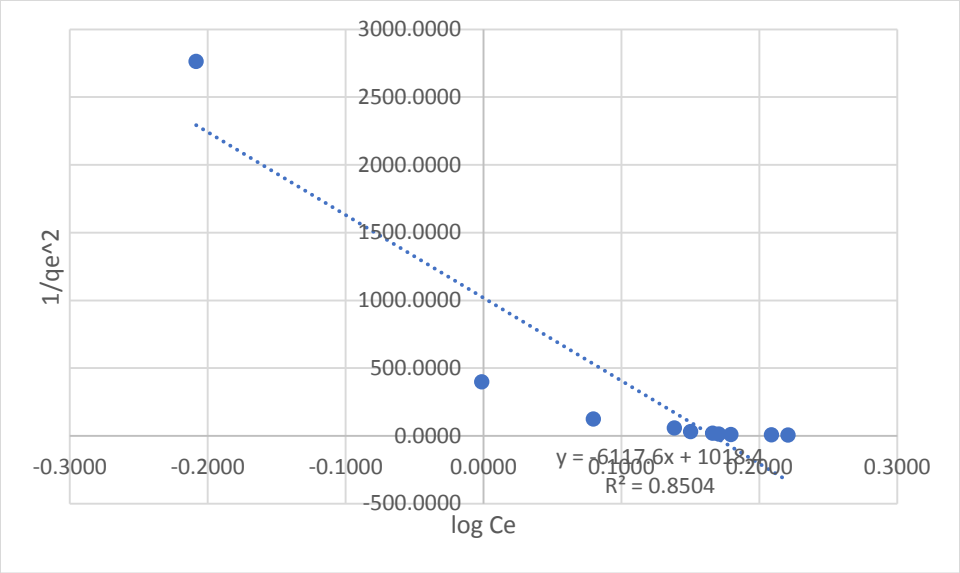

Figure B.7.b. Plot of Experimental Data from the Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves fit to the Linearized Harkins Jura Isotherm

Halsey

Table B.9.c Halsey Isotherm Model

Concentration	Absorbance	Equilibrium Concentration,Ce	Mass of adsorbent	Mass of dye adsobed	Adsorption Capacity, qe	ln ce	ln qe
1	0.055	0.6187	1.002	0.01906	0.0190	-.4800	-3.9621
2	0.105	0.9969	1.001	0.05015	0.0501	-.0030	-2.9937
3	0.132	1.2012	1.002	0.0899	0.0897	0.1833	-2.4106
4	0.155	1.3751	1	0.1312	0.1312	0.3186	-2.0307
5	0.16	1.4130	1.001	0.1793	0.1791	0.3457	-1.7194
6	0.167	1.4659	0.9999	0.2267	0.2267	0.3825	-1.4840
7	0.169	1.4810	1	0.2759	0.2759	0.3928	-1.2876
8	0.173	1.5113	1.002	0.3244	0.3237	0.4130	-1.1277
9	0.187	1.6172	1.001	0.3691	0.3687	0.4807	-0.9976
10	0.193	1.6626	1.003	0.4168	0.4156	0.5084	-0.8780

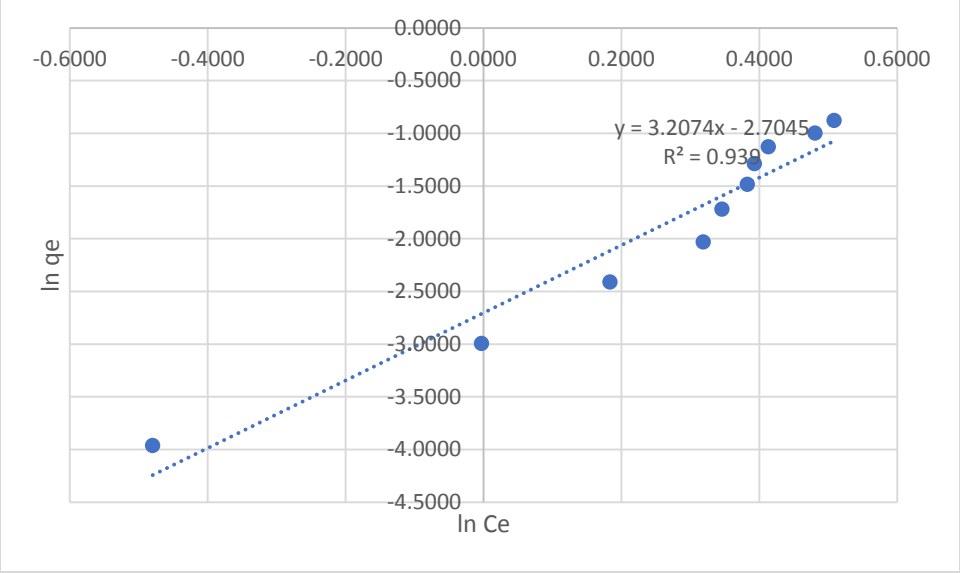

Figure B.7.c. Plot of Experimental Data from the Adsorption of Basic Fuchsin Dye onto Dried Cauliflower Leaves fit to the Linearized Halsey Isotherm.

C. FORMULAS USED IN COMPUTATION

1. Final Concentration After Adsorption

$$\text{Final Con}'\text{cn} = \frac{\text{Absorbance Reading } + \text{Calibration curve intercept}}{\text{Calibration curve slope}}$$

2. Percentage Removal Dye

$$\%\text{Dye Removal } = \frac{\text{Initial Concentration} - \text{Final Concentration}}{\text{Initial Concentration}} * 100$$

3. Adsorption Capacity

$$\text{q} = \frac{\text{Milligrams of dye adsorbed}}{\text{Weight of dried cauliflower leaves (g)}}$$

D. SAMPLE COMPUTATIONS

1. Final Concentration After Adsorption

   Absorbance =0.210

   Final Concentration= [(0.1322* 0.210) +0.0628]

   Final Concentration= 1.79123

2. Percentage Removal Dye

   Initial Concentration = 7

$$\%\text{Dye Removal} = \frac{7 - 1.79123}{7} * 100$$

$$\%\text{Dye Removal} = 74.4111\%$$

3. Adsorption Capacity

$$\text{Milligrams of dye adsorbed} = 0.10688351$$

$$\text{Weight of dried cauliflower leaves (g)} = 1.0002\text{g}$$

$$\text{q} = \frac{0.10688351}{1.0002}$$

$$\text{q} = 0.106862137$$

E. DOCUMENTATION

Figure 1. Collection and Washing of Cauliflower Leaves

Figure 2. Sun drying of washed Cauliflower Leaves

Figure 3. Screening of dried Cauliflower leaves using USA Sieve Series

Figure 4. Washing of screened leaves with distilled water and drying in an oven

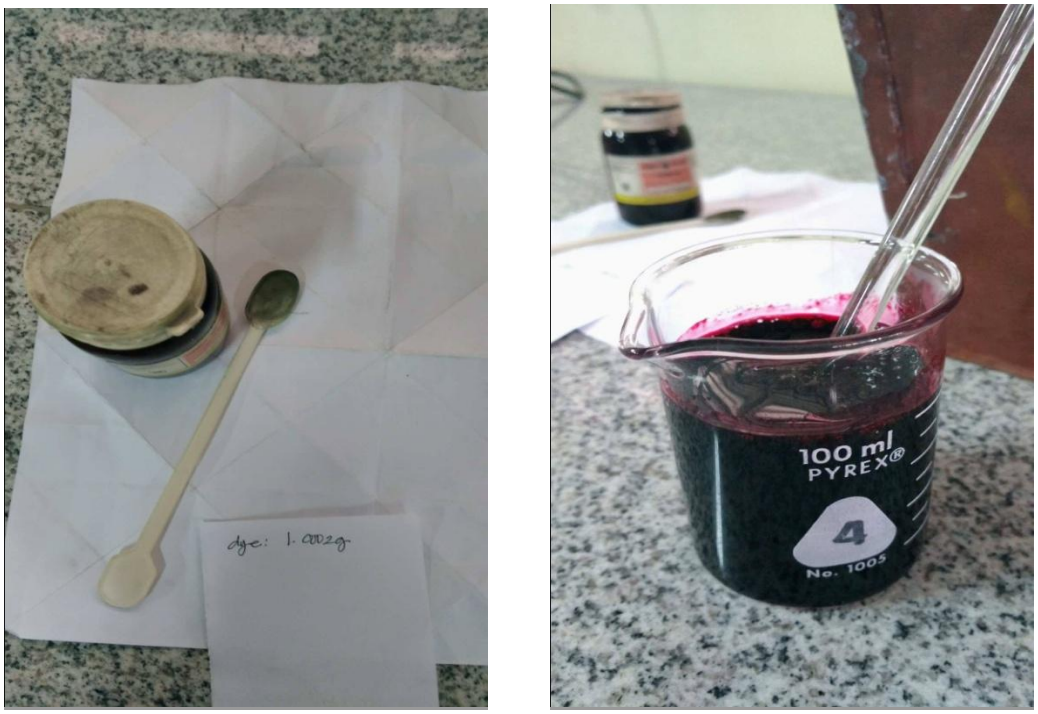

Figure 5. Preparation of Stock Solution

Figure 6. Preparation of dye solutions

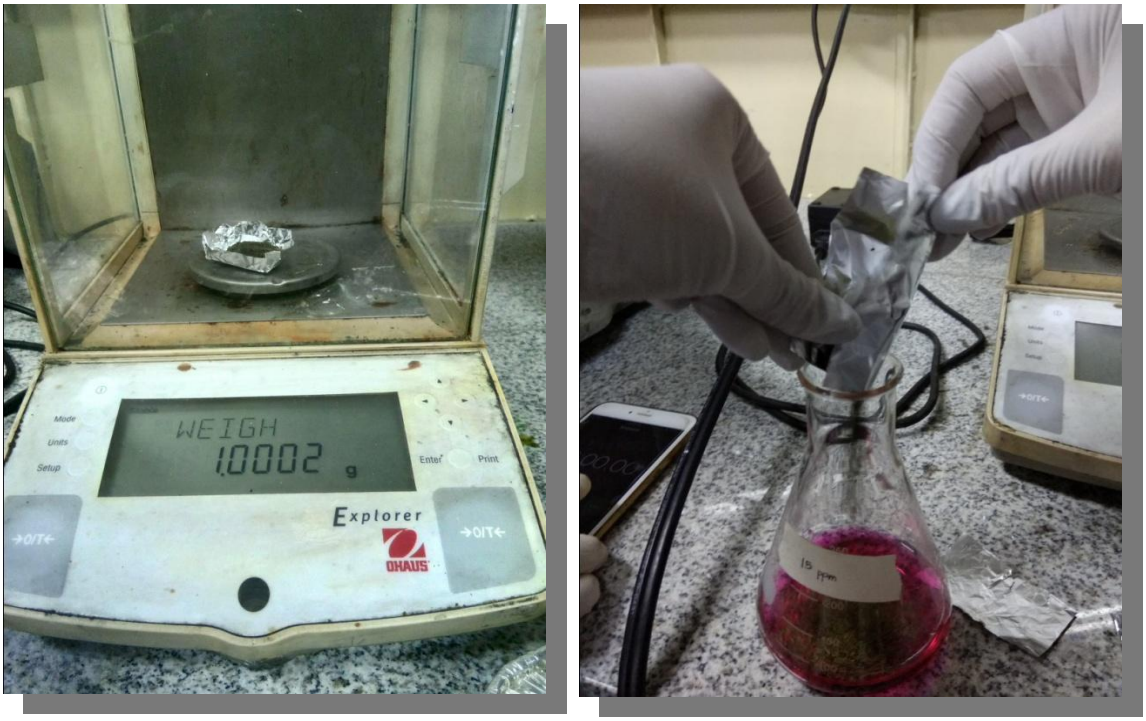

Figure 7. Weighing and adding of adsorbent to flasks

Figure 8. Subjecting the adsorbent to the different parameters

Figure .9: Measuring the absorbance using the Spectrophotometer