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# Adsorption and Microfiltration Processes to Treat Dye and Coffee Wastewater.

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# ADSORPTION AND MICROFILTRATION PROCESSES TO TREAT DYE AND COFFEE WASTEWATER

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# DEDICATION

This work is dedicated to my parents and family members for their constant support.

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**ABSTRACT**

Wastewater from coffee processing industry creates high biological and chemical oxygen demand in the surface water. In addition to coffee wastewater from coffee industry, dyes from textile industry enter surface water affecting water quality in terms of transmissivity of light. Adsorption is an economical wastewater treatment process to remove color from dye and coffee wastewater.

In the current thesis, adsorption using low-cost adsorbents like peanut hull and onion peel are used to treat combined dye and coffee wastewater. Three representative dyes including acid black 48, disperse yellow 3, crystal violet certified with processed coffee is used in preparing batch adsorption samples. Using UV-Vis Spectrophotometer, absorbance and transmittance of the wastewater samples are measured. After adsorbents reach adsorption capacity, the suspended solids are removed using Whatman 41 microfilters. To understand the change in organic carbon before and after treatment in the wastewater, NPOC (Non-Purgeable Organic Carbon) is compared using Shimadzu TOC analyzer.

This thesis focuses on the two-stage treatment process of adsorption and microfiltration in a binary mixture of dye and coffee wastewater. Increasing Adsorbent dosage in the representative wastewater samples gives us the idea of optimum dosage required in the treatment process. The comparative study of adsorbent dosage with transmittance and NPOC gives us an understanding of the efficiency of low-cost adsorbents when compared to Powdered Activated Carbon.

Keywords: Adsorption, Micro-filtration, Non-purgeable Organic Carbon (NPOC), Dye and coffee wastewater, Total Suspended Solids (TSS)

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# CHAPTER I

# INTRODUCTION

## 1.1 Introduction

In the contemporary world, water resources are exploited due to increasing usage in agriculture and industry. According to United States Geological Survey (USGS), about 355,000 (MGD) of water was withdrawn for use (1). This can create water stress in certain areas and increase the energy demand for the water and wastewater treatment. For pumping and treatment of water and wastewater approximately 3-4% of energy i.e. $4*10^{13}$ btu is used in the united states annually (2). This can create both energy and an environmental burden due to the depletion of energy resources like fossil fuels and increase the greenhouse gas (GHG) emissions. This creates the need for low cost and economical treatment technologies to be used in water and wastewater treatment processes.

Apart from the increase in water usage, point and non-point sources of pollution are contaminating surface water in lakes, rivers with synthetic chemicals which are difficult to treat. Coffee is the second largest consuming commodity after crude oil and other subsidiary fuels creates a lot of wastewater with effluent containing organic waste that can increase the Biological oxygen demand in the surface water. Industries like textile, pharmaceutical, paper and pulp use large amount of water in processing and daily operations. This result in large quantities of wastewater being produced by these industries which can reduce dissolved oxygen in the aquatic environment.

Dyes used in these industries influence water quality due to change in color and prevent sunlight to pass through water. Some of the organic chemicals in the textile dyes are resistant to biological degradation (3). Wastewater of combined coffee and dye can contain complex chemical compounds which might be difficult to treat. Colored dyes not only affect the transparency of water but also can be mutagenic, cancerous, and toxic (3).

The chemical structure of the dyes makes them resistant to fading on exposure to sunlight. They are difficult to decolorize due to synthetic nature and complex structure. To treat dye wastewater various methods are used such as photocatalytic oxidation, ozonation, and electrochemical Destruction (4). For effective and economic treatment of the dye wastewater adsorption technique is used with adsorbents like Activated Carbon, Peanut hull Ash and Onion Peel. Adsorption is widely used because of the low capital cost and efficiency in removing color. To maintain water quality, an additional treatment stage of membrane filtration is used.

## 1.2 Objectives

The objective of the thesis is to observe and analyze the treatment of dye and coffee wastewater using low-cost adsorbents. Summary of the objectives are in the following manner

1. Studying the color removal and increasing the transparency of wastewater using adsorption and microfiltration.

2. Analyzing the BOD removal using Total Organic Carbon in the wastewater after combined adsorption and microfiltration processes.
3. Understanding the dye strength and removal trend of the adsorbent using the plot of transmittance vs adsorbent dosage
4. Observing the water quality after two-stage treatment of adsorption and micro-filtration

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Dyes

Dye is a colored, ionizing, and aromatic compound that has an affinity towards a substrate to which they are applied. They are generally applied to aqueous solutions and most of them are soluble in water. Dyes have the property to absorb light between the wavelength (400-700 nm) i.e. the visible range. Dyes are colored because of the presence of chromophore which is responsible for absorbing and varying the electromagnetic radiation. This property of color and affinity towards water makes the dye a significant pollutant in the wastewater effluent of various textile industries (5).

Biological wastewater treatment is not effective in the treatment of dye wastewater because of the synthetic origin and complex aromatic structure which makes them stable. Based on the ionic properties of dyes they are categorized as cationic, anionic, and non-ionic.

## 2.2 Classification of dyes

Dyes can be classified based on several ways. Each type of dye has a unique chemical structure and bonding characteristics. Based on certain important factors dyes are classified as follows:

1. Classification of dyes based on chemical structure
2. Classification based on the origin
3. Classification based on applicability or industrial usage

### *2.2.1 Classification based on chemical structure*

Chemical classification of the dye is based on the chromophore present in their structures. Some of them are as follows:

1. Azo dyes
2. Nitro or nitroso dyes
3. Triaryl methane dyes
4. Anthraquinone dyes
5. Indigo dyes

Azo dyes are synthetic organic dyes that contain the nitrogen as the azo group such as -N=N- as the chromophore in the chemical structure. They are commercial and highly colored. They are mostly prepared by azo coupling of the amine with an aromatic compound (5). Some of them are methyl orange, congo red and so on.

Nitro or Nitroso dyes contain nitro groups as chromophore and OH- as auxo chrome. Nitroso dyes are aromatic compounds that are resistant to light and heat which are commonly used for dyeing rubbers in the production of wallpapers and paint industry. Some of the nitro and nitroso dyes are naphthol yellow, naphthol green B, mordant green.

Triaryl methane dyes are synthetic organic compounds which have triphenylmethane backbone in the structure. Some of the examples are malachite green, phenolphthalein.

Anthraquinone dyes are organic compounds which have ketone groups in the central ring. They are poorly soluble in water but highly soluble in the organic solvents. Some of the examples of anthraquinone dyes are alizarin, anthrapyrimidine yellow.

Indigo dye is an organic compound which is usually extracted from indigo. It contains carbonyl chromophore. It is used for dyeing textiles and in the production of denim jeans.

*2.2.2 Classification based on origin*

Dyes can be classified based on the source of material. They are mainly classified as follows:

1. Natural Dyes
2. Synthetic Dyes

*Natural dyes*

Natural dyes are colorants derived from natural sources like plants, minerals, and other invertebrates. Dyeing process has been used in the textile industry by humans for thousands of years. Fabrics like silk and wool can be colored by simply dipping in dye water but cotton requires a mordant such as alum to evenly distribute the color. Some of the examples of natural dyes are madder, cochineal.

*Synthetic dyes*

Dyes derived from complex organic and inorganic compounds by man are called synthetic dyes. William Henry Perkin accidentally discovered the first synthetic dye in search of finding a cure for malaria. Since the discovery, they are produced in large scale because of the low production costs and easy application to the fabric. Some of the synthetic dyes are acid dyes, azo dyes, reactive dyes, disperse dyes and so on.

*2.2.3 Classification based on industrial usage*

Most dyes are used in the Textile industry for dyeing fabrics. Classification of the dye in the industries is based on the applicability of dye and fabric. Some of the dyes used are azo dyes, direct dyes, vat dyes, basic dyes, fiber-reactive dyes.

## 2.3 Dyes in wastewater

Textile industries use large amounts of water in the dyeing process. This results in a high volume of dye wastewater enter the surface water. The most significant environmental concern of dye in surface water is that it absorbs and reflect sunlight. Absorption of sunlight reduces the photosynthesis of algae which in turn affects the food chain. The half-life of dyes is very high which makes them remain in the environment for a long time. Due to their stability they are difficult to treat using biological treatment processes. Some of the azo dyes used in the textile industry contains benzidine which is a known carcinogen. Dye wastewater due to the complex aromatic structure and synthetic nature is difficult to treat biologically and not easily biodegradable (6).

## 2.4 Coffee wastewater

Coffee wastewater is the effluent of coffee processing industry. Coffee produced using wet milling process takes large amount of water and release contaminants in the surface water. The resulting effluent after coffee processing contains high amounts of sugar and pectin. The sugar and pectin can be broken down to acetic acid by dissolved oxygen. Depleting DO (Dissolved Oxygen) results in high BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand). Also, the fermentation process used in the effluent from pulpers in the coffee processing pH of the water may be dropped from 7 to 4. This can create acidic conditions in surface water and affect aquatic life (7,8).

**2.5 Acid black 48**

Acid black 48 is a non-disperse, anthraquinone dye. It has the physical characteristic of grey to navy blue color. It has sulfonic acid groups which render the solubility in water. The dye has the affinity to fabric without the need of auxiliary binding agents such as mordants.

The structure of acid black 48 contains amine and sodium hexane sulfonate groups with ketone in the central ring. Anthraquinone dyes are commercially not widely used because they are not cost effective (9).

**2.6 Crystal violet certified**

Crystal violet is a basic dye which is positively charged. This property makes the dye bond with negative charged materials such as acrylics and other synthetic materials. It is triaryl methane dye which can be used as histological stain and Gram's method of classifying bacteria. It has antibacterial, antifungal characteristics and was formerly used as an antiseptic in tropical medication. It has veterinary uses such as prevent the growth of fungi in poultry feed due to its mutagenic and bacteriostatic agent characteristics.

Due to its physical and chemical characteristics, crystal violet persists in environment for long time and poses toxic effects. It is a potential carcinogen and promotes tumor growth in fish affecting food chain (10).

### 2.7 Disperse yellow 3

Disperse Yellow 3 belongs to the group of azo dyes that are not easily soluble in water. They are identified with the physical characteristic of yellow powder. Being a part of azo dye, Disperse Yellow 3 can be used in dyeing of fabrics. It has the characteristic of chromophore azo group (-N=N-). It has been banned by European Union because of the skin sensitizing and allergic properties of the dye. The World Health Organization (WHO) has categorized the dye as a potential carcinogen. Some lab rats exposed to the disperse yellow 3 has developed benign liver tumors. Azo dyes have lower water solubility but, when released to surface water they remain in low concentrations (11). Azo disperse dyes are likely to deposit as sediment in soil if they are released into the soil in the form of sludge. This low solubility of azo disperse dyes in water and volatility in the environment, the bioavailability of the dye to the aquatic species is very high.

### 2.8 Dye wastewater quality parameters

To describe the quality of dye and coffee wastewater we have considered spectrophotometer parameters like absorbance and transmittance. Distilled water is considered as a benchmark for calibration with the absorbance of monochromatic light being 0 and transmittance 100.

Spectrophotometry can be used to calculate water quality parameters like COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand) and concentration of contaminants in the water. Hence the parameters we have considered like absorbance and transmittance is proportional to the concentration of dye and coffee wastewater using beer lambert's law.

## 2.9Absorbance

Absorbance is the measurement of amount of UV/Visible light absorbed by a given sample. Matter in the wastewater samples such as organics, color and nitrates can attract light in different regions of UV-Vis spectrum wavelength. It is given by $A = \log(\frac{1}{T})$ where T is transmittance along the path length of the cell (12).

## 2.10 Transmittance

Transmittance is the fraction of electromagnetic light that pass through the batch sample. Transmittance T is defined as $T = \frac{\Phi_p}{\Phi_r}$, where $\Phi_p$ represents the amount of radiant flux passing through the cell and $\Phi_r$ represents the amount of radiant flux received by the incident light. For an example if a monochromatic light is passed through a sample then when 40% (A =0.2218) of light is absorbed the remaining 60% is the transmittance. The relation between absorbance and transmittance can be theoretically observed using beer-lambert's law (13).

## 2.11 NPOC

NPOC stands for Non-purgeable organic carbon. This component is used to measure the organic carbon of the sample after purging the purgeable organic carbon by adding Hydrochloric acid. When adding the acid IC (Inorganic Carbon) is removed with POC (Purgeable Organic Carbon) in the form of $CO_2$.When a sample contains no inorganic carbon then the TC can be referred to as NPOC. Therefore NPOC = TC – IC

When there are Volatile organic compounds in the sample then NPOC is measured as TC-IC (Total Carbon – Inorganic Carbon)

### 2.12 Treatment technologies in dye wastewater treatment

There are several treatment processes involved in treating dye wastewater. To obtain maximum efficiency and economic viability combined biological with physio-chemical process are used in the dye wastewater treatment plant. Some of the treatment process involves coagulation, adsorption, electrochemical destruction and so on.

### 2.13 Adsorption

Adsorption is defined as a process in which contaminants are adhered to the surface. In a solution where the particles come in to contact with a surface that contains pores to adhere to. This surface phenomenon is because of the electrostatic attraction between the solute particles and the surface of the body in the solution. The contaminants or solute particles which are adhered to the surface are called adsorbate. The solid body on which the particles are accumulated is called adsorbent. Based on the nature of forces acting between the adsorbate and adsorbent, the adsorption process can be classified in to physisorption and chemisorption (14).

In physisorption the nature of bonding involved between adsorbate and adsorbent are the weak van der Waals forces. It is reversible in nature. It is an exothermic process where the heat energy is released in the binding process. Chemisorption mainly occurs because of the covalent bonding between the contaminants and the surface of adsorbent. Chemical adsorption is irreversible. It is an exothermic process but occurs slowly at high temperatures (15).

## 2.14 Adsorption of dyes

To treat dye wastewater from textile industries adsorption is considered as an effective treatment process. Synthetic textile dyes contain organic pollutants which are complex to degrade biologically. This makes the aerobic biological treatment process ineffective to treat dyes in wastewater. Based on several case studies it is observed that activated carbon being an adsorbent gives excellent results in removing color from dye wastewater. But engineering requires a cost-effective treatment to make the treatment process economical.

Hence, several low-cost adsorbents like rice husk ash, fly ash can be used to treat dye wastewater. In a municipal wastewater treatment plant activated carbon can be prepared from sludge. It is cost effective and an efficient way to dispose waste. The sludge contains high nutrients and carbonaceous material that cannot be allowed to be disposed in to land directly (15). Hence activated carbon directly produced at the wastewater treatment plant can be considered as the low-cost adsorbent to treat wastewater.

## 2.15 Effect of adsorbent dosage on dye wastewater

The effect of adsorbent dosage can be observed with change in transmittance. As predicted the percentage removal of color is directly proportional to the adsorbent dosage. As the dose increases the removal capacity reaches to a threshold because of the excess availability of the adsorbent that is accessible to adsorbate. Initially adding adsorbent provides extra surface area and larger number of sorption sites for the adsorbate to get adhered to the surface of the adsorbent. As the adsorbent sites increase more than required the treatment efficiency do not increase due to saturation (16).

**2.16 Effect of pH**

pH is a very important factor in the dye wastewater adsorption process. The electrostatic forces vary according to the pH of the aqueous solution. Therefore, the pH of the dye wastewater plays an important role in the adsorption process. Let us consider an adsorbent which is electropositive. For cationic dyes at lower pH indicating that more positive (H+) ions decrease the amount of dye to be adsorbed because of the less negative charged adsorption sites in the adsorbent (17). For anionic dyes the at low pH the percentage of dye removal increases because of the more positive adsorbent sites.

**2.17 Effect of temperature**

Adsorption is affected by several factors including change in temperature. In the adsorption process two major factors are affected i.e., the equilibrium with respect to the exothermicity and the swelling capacity of the adsorbent. The uptake of the contaminants usually depends on whether the process of adsorption is exothermic or endothermic. To understand whether the adsorption process is endothermic or exothermic depends majorly on Gibbs free energy, enthalpy, and entropy in the adsorption process with change in temperature (18).

**2.18 Effect of dye adsorbent contact time**

The effect of adsorbent varies with the dye contact time. Based on the reference it is observed that as the contact time increased from 5 to 24 hrs. the %absorbance increased from 78 to 88% (19). During the initial period of the contact time i.e. in the first 30 mins the rate of adsorption is rapid due to strong electrostatic forces between dye and adsorbent. After reaching the saturation of adsorption capacity i.e. after attaining the equilibrium, the rate of adsorption is constant. The main reason of adsorption being constant after reaching the saturated adsorption capacity is because of all the available adsorbent surface being filled with the adsorbate.

### 2.19 Types of adsorbents

Industrially adsorbents are classified in to three categories. They are as follows

- Carbon based- Typically hydrophobic and nonpolar
- Polymer based- In a porous polymer matrix, they might be polar on non-polar
- Oxygen containing adsorbents- Typically hydrophilic such as Silica gel and zeolites Based on origin adsorbents are classified as natural and synthetic.

Natural adsorbents used in the process of adsorption include, clay, graphite, charcoal, zeolites and so on. Synthetic adsorbents include byproducts of agricultural and industrial waste such as fly ash, rice husk ash, Peanut hull, Onion Peel and so on. Adsorption capacity of an adsorbent depends on surface area and pore size distribution of the adsorbent material (20).

### 2.20 Membrane filtration methods

Membrane filtration or separation process are used to remove contaminants in the solution by passing the solution through a semipermeable membrane. The separation process of contaminants from the solution depends on the driving force or pressure acting on the semipermeable membrane. Membrane filtration technologies based on the pore size of the membranes are as follows: Microfiltration, Ultra-filtration, Nano-filtration, and reverse osmosis (21).

## 2.21 Microfiltration

Microfiltration is the separation process where suspended particles or inorganics are removed by using a semi-permeable membrane. The separation process is based on driving pressure acting on the membrane. The membranes used in the microfiltration process are designed to remove particles such as sediment, algae, and large bacteria. Although the separation process has wide variety of applications in water treatment process. It is widely used in the treatment of potable water supply.

The main advantage of using the membranes in the treatment of water is because of averting chemicals such as chlorine being used as a traditional disinfectant (22). This makes the membrane process a two-stage treatment including filtration and disinfection together. The only disadvantage in membrane separation process is fouling. Fouling i.e. deposition of sediments on the semipermeable membrane decreases the flux capacity and overall efficiency of the membrane (23,24).

# CHAPTER III

# MATERIALS AND METHODS

## 3.1 Dyes

Dyes used in the treatment process are as follows

1. Acid black 48
2. Crystal violet certified
3. Disperse yellow 3

## 3.2 Adsorbents used

Adsorbents used in the treatment process are as follows:

1. Powdered activated carbon (DARCO, Grade HDC)
2. Peanut hull
3. Onion peel

## 3.3 Equipment used

1. Weighing balance (Ohaus PA1502)
2. Spectrophotometer (Carolina #65-3303)
3. Open air platform shaker (Innova 2300)
4. TOC Analyzer (Shimadzu TOC-L)

### 3.4 Adsorbent preparation

The peanut hulls are bought from Walmart in Cleveland, Ohio. They were ground using blender and sieved to different sizes (3.327-2.362 mm, 2.38-2.362 mm, 2.362-0.6 mm, 0.6-0.425 mm, <0.425 mm). The sieved peanut hull is used as an adsorbent to treat the combined dye and coffee wastewater at different concentrations.

Onion peels used in the treatment process are bought from Sam's club in Cleveland, Ohio. The peel is taken and ground to a fine powder in the blender. The ground onion peel is sieved using 0.6mm US standard sieve. Later the adsorbent is dried in the hot air oven at a temperature of $105^0$C for a period of 24 hrs. to remove any moisture in the ground onion peel. Later the dried onion peel is used at different dosages as a low-cost adsorbent in the treatment process.

### 3.5 Method

A weighing balance with the precision of ± 0.01 g is used for weighing the materials such as dyes, coffee waste and so on. From the weighing materials, dye, and coffee wastewater stock solution of 1L is prepared. From the stock solution, the wastewater is diluted, and the adsorption tests are conducted in batch mode.

The diluted solutions with wastewater were analyzed by absorbance and transmittance using a spectrophotometer. Representative samples of different concentrations were taken to the TOC analyzer and NPOC (Non-Purgeable Organic Carbon) is measured.

Low-cost adsorbents like activated carbon, peanut hull and onion peel are added in the batch adsorption samples. Adsorbents are added with predefined measurements and put on the shaker where the samples are mixed at 100 rpm for 1 minute (Fast Shake) and 30 rpm for 1 hour (Slow shake). After shaking and mixing the samples are left to settle for an hour. The samples are filtered using microfilters (Whatman 41) with pore size 20-25 µm. After combined adsorption and microfiltration, absorbance and transmittance values are analyzed using the spectrophotometer. With the remaining treated sample NPOC values are measured using the Shimadzu TOC analyzer

### 3.6 Run protocols

Table 1 to Table 27 are the tables of run protocols for this research study. The parameters which are varied in this research consist of type of dyes and concentration of dye wastewater and concentration of coffee wastewater type of adsorbent and dosage of adsorbent

**Table I:** Run protocol of low strength acid black 48 with PAC.

| Run order | Dye concentration(low) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 50 | 0 | 0 |
| 2 | 50 | 0 | 100 |
| 3 | 50 | 0 | 150 |
| 4 | 50 | 0 | 200 |
| 5 | 50 | 0 | 250 |
| 6 | 50 | 0 | 300 |
| 7 | 50 | 0.2 | 0 |
| 8 | 50 | 0.2 | 100 |
| 9 | 50 | 0.2 | 150 |
| 10 | 50 | 0.2 | 200 |
| 11 | 50 | 0.2 | 250 |
| 12 | 50 | 0.2 | 300 |
| 13 | 50 | 0.4 | 0 |
| 14 | 50 | 0.4 | 100 |
| 15 | 50 | 0.4 | 150 |
| 16 | 50 | 0.4 | 200 |
| 17 | 50 | 0.4 | 250 |
| 18 | 50 | 0.4 | 300 |
| 19 | 50 | 0.6 | 0 |
| 20 | 50 | 0.6 | 100 |
| 21 | 50 | 0.6 | 150 |
| 22 | 50 | 0.6 | 200 |
| 23 | 50 | 0.6 | 250 |
| 24 | 50 | 0.6 | 300 |
| 25 | 50 | 0.8 | 0 |
| 26 | 50 | 0.8 | 100 |
| 27 | 50 | 0.8 | 150 |
| 28 | 50 | 0.8 | 200 |
| 29 | 50 | 0.8 | 250 |
| 30 | 50 | 0.8 | 300 |
| 31 | 50 | 1 | 0 |
| 32 | 50 | 1 | 100 |
| 33 | 50 | 1 | 150 |
| 34 | 50 | 1 | 200 |
| 35 | 50 | 1 | 250 |
| 36 | 100 | 1 | 300 |

**Table II:** Run protocol of medium strength acid black 48 with PAC.

| Run order | Dye concentration(medium) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 100 | 0 | 100 |
| 3 | 100 | 0 | 150 |
| 4 | 100 | 0 | 200 |
| 5 | 100 | 0 | 250 |
| 6 | 100 | 0 | 300 |
| 7 | 100 | 0.2 | 0 |
| 8 | 100 | 0.2 | 100 |
| 9 | 100 | 0.2 | 150 |
| 10 | 100 | 0.2 | 200 |
| 11 | 100 | 0.2 | 250 |
| 12 | 100 | 0.2 | 300 |
| 13 | 100 | 0.4 | 0 |
| 14 | 100 | 0.4 | 100 |
| 15 | 100 | 0.4 | 150 |
| 16 | 100 | 0.4 | 200 |
| 17 | 100 | 0.4 | 250 |
| 18 | 100 | 0.4 | 300 |
| 19 | 100 | 0.6 | 0 |
| 20 | 100 | 0.6 | 100 |
| 21 | 100 | 0.6 | 150 |
| 22 | 100 | 0.6 | 200 |
| 23 | 100 | 0.6 | 250 |
| 24 | 100 | 0.6 | 300 |
| 25 | 100 | 0.8 | 0 |
| 26 | 100 | 0.8 | 100 |
| 27 | 100 | 0.8 | 150 |
| 28 | 100 | 0.8 | 200 |
| 29 | 100 | 0.8 | 250 |
| 30 | 100 | 0.8 | 300 |
| 31 | 100 | 1 | 0 |
| 32 | 100 | 1 | 100 |
| 33 | 100 | 1 | 150 |
| 34 | 100 | 1 | 200 |
| 35 | 100 | 1 | 250 |
| 36 | 100 | 1 | 300 |

**Table III:** Run protocol of high strength acid black 48 with PAC.

| Run order | Dye concentration(high) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 200 | 0 | 0 |
| 2 | 200 | 0 | 100 |
| 3 | 200 | 0 | 150 |
| 4 | 200 | 0 | 200 |
| 5 | 200 | 0 | 250 |
| 6 | 200 | 0 | 300 |
| 7 | 200 | 0.2 | 0 |
| 8 | 200 | 0.2 | 100 |
| 9 | 200 | 0.2 | 150 |
| 10 | 200 | 0.2 | 200 |
| 11 | 200 | 0.2 | 250 |
| 12 | 200 | 0.2 | 300 |
| 13 | 200 | 0.4 | 0 |
| 14 | 200 | 0.4 | 100 |
| 15 | 200 | 0.4 | 150 |
| 16 | 200 | 0.4 | 200 |
| 17 | 200 | 0.4 | 250 |
| 18 | 200 | 0.4 | 300 |
| 19 | 200 | 0.6 | 0 |
| 20 | 200 | 0.6 | 100 |
| 21 | 200 | 0.6 | 150 |
| 22 | 200 | 0.6 | 200 |
| 23 | 200 | 0.6 | 250 |
| 24 | 200 | 0.6 | 300 |
| 25 | 200 | 0.8 | 0 |
| 26 | 200 | 0.8 | 100 |
| 27 | 200 | 0.8 | 150 |
| 28 | 200 | 0.8 | 200 |
| 29 | 200 | 0.8 | 250 |
| 30 | 200 | 0.8 | 300 |
| 31 | 200 | 1 | 0 |
| 32 | 200 | 1 | 100 |
| 33 | 200 | 1 | 150 |
| 34 | 200 | 1 | 200 |
| 35 | 200 | 1 | 250 |
| 36 | 200 | 1 | 300 |

**Table IV:** Run protocol of low strength acid black 48 with peanut hull.

| Run order | Dye concentration(low) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 50 | 0 | 0 |
| 2 | 50 | 0 | 100 |
| 3 | 50 | 0 | 150 |
| 4 | 50 | 0 | 200 |
| 5 | 50 | 0 | 250 |
| 6 | 50 | 0 | 300 |
| 7 | 50 | 3.327-2.38 | 0 |
| 8 | 50 | 3.327-2.38 | 100 |
| 9 | 50 | 3.327-2.38 | 150 |
| 10 | 50 | 3.327-2.38 | 200 |
| 11 | 50 | 3.327-2.38 | 250 |
| 12 | 50 | 3.327-2.38 | 300 |
| 13 | 50 | 2.38-2.362 | 0 |
| 14 | 50 | 2.38-2.362 | 100 |
| 15 | 50 | 2.38-2.362 | 150 |
| 16 | 50 | 2.38-2.362 | 200 |
| 17 | 50 | 2.38-2.362 | 250 |
| 18 | 50 | 2.38-2.362 | 300 |
| 19 | 50 | 2362-0.6 | 0 |
| 20 | 50 | 2362-0.6 | 100 |
| 21 | 50 | 2.362-0.6 | 150 |
| 22 | 50 | 2.362-0.6 | 200 |
| 23 | 50 | 2.362-0.6 | 250 |
| 24 | 50 | 2.362-0.6 | 300 |
| 25 | 50 | 0.6-0.425 | 0 |
| 26 | 50 | 0.6-0.425 | 100 |
| 27 | 50 | 0.6-0.425 | 150 |
| 28 | 50 | 0.6-0.425 | 200 |
| 29 | 50 | 0.6-0.425 | 250 |
| 30 | 50 | 0.6-0.425 | 300 |
| 31 | 50 | <0.425 | 0 |
| 32 | 50 | <0.425 | 100 |
| 33 | 50 | <0.425 | 150 |
| 34 | 50 | <0.425 | 200 |
| 35 | 50 | <0.425 | 250 |
| 36 | 50 | <0.425 | 300 |

**Table V:** Run protocol of medium strength acid black 48 with peanut hull.

| Run order | Dye concentration(medium) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 100 | 0 | 100 |
| 3 | 100 | 0 | 150 |
| 4 | 100 | 0 | 200 |
| 5 | 100 | 0 | 250 |
| 6 | 100 | 0 | 300 |
| 7 | 100 | 3.327-2.38 | 0 |
| 8 | 100 | 3.327-2.38 | 100 |
| 9 | 100 | 3.327-2.38 | 150 |
| 10 | 100 | 3.327-2.38 | 200 |
| 11 | 100 | 3.327-2.38 | 250 |
| 12 | 100 | 3.327-2.38 | 300 |
| 13 | 100 | 2.38-2.362 | 0 |
| 14 | 100 | 2.38-2.362 | 100 |
| 15 | 100 | 2.38-2.362 | 150 |
| 16 | 100 | 2.38-2.362 | 200 |
| 17 | 100 | 2.38-2.362 | 250 |
| 18 | 100 | 2.38-2.362 | 300 |
| 19 | 100 | 2362-0.6 | 0 |
| 20 | 100 | 2362-0.6 | 100 |
| 21 | 100 | 2.362-0.6 | 150 |
| 22 | 100 | 2.362-0.6 | 200 |
| 23 | 100 | 2.362-0.6 | 250 |
| 24 | 100 | 2.362-0.6 | 300 |
| 25 | 100 | 0.6-0.425 | 0 |
| 26 | 100 | 0.6-0.425 | 100 |
| 27 | 100 | 0.6-0.425 | 150 |
| 28 | 100 | 0.6-0.425 | 200 |
| 29 | 100 | 0.6-0.425 | 250 |
| 30 | 100 | 0.6-0.425 | 300 |
| 31 | 100 | <0.425 | 0 |
| 32 | 100 | <0.425 | 100 |
| 33 | 100 | <0.425 | 150 |
| 34 | 100 | <0.425 | 200 |
| 35 | 100 | <0.425 | 250 |
| 36 | 100 | <0.425 | 300 |

**Table VI:** Run protocol of high strength acid black 48 with peanut hull.

| Run order | Dye concentration(high) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 200 | 0 | 0 |
| 2 | 200 | 0 | 100 |
| 3 | 200 | 0 | 150 |
| 4 | 200 | 0 | 200 |
| 5 | 200 | 0 | 250 |
| 6 | 200 | 0 | 300 |
| 7 | 200 | 3.327-2.38 | 0 |
| 8 | 200 | 3.327-2.38 | 100 |
| 9 | 200 | 3.327-2.38 | 150 |
| 10 | 200 | 3.327-2.38 | 200 |
| 11 | 200 | 3.327-2.38 | 250 |
| 12 | 200 | 3.327-2.38 | 300 |
| 13 | 200 | 2.38-2.362 | 0 |
| 14 | 200 | 2.38-2.362 | 100 |
| 15 | 200 | 2.38-2.362 | 150 |
| 16 | 200 | 2.38-2.362 | 200 |
| 17 | 200 | 2.38-2.362 | 250 |
| 18 | 200 | 2.38-2.362 | 300 |
| 19 | 200 | 2362-0.6 | 0 |
| 20 | 200 | 2362-0.6 | 100 |
| 21 | 200 | 2.362-0.6 | 150 |
| 22 | 200 | 2.362-0.6 | 200 |
| 23 | 200 | 2.362-0.6 | 250 |
| 24 | 200 | 2.362-0.6 | 300 |
| 25 | 200 | 0.6-0.425 | 0 |
| 26 | 200 | 0.6-0.425 | 100 |
| 27 | 200 | 0.6-0.425 | 150 |
| 28 | 200 | 0.6-0.425 | 200 |
| 29 | 200 | 0.6-0.425 | 250 |
| 30 | 200 | 0.6-0.425 | 300 |
| 31 | 200 | <0.425 | 0 |
| 32 | 200 | <0.425 | 100 |
| 33 | 200 | <0.425 | 150 |
| 34 | 200 | <0.425 | 200 |
| 35 | 200 | <0.425 | 250 |
| 36 | 200 | <0.425 | 300 |

**Table VII:** Run protocol of low strength acid black 48 with onion peel.

| Run order | Dye concentration(low) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 50 | 0 | 0 |
| 2 | 50 | 0 | 100 |
| 3 | 50 | 0 | 150 |
| 4 | 50 | 0 | 200 |
| 5 | 50 | 0 | 250 |
| 6 | 50 | 0 | 300 |
| 7 | 50 | 0.4 | 0 |
| 8 | 50 | 0.4 | 100 |
| 9 | 50 | 0.4 | 150 |
| 10 | 50 | 0.4 | 200 |
| 11 | 50 | 0.4 | 250 |
| 12 | 50 | 0.4 | 300 |
| 13 | 50 | 0.8 | 0 |
| 14 | 50 | 0.8 | 100 |
| 15 | 50 | 0.8 | 150 |
| 16 | 50 | 0.8 | 200 |
| 17 | 50 | 0.8 | 250 |
| 18 | 50 | 0.8 | 300 |
| 19 | 50 | 1.2 | 0 |
| 20 | 50 | 1.2 | 100 |
| 21 | 50 | 1.2 | 150 |
| 22 | 50 | 1.2 | 200 |
| 23 | 50 | 1.2 | 250 |
| 24 | 50 | 1.2 | 300 |
| 25 | 50 | 1.6 | 0 |
| 26 | 50 | 1.6 | 100 |
| 27 | 50 | 1.6 | 150 |
| 28 | 50 | 1.6 | 200 |
| 29 | 50 | 1.6 | 250 |
| 30 | 50 | 1.6 | 300 |
| 31 | 50 | 2 | 0 |
| 32 | 50 | 2 | 100 |
| 33 | 50 | 2 | 150 |
| 34 | 50 | 2 | 200 |
| 35 | 50 | 2 | 250 |
| 36 | 50 | 2 | 300 |

**Table VIII:** Run protocol of medium strength acid black 48 with onion peel**.**

| Run order | Dye concentration(medium) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 100 | 0 | 100 |
| 3 | 100 | 0 | 150 |
| 4 | 100 | 0 | 200 |
| 5 | 100 | 0 | 250 |
| 6 | 100 | 0 | 300 |
| 7 | 100 | 0.4 | 0 |
| 8 | 100 | 0.4 | 100 |
| 9 | 100 | 0.4 | 150 |
| 10 | 100 | 0.4 | 200 |
| 11 | 100 | 0.4 | 250 |
| 12 | 100 | 0.4 | 300 |
| 13 | 100 | 0.8 | 0 |
| 14 | 100 | 0.8 | 100 |
| 15 | 100 | 0.8 | 150 |
| 16 | 100 | 0.8 | 200 |
| 17 | 100 | 0.8 | 250 |
| 18 | 100 | 0.8 | 300 |
| 19 | 100 | 1.2 | 0 |
| 20 | 100 | 1.2 | 100 |
| 21 | 100 | 1.2 | 150 |
| 22 | 100 | 1.2 | 200 |
| 23 | 100 | 1.2 | 250 |
| 24 | 100 | 1.2 | 300 |
| 25 | 100 | 1.6 | 0 |
| 26 | 100 | 1.6 | 100 |
| 27 | 100 | 1.6 | 150 |
| 28 | 100 | 1.6 | 200 |
| 29 | 100 | 1.6 | 250 |
| 30 | 100 | 1.6 | 300 |
| 31 | 100 | 2 | 0 |
| 32 | 100 | 2 | 100 |
| 33 | 100 | 2 | 150 |
| 34 | 100 | 2 | 200 |
| 35 | 100 | 2 | 250 |
| 36 | 100 | 2 | 300 |

**Table IX:** Run protocol of high strength acid black 48 with onion peel.

| Run order | Dye concentration(high) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 200 | 0 | 0 |
| 2 | 200 | 0 | 100 |
| 3 | 200 | 0 | 150 |
| 4 | 200 | 0 | 200 |
| 5 | 200 | 0 | 250 |
| 6 | 200 | 0 | 300 |
| 7 | 200 | 0.4 | 0 |
| 8 | 200 | 0.4 | 100 |
| 9 | 200 | 0.4 | 150 |
| 10 | 200 | 0.4 | 200 |
| 11 | 200 | 0.4 | 250 |
| 12 | 200 | 0.4 | 300 |
| 13 | 200 | 0.8 | 0 |
| 14 | 200 | 0.8 | 100 |
| 15 | 200 | 0.8 | 150 |
| 16 | 200 | 0.8 | 200 |
| 17 | 200 | 0.8 | 250 |
| 18 | 200 | 0.8 | 300 |
| 19 | 200 | 1.2 | 0 |
| 20 | 200 | 1.2 | 100 |
| 21 | 200 | 1.2 | 150 |
| 22 | 200 | 1.2 | 200 |
| 23 | 200 | 1.2 | 250 |
| 24 | 200 | 1.2 | 300 |
| 25 | 200 | 1.6 | 0 |
| 26 | 200 | 1.6 | 100 |
| 27 | 200 | 1.6 | 150 |
| 28 | 200 | 1.6 | 200 |
| 29 | 200 | 1.6 | 250 |
| 30 | 200 | 1.6 | 300 |
| 31 | 200 | 2 | 0 |
| 32 | 200 | 2 | 100 |
| 33 | 200 | 2 | 150 |
| 34 | 200 | 2 | 200 |
| 35 | 200 | 2 | 250 |
| 36 | 200 | 2 | 300 |

**Table X:** Run protocol of low strength crystal violet with PAC.

| Run order | Dye concentration(low) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 5 | 0 | 0 |
| 2 | 5 | 0 | 100 |
| 3 | 5 | 0 | 150 |
| 4 | 5 | 0 | 200 |
| 5 | 5 | 0 | 250 |
| 6 | 5 | 0 | 300 |
| 7 | 5 | 0.2 | 0 |
| 8 | 5 | 0.2 | 100 |
| 9 | 5 | 0.2 | 150 |
| 10 | 5 | 0.2 | 200 |
| 11 | 5 | 0.2 | 250 |
| 12 | 5 | 0.2 | 300 |
| 13 | 5 | 0.4 | 0 |
| 14 | 5 | 0.4 | 100 |
| 15 | 5 | 0.4 | 150 |
| 16 | 5 | 0.4 | 200 |
| 17 | 5 | 0.4 | 250 |
| 18 | 5 | 0.4 | 300 |
| 19 | 5 | 0.6 | 0 |
| 20 | 5 | 0.6 | 100 |
| 21 | 5 | 0.6 | 150 |
| 22 | 5 | 0.6 | 200 |
| 23 | 5 | 0.6 | 250 |
| 24 | 5 | 0.6 | 300 |
| 25 | 5 | 0.8 | 0 |
| 26 | 5 | 0.8 | 100 |
| 27 | 5 | 0.8 | 150 |
| 28 | 5 | 0.8 | 200 |
| 29 | 5 | 0.8 | 250 |
| 30 | 5 | 0.8 | 300 |
| 31 | 5 | 1 | 0 |
| 32 | 5 | 1 | 100 |
| 33 | 5 | 1 | 150 |
| 34 | 5 | 1 | 200 |
| 35 | 5 | 1 | 250 |
| 36 | 5 | 1 | 300 |

**Table XI:** Run protocol of medium strength crystal violet with PAC.

| Run order | Dye concentration(medium) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 10 | 0 | 0 |
| 2 | 10 | 0 | 100 |
| 3 | 10 | 0 | 150 |
| 4 | 10 | 0 | 200 |
| 5 | 10 | 0 | 250 |
| 6 | 10 | 0 | 300 |
| 7 | 10 | 0.2 | 0 |
| 8 | 10 | 0.2 | 100 |
| 9 | 10 | 0.2 | 150 |
| 10 | 10 | 0.2 | 200 |
| 11 | 10 | 0.2 | 250 |
| 12 | 10 | 0.2 | 300 |
| 13 | 10 | 0.4 | 0 |
| 14 | 10 | 0.4 | 100 |
| 15 | 10 | 0.4 | 150 |
| 16 | 10 | 0.4 | 200 |
| 17 | 10 | 0.4 | 250 |
| 18 | 10 | 0.4 | 300 |
| 19 | 10 | 0.6 | 0 |
| 20 | 10 | 0.6 | 100 |
| 21 | 10 | 0.6 | 150 |
| 22 | 10 | 0.6 | 200 |
| 23 | 10 | 0.6 | 250 |
| 24 | 10 | 0.6 | 300 |
| 25 | 10 | 0.8 | 0 |
| 26 | 10 | 0.8 | 100 |
| 27 | 10 | 0.8 | 150 |
| 28 | 10 | 0.8 | 200 |
| 29 | 10 | 0.8 | 250 |
| 30 | 10 | 0.8 | 300 |
| 31 | 10 | 1 | 0 |
| 32 | 10 | 1 | 100 |
| 33 | 10 | 1 | 150 |
| 34 | 10 | 1 | 200 |
| 35 | 10 | 1 | 250 |
| 36 | 10 | 1 | 300 |

**Table XII:** Run protocol of high strength crystal violet with PAC.

| Run order | Dye concentration(high) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 20 | 0 | 0 |
| 2 | 20 | 0 | 100 |
| 3 | 20 | 0 | 150 |
| 4 | 20 | 0 | 200 |
| 5 | 20 | 0 | 250 |
| 6 | 20 | 0 | 300 |
| 7 | 20 | 0.2 | 0 |
| 8 | 20 | 0.2 | 100 |
| 9 | 20 | 0.2 | 150 |
| 10 | 20 | 0.2 | 200 |
| 11 | 20 | 0.2 | 250 |
| 12 | 20 | 0.2 | 300 |
| 13 | 20 | 0.4 | 0 |
| 14 | 20 | 0.4 | 100 |
| 15 | 20 | 0.4 | 150 |
| 16 | 20 | 0.4 | 200 |
| 17 | 20 | 0.4 | 250 |
| 18 | 20 | 0.4 | 300 |
| 19 | 20 | 0.6 | 0 |
| 20 | 20 | 0.6 | 100 |
| 21 | 20 | 0.6 | 150 |
| 22 | 20 | 0.6 | 200 |
| 23 | 20 | 0.6 | 250 |
| 24 | 20 | 0.6 | 300 |
| 25 | 20 | 0.8 | 0 |
| 26 | 20 | 0.8 | 100 |
| 27 | 20 | 0.8 | 150 |
| 28 | 20 | 0.8 | 200 |
| 29 | 20 | 0.8 | 250 |
| 30 | 20 | 0.8 | 300 |
| 31 | 20 | 1 | 0 |
| 32 | 20 | 1 | 100 |
| 33 | 20 | 1 | 150 |
| 34 | 20 | 1 | 200 |
| 35 | 20 | 1 | 250 |
| 36 | 20 | 1 | 300 |

**Table XIII:** Run protocol of low strength crystal violet with peanut hull.

| Run order | Dye concentration(low) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 5 | 0 | 0 |
| 2 | 5 | 0 | 100 |
| 3 | 5 | 0 | 150 |
| 4 | 5 | 0 | 200 |
| 5 | 5 | 0 | 250 |
| 6 | 5 | 0 | 300 |
| 7 | 5 | 3.327-2.38 | 0 |
| 8 | 5 | 3.327-2.38 | 100 |
| 9 | 5 | 3.327-2.38 | 150 |
| 10 | 5 | 3.327-2.38 | 200 |
| 11 | 5 | 3.327-2.38 | 250 |
| 12 | 5 | 3.327-2.38 | 300 |
| 13 | 5 | 2.38-2.362 | 0 |
| 14 | 5 | 2.38-2.362 | 100 |
| 15 | 5 | 2.38-2.362 | 150 |
| 16 | 5 | 2.38-2.362 | 200 |
| 17 | 5 | 2.38-2.362 | 250 |
| 18 | 5 | 2.38-2.362 | 300 |
| 19 | 5 | 2362-0.6 | 0 |
| 20 | 5 | 2362-0.6 | 100 |
| 21 | 5 | 2.362-0.6 | 150 |
| 22 | 5 | 2.362-0.6 | 200 |
| 23 | 5 | 2.362-0.6 | 250 |
| 24 | 5 | 2.362-0.6 | 300 |
| 25 | 5 | 0.6-0.425 | 0 |
| 26 | 5 | 0.6-0.425 | 100 |
| 27 | 5 | 0.6-0.425 | 150 |
| 28 | 5 | 0.6-0.425 | 200 |
| 29 | 5 | 0.6-0.425 | 250 |
| 30 | 5 | 0.6-0.425 | 300 |
| 31 | 5 | <0.425 | 0 |
| 32 | 5 | <0.425 | 100 |
| 33 | 5 | <0.425 | 150 |
| 34 | 5 | <0.425 | 200 |
| 35 | 5 | <0.425 | 250 |
| 36 | 5 | <0.425 | 300 |

**Table XIV:** Run protocol of medium strength crystal violet with peanut hull.

| Run order | Dye concentration(medium) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 10 | 0 | 0 |
| 2 | 10 | 0 | 100 |
| 3 | 10 | 0 | 150 |
| 4 | 10 | 0 | 200 |
| 5 | 10 | 0 | 250 |
| 6 | 10 | 0 | 300 |
| 7 | 10 | 3.327-2.38 | 0 |
| 8 | 10 | 3.327-2.38 | 100 |
| 9 | 10 | 3.327-2.38 | 150 |
| 10 | 10 | 3.327-2.38 | 200 |
| 11 | 10 | 3.327-2.38 | 250 |
| 12 | 10 | 3.327-2.38 | 300 |
| 13 | 10 | 2.38-2.362 | 0 |
| 14 | 10 | 2.38-2.362 | 100 |
| 15 | 10 | 2.38-2.362 | 150 |
| 16 | 10 | 2.38-2.362 | 200 |
| 17 | 10 | 2.38-2.362 | 250 |
| 18 | 10 | 2.38-2.362 | 300 |
| 19 | 10 | 2362-0.6 | 0 |
| 20 | 10 | 2362-0.6 | 100 |
| 21 | 10 | 2.362-0.6 | 150 |
| 22 | 10 | 2.362-0.6 | 200 |
| 23 | 10 | 2.362-0.6 | 250 |
| 24 | 10 | 2.362-0.6 | 300 |
| 25 | 10 | 0.6-0.425 | 0 |
| 26 | 10 | 0.6-0.425 | 100 |
| 27 | 10 | 0.6-0.425 | 150 |
| 28 | 10 | 0.6-0.425 | 200 |
| 29 | 10 | 0.6-0.425 | 250 |
| 30 | 10 | 0.6-0.425 | 300 |
| 31 | 10 | <0.425 | 0 |
| 32 | 10 | <0.425 | 100 |
| 33 | 10 | <0.425 | 150 |
| 34 | 10 | <0.425 | 200 |
| 35 | 10 | <0.425 | 250 |
| 36 | 10 | <0.425 | 300 |

**Table XV:** Run protocol of high strength crystal violet with peanut hull**.**

| Run order | Dye concentration(high) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 20 | 0 | 0 |
| 2 | 20 | 0 | 100 |
| 3 | 20 | 0 | 150 |
| 4 | 20 | 0 | 200 |
| 5 | 20 | 0 | 250 |
| 6 | 20 | 0 | 300 |
| 7 | 20 | 3.327-2.38 | 0 |
| 8 | 20 | 3.327-2.38 | 100 |
| 9 | 20 | 3.327-2.38 | 150 |
| 10 | 20 | 3.327-2.38 | 200 |
| 11 | 20 | 3.327-2.38 | 250 |
| 12 | 20 | 3.327-2.38 | 300 |
| 13 | 20 | 2.38-2.362 | 0 |
| 14 | 20 | 2.38-2.362 | 100 |
| 15 | 20 | 2.38-2.362 | 150 |
| 16 | 20 | 2.38-2.362 | 200 |
| 17 | 20 | 2.38-2.362 | 250 |
| 18 | 20 | 2.38-2.362 | 300 |
| 19 | 20 | 2362-0.6 | 0 |
| 20 | 20 | 2362-0.6 | 100 |
| 21 | 20 | 2.362-0.6 | 150 |
| 22 | 20 | 2.362-0.6 | 200 |
| 23 | 20 | 2.362-0.6 | 250 |
| 24 | 20 | 2.362-0.6 | 300 |
| 25 | 20 | 0.6-0.425 | 0 |
| 26 | 20 | 0.6-0.425 | 100 |
| 27 | 20 | 0.6-0.425 | 150 |
| 28 | 20 | 0.6-0.425 | 200 |
| 29 | 20 | 0.6-0.425 | 250 |
| 30 | 20 | 0.6-0.425 | 300 |
| 31 | 20 | <0.425 | 0 |
| 32 | 20 | <0.425 | 100 |
| 33 | 20 | <0.425 | 150 |
| 34 | 20 | <0.425 | 200 |
| 35 | 20 | <0.425 | 250 |
| 36 | 20 | <0.425 | 300 |

**Table XVI:** Run protocol of low strength crystal violet with onion peel.

| Run order | Dye concentration(low) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 5 | 0 | 0 |
| 2 | 5 | 0 | 100 |
| 3 | 5 | 0 | 150 |
| 4 | 5 | 0 | 200 |
| 5 | 5 | 0 | 250 |
| 6 | 5 | 0 | 300 |
| 7 | 5 | 0.4 | 0 |
| 8 | 5 | 0.4 | 100 |
| 9 | 5 | 0.4 | 150 |
| 10 | 5 | 0.4 | 200 |
| 11 | 5 | 0.4 | 250 |
| 12 | 5 | 0.4 | 300 |
| 13 | 5 | 0.8 | 0 |
| 14 | 5 | 0.8 | 100 |
| 15 | 5 | 0.8 | 150 |
| 16 | 5 | 0.8 | 200 |
| 17 | 5 | 0.8 | 250 |
| 18 | 5 | 0.8 | 300 |
| 19 | 5 | 1.2 | 0 |
| 20 | 5 | 1.2 | 100 |
| 21 | 5 | 1.2 | 150 |
| 22 | 5 | 1.2 | 200 |
| 23 | 5 | 1.2 | 250 |
| 24 | 5 | 1.2 | 300 |
| 25 | 5 | 1.6 | 0 |
| 26 | 5 | 1.6 | 100 |
| 27 | 5 | 1.6 | 150 |
| 28 | 5 | 1.6 | 200 |
| 29 | 5 | 1.6 | 250 |
| 30 | 5 | 1.6 | 300 |
| 31 | 5 | 2 | 0 |
| 32 | 5 | 2 | 100 |
| 33 | 5 | 2 | 150 |
| 34 | 5 | 2 | 200 |
| 35 | 5 | 2 | 250 |
| 36 | 5 | 2 | 300 |

**Table XVII:** Run protocol of medium strength crystal violet with onion peel**.**

| Run order | Dye concentration(medium) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 10 | 0 | 0 |
| 2 | 10 | 0 | 100 |
| 3 | 10 | 0 | 150 |
| 4 | 10 | 0 | 200 |
| 5 | 10 | 0 | 250 |
| 6 | 10 | 0 | 300 |
| 7 | 10 | 0.4 | 0 |
| 8 | 10 | 0.4 | 100 |
| 9 | 10 | 0.4 | 150 |
| 10 | 10 | 0.4 | 200 |
| 11 | 10 | 0.4 | 250 |
| 12 | 10 | 0.4 | 300 |
| 13 | 10 | 0.8 | 0 |
| 14 | 10 | 0.8 | 100 |
| 15 | 10 | 0.8 | 150 |
| 16 | 10 | 0.8 | 200 |
| 17 | 10 | 0.8 | 250 |
| 18 | 10 | 0.8 | 300 |
| 19 | 10 | 1.2 | 0 |
| 20 | 10 | 1.2 | 100 |
| 21 | 10 | 1.2 | 150 |
| 22 | 10 | 1.2 | 200 |
| 23 | 10 | 1.2 | 250 |
| 24 | 10 | 1.2 | 300 |
| 25 | 10 | 1.6 | 0 |
| 26 | 10 | 1.6 | 100 |
| 27 | 10 | 1.6 | 150 |
| 28 | 10 | 1.6 | 200 |
| 29 | 10 | 1.6 | 250 |
| 30 | 10 | 1.6 | 300 |
| 31 | 10 | 2 | 0 |
| 32 | 10 | 2 | 100 |
| 33 | 10 | 2 | 150 |
| 34 | 10 | 2 | 200 |
| 35 | 10 | 2 | 250 |
| 36 | 10 | 2 | 300 |

**Table XVIII:** Run protocol of high strength crystal violet with onion peel.

| Run order | Dye concentration(high) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 20 | 0 | 0 |
| 2 | 20 | 0 | 100 |
| 3 | 20 | 0 | 150 |
| 4 | 20 | 0 | 200 |
| 5 | 20 | 0 | 250 |
| 6 | 20 | 0 | 300 |
| 7 | 20 | 0.4 | 0 |
| 8 | 20 | 0.4 | 100 |
| 9 | 20 | 0.4 | 150 |
| 10 | 20 | 0.4 | 200 |
| 11 | 20 | 0.4 | 250 |
| 12 | 20 | 0.4 | 300 |
| 13 | 20 | 0.8 | 0 |
| 14 | 20 | 0.8 | 100 |
| 15 | 20 | 0.8 | 150 |
| 16 | 20 | 0.8 | 200 |
| 17 | 20 | 0.8 | 250 |
| 18 | 20 | 0.8 | 300 |
| 19 | 20 | 1.2 | 0 |
| 20 | 20 | 1.2 | 100 |
| 21 | 20 | 1.2 | 150 |
| 22 | 20 | 1.2 | 200 |
| 23 | 20 | 1.2 | 250 |
| 24 | 20 | 1.2 | 300 |
| 25 | 20 | 1.6 | 0 |
| 26 | 20 | 1.6 | 100 |
| 27 | 20 | 1.6 | 150 |
| 28 | 20 | 1.6 | 200 |
| 29 | 20 | 1.6 | 250 |
| 30 | 20 | 1.6 | 300 |
| 31 | 20 | 2 | 0 |
| 32 | 20 | 2 | 100 |
| 33 | 20 | 2 | 150 |
| 34 | 20 | 2 | 200 |
| 35 | 20 | 2 | 250 |
| 36 | 20 | 2 | 300 |

**Table XIX:** Run protocol of low strength disperse yellow 3 with PAC.

| Run order | Dye concentration(low) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 50 | 0 | 0 |
| 2 | 50 | 0 | 100 |
| 3 | 50 | 0 | 150 |
| 4 | 50 | 0 | 200 |
| 5 | 50 | 0 | 250 |
| 6 | 50 | 0 | 300 |
| 7 | 50 | 0.2 | 0 |
| 8 | 50 | 0.2 | 100 |
| 9 | 50 | 0.2 | 150 |
| 10 | 50 | 0.2 | 200 |
| 11 | 50 | 0.2 | 250 |
| 12 | 50 | 0.2 | 300 |
| 13 | 50 | 0.4 | 0 |
| 14 | 50 | 0.4 | 100 |
| 15 | 50 | 0.4 | 150 |
| 16 | 50 | 0.4 | 200 |
| 17 | 50 | 0.4 | 250 |
| 18 | 50 | 0.4 | 300 |
| 19 | 50 | 0.6 | 0 |
| 20 | 50 | 0.6 | 100 |
| 21 | 50 | 0.6 | 150 |
| 22 | 50 | 0.6 | 200 |
| 23 | 50 | 0.6 | 250 |
| 24 | 50 | 0.6 | 300 |
| 25 | 50 | 0.8 | 0 |
| 26 | 50 | 0.8 | 100 |
| 27 | 50 | 0.8 | 150 |
| 28 | 50 | 0.8 | 200 |
| 29 | 50 | 0.8 | 250 |
| 30 | 50 | 0.8 | 300 |
| 31 | 50 | 1 | 0 |
| 32 | 50 | 1 | 100 |
| 33 | 50 | 1 | 150 |
| 34 | 50 | 1 | 200 |
| 35 | 50 | 1 | 250 |
| 36 | 50 | 1 | 300 |

**Table XX:** Run protocol of medium strength disperse yellow 3 with PAC.

| **Run order** | **Dye concentration(medium) (ppm)** | **Adsorbent dosage (g)** | **Coffee concentration (ppm)** |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 100 | 0 | 100 |
| 3 | 100 | 0 | 150 |
| 4 | 100 | 0 | 200 |
| 5 | 100 | 0 | 250 |
| 6 | 100 | 0 | 300 |
| 7 | 100 | 0.2 | 0 |
| 8 | 100 | 0.2 | 100 |
| 9 | 100 | 0.2 | 150 |
| 10 | 100 | 0.2 | 200 |
| 11 | 100 | 0.2 | 250 |
| 12 | 100 | 0.2 | 300 |
| 13 | 100 | 0.4 | 0 |
| 14 | 100 | 0.4 | 100 |
| 15 | 100 | 0.4 | 150 |
| 16 | 100 | 0.4 | 200 |
| 17 | 100 | 0.4 | 250 |
| 18 | 100 | 0.4 | 300 |
| 19 | 100 | 0.6 | 0 |
| 20 | 100 | 0.6 | 100 |
| 21 | 100 | 0.6 | 150 |
| 22 | 100 | 0.6 | 200 |
| 23 | 100 | 0.6 | 250 |
| 24 | 100 | 0.6 | 300 |
| 25 | 100 | 0.8 | 0 |
| 26 | 100 | 0.8 | 100 |
| 27 | 100 | 0.8 | 150 |
| 28 | 100 | 0.8 | 200 |
| 29 | 100 | 0.8 | 250 |
| 30 | 100 | 0.8 | 300 |
| 31 | 100 | 1 | 0 |
| 32 | 100 | 1 | 100 |
| 33 | 100 | 1 | 150 |
| 34 | 100 | 1 | 200 |
| 35 | 100 | 1 | 250 |
| 36 | 100 | 1 | 300 |

**Table XXI:** Run protocol of high strength disperse yellow 3 with PAC.

| Run order | Dye concentration(high) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 150 | 0 | 0 |
| 2 | 150 | 0 | 100 |
| 3 | 150 | 0 | 150 |
| 4 | 150 | 0 | 200 |
| 5 | 150 | 0 | 250 |
| 6 | 150 | 0 | 300 |
| 7 | 150 | 0.2 | 0 |
| 8 | 150 | 0.2 | 100 |
| 9 | 150 | 0.2 | 150 |
| 10 | 150 | 0.2 | 200 |
| 11 | 150 | 0.2 | 250 |
| 12 | 150 | 0.2 | 300 |
| 13 | 150 | 0.4 | 0 |
| 14 | 150 | 0.4 | 100 |
| 15 | 150 | 0.4 | 150 |
| 16 | 150 | 0.4 | 200 |
| 17 | 150 | 0.4 | 250 |
| 18 | 150 | 0.4 | 300 |
| 19 | 150 | 0.6 | 0 |
| 20 | 150 | 0.6 | 100 |
| 21 | 150 | 0.6 | 150 |
| 22 | 150 | 0.6 | 200 |
| 23 | 150 | 0.6 | 250 |
| 24 | 150 | 0.6 | 300 |
| 25 | 150 | 0.8 | 0 |
| 26 | 150 | 0.8 | 100 |
| 27 | 150 | 0.8 | 150 |
| 28 | 150 | 0.8 | 200 |
| 29 | 150 | 0.8 | 250 |
| 30 | 150 | 0.8 | 300 |
| 31 | 150 | 1 | 0 |
| 32 | 150 | 1 | 100 |
| 33 | 150 | 1 | 150 |
| 34 | 150 | 1 | 200 |
| 35 | 150 | 1 | 250 |
| 36 | 150 | 1 | 300 |

**Table XXII:** Run protocol of low strength disperse yellow 3 with peanut hull.

| Run order | Dye concentration(low) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 50 | 0 | 0 |
| 2 | 50 | 0 | 100 |
| 3 | 50 | 0 | 150 |
| 4 | 50 | 0 | 200 |
| 5 | 50 | 0 | 250 |
| 6 | 50 | 0 | 300 |
| 7 | 50 | 3.327-2.38 | 0 |
| 8 | 50 | 3.327-2.38 | 100 |
| 9 | 50 | 3.327-2.38 | 150 |
| 10 | 50 | 3.327-2.38 | 200 |
| 11 | 50 | 3.327-2.38 | 250 |
| 12 | 50 | 3.327-2.38 | 300 |
| 13 | 50 | 2.38-2.362 | 0 |
| 14 | 50 | 2.38-2.362 | 100 |
| 15 | 50 | 2.38-2.362 | 150 |
| 16 | 50 | 2.38-2.362 | 200 |
| 17 | 50 | 2.38-2.362 | 250 |
| 18 | 50 | 2.38-2.362 | 300 |
| 19 | 50 | 2362-0.6 | 0 |
| 20 | 50 | 2362-0.6 | 100 |
| 21 | 50 | 2.362-0.6 | 150 |
| 22 | 50 | 2.362-0.6 | 200 |
| 23 | 50 | 2.362-0.6 | 250 |
| 24 | 50 | 2.362-0.6 | 300 |
| 25 | 50 | 0.6-0.425 | 0 |
| 26 | 50 | 0.6-0.425 | 100 |
| 27 | 50 | 0.6-0.425 | 150 |
| 28 | 50 | 0.6-0.425 | 200 |
| 29 | 50 | 0.6-0.425 | 250 |
| 30 | 50 | 0.6-0.425 | 300 |
| 31 | 50 | <0.425 | 0 |
| 32 | 50 | <0.425 | 100 |
| 33 | 50 | <0.425 | 150 |
| 34 | 50 | <0.425 | 200 |
| 35 | 50 | <0.425 | 250 |
| 36 | 50 | <0.425 | 300 |

**Table XXIII:** Run protocol of medium strength disperse yellow 3 with peanut hull.

| Run order | Dye concentration(medium) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 100 | 0 | 100 |
| 3 | 100 | 0 | 150 |
| 4 | 100 | 0 | 200 |
| 5 | 100 | 0 | 250 |
| 6 | 100 | 0 | 300 |
| 7 | 100 | 3.327-2.38 | 0 |
| 8 | 100 | 3.327-2.38 | 100 |
| 9 | 100 | 3.327-2.38 | 150 |
| 10 | 100 | 3.327-2.38 | 200 |
| 11 | 100 | 3.327-2.38 | 250 |
| 12 | 100 | 3.327-2.38 | 300 |
| 13 | 100 | 2.38-2.362 | 0 |
| 14 | 100 | 2.38-2.362 | 100 |
| 15 | 100 | 2.38-2.362 | 150 |
| 16 | 100 | 2.38-2.362 | 200 |
| 17 | 100 | 2.38-2.362 | 250 |
| 18 | 100 | 2.38-2.362 | 300 |
| 19 | 100 | 2362-0.6 | 0 |
| 20 | 100 | 2362-0.6 | 100 |
| 21 | 100 | 2.362-0.6 | 150 |
| 22 | 100 | 2.362-0.6 | 200 |
| 23 | 100 | 2.362-0.6 | 250 |
| 24 | 100 | 2.362-0.6 | 300 |
| 25 | 100 | 0.6-0.425 | 0 |
| 26 | 100 | 0.6-0.425 | 100 |
| 27 | 100 | 0.6-0.425 | 150 |
| 28 | 100 | 0.6-0.425 | 200 |
| 29 | 100 | 0.6-0.425 | 250 |
| 30 | 100 | 0.6-0.425 | 300 |
| 31 | 100 | <0.425 | 0 |
| 32 | 100 | <0.425 | 100 |
| 33 | 100 | <0.425 | 150 |
| 34 | 100 | <0.425 | 200 |
| 35 | 100 | <0.425 | 250 |
| 36 | 100 | <0.425 | 300 |

**Table XXIV:** Run protocol of high strength disperse yellow 3 with peanut hull**.**

| Run order | Dye concentration(high) (ppm) | Adsorbent size (mm) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 150 | 0 | 0 |
| 2 | 150 | 0 | 100 |
| 3 | 150 | 0 | 150 |
| 4 | 150 | 0 | 200 |
| 5 | 150 | 0 | 250 |
| 6 | 150 | 0 | 300 |
| 7 | 150 | 3.327-2.38 | 0 |
| 8 | 150 | 3.327-2.38 | 100 |
| 9 | 150 | 3.327-2.38 | 150 |
| 10 | 150 | 3.327-2.38 | 200 |
| 11 | 150 | 3.327-2.38 | 250 |
| 12 | 150 | 3.327-2.38 | 300 |
| 13 | 150 | 2.38-2.362 | 0 |
| 14 | 150 | 2.38-2.362 | 100 |
| 15 | 150 | 2.38-2.362 | 150 |
| 16 | 150 | 2.38-2.362 | 200 |
| 17 | 150 | 2.38-2.362 | 250 |
| 18 | 150 | 2.38-2.362 | 300 |
| 19 | 150 | 2362-0.6 | 0 |
| 20 | 150 | 2362-0.6 | 100 |
| 21 | 150 | 2.362-0.6 | 150 |
| 22 | 150 | 2.362-0.6 | 200 |
| 23 | 150 | 2.362-0.6 | 250 |
| 24 | 150 | 2.362-0.6 | 300 |
| 25 | 150 | 0.6-0.425 | 0 |
| 26 | 150 | 0.6-0.425 | 100 |
| 27 | 150 | 0.6-0.425 | 150 |
| 28 | 150 | 0.6-0.425 | 200 |
| 29 | 150 | 0.6-0.425 | 250 |
| 30 | 150 | 0.6-0.425 | 300 |
| 31 | 150 | <0.425 | 0 |
| 32 | 150 | <0.425 | 100 |
| 33 | 150 | <0.425 | 150 |
| 34 | 150 | <0.425 | 200 |
| 35 | 150 | <0.425 | 250 |
| 36 | 150 | <0.425 | 300 |

**Table XXV:** Run protocol of low strength disperse yellow 3 with onion peel.

| Run order | Dye concentration(low) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 50 | 0 | 0 |
| 2 | 50 | 0 | 100 |
| 3 | 50 | 0 | 150 |
| 4 | 50 | 0 | 200 |
| 5 | 50 | 0 | 250 |
| 6 | 50 | 0 | 300 |
| 7 | 50 | 0.4 | 0 |
| 8 | 50 | 0.4 | 100 |
| 9 | 50 | 0.4 | 150 |
| 10 | 50 | 0.4 | 200 |
| 11 | 50 | 0.4 | 250 |
| 12 | 50 | 0.4 | 300 |
| 13 | 50 | 0.8 | 0 |
| 14 | 50 | 0.8 | 100 |
| 15 | 50 | 0.8 | 150 |
| 16 | 50 | 0.8 | 200 |
| 17 | 50 | 0.8 | 250 |
| 18 | 50 | 0.8 | 300 |
| 19 | 50 | 1.2 | 0 |
| 20 | 50 | 1.2 | 100 |
| 21 | 50 | 1.2 | 150 |
| 22 | 50 | 1.2 | 200 |
| 23 | 50 | 1.2 | 250 |
| 24 | 50 | 1.2 | 300 |
| 25 | 50 | 1.6 | 0 |
| 26 | 50 | 1.6 | 100 |
| 27 | 50 | 1.6 | 150 |
| 28 | 50 | 1.6 | 200 |
| 29 | 50 | 1.6 | 250 |
| 30 | 50 | 1.6 | 300 |
| 31 | 50 | 2 | 0 |
| 32 | 50 | 2 | 100 |
| 33 | 50 | 2 | 150 |
| 34 | 50 | 2 | 200 |
| 35 | 50 | 2 | 250 |
| 36 | 50 | 2 | 300 |

**Table XXVI:** Run protocol of medium strength disperse yellow 3 with onion peel.

| Run order | Dye concentration(medium) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 100 | 0 | 100 |
| 3 | 100 | 0 | 150 |
| 4 | 100 | 0 | 200 |
| 5 | 100 | 0 | 250 |
| 6 | 100 | 0 | 300 |
| 7 | 100 | 0.4 | 0 |
| 8 | 100 | 0.4 | 100 |
| 9 | 100 | 0.4 | 150 |
| 10 | 100 | 0.4 | 200 |
| 11 | 100 | 0.4 | 250 |
| 12 | 100 | 0.4 | 300 |
| 13 | 100 | 0.8 | 0 |
| 14 | 100 | 0.8 | 100 |
| 15 | 100 | 0.8 | 150 |
| 16 | 100 | 0.8 | 200 |
| 17 | 100 | 0.8 | 250 |
| 18 | 100 | 0.8 | 300 |
| 19 | 100 | 1.2 | 0 |
| 20 | 100 | 1.2 | 100 |
| 21 | 100 | 1.2 | 150 |
| 22 | 100 | 1.2 | 200 |
| 23 | 100 | 1.2 | 250 |
| 24 | 100 | 1.2 | 300 |
| 25 | 100 | 1.6 | 0 |
| 26 | 100 | 1.6 | 100 |
| 27 | 100 | 1.6 | 150 |
| 28 | 100 | 1.6 | 200 |
| 29 | 100 | 1.6 | 250 |
| 30 | 100 | 1.6 | 300 |
| 31 | 100 | 2 | 0 |
| 32 | 100 | 2 | 100 |
| 33 | 100 | 2 | 150 |
| 34 | 100 | 2 | 200 |
| 35 | 100 | 2 | 250 |
| 36 | 100 | 2 | 300 |

**Table XXVII:** Run protocol of high strength disperse yellow 3 with onion peel.

| Run order | Dye concentration(high) (ppm) | Adsorbent dosage (g) | Coffee concentration (ppm) |
|---|---|---|---|
| 1 | 150 | 0 | 0 |
| 2 | 150 | 0 | 100 |
| 3 | 150 | 0 | 150 |
| 4 | 150 | 0 | 200 |
| 5 | 150 | 0 | 250 |
| 6 | 150 | 0 | 300 |
| 7 | 150 | 0.4 | 0 |
| 8 | 150 | 0.4 | 100 |
| 9 | 150 | 0.4 | 150 |
| 10 | 150 | 0.4 | 200 |
| 11 | 150 | 0.4 | 250 |
| 12 | 150 | 0.4 | 300 |
| 13 | 150 | 0.8 | 0 |
| 14 | 150 | 0.8 | 100 |
| 15 | 150 | 0.8 | 150 |
| 16 | 150 | 0.8 | 200 |
| 17 | 150 | 0.8 | 250 |
| 18 | 150 | 0.8 | 300 |
| 19 | 150 | 1.2 | 0 |
| 20 | 150 | 1.2 | 100 |
| 21 | 150 | 1.2 | 150 |
| 22 | 150 | 1.2 | 200 |
| 23 | 150 | 1.2 | 250 |
| 24 | 150 | 1.2 | 300 |
| 25 | 150 | 1.6 | 0 |
| 26 | 150 | 1.6 | 100 |
| 27 | 150 | 1.6 | 150 |
| 28 | 150 | 1.6 | 200 |
| 29 | 150 | 1.6 | 250 |
| 30 | 150 | 1.6 | 300 |
| 31 | 150 | 2 | 0 |
| 32 | 150 | 2 | 100 |
| 33 | 150 | 2 | 150 |
| 34 | 150 | 2 | 200 |
| 35 | 150 | 2 | 250 |
| 36 | 150 | 2 | 300 |

# CHAPTER IV

# RESULTS AND DISCUSSION

In the Appendix A and B 976 sample runs are presented as follows

1. Appendix A contains tables of all the sample runs
2. Appendix B contains figures of all the sample runs

## 4.1 Results

The results in the tables are compared to interpret and understand the treatment performance of the low-cost adsorbents like Peanut hull, Onion Peel. Various adsorbent sizes with Peanut hull and dosages with Onion Peel are used with different coffee concentrations and compared with varying dye concentration (Low, Medium and High). Using UV-Visible spectrophotometer absorbance and transmittance readings are measured before and after the treatment i.e. after adsorption and microfiltration.

The terms BT, AT in the table listed indicates before treatment and after treatment of batch adsorption of dye and coffee wastewater samples.

The following tables in the results and discussion tells the transmittance of different dyes and coffee wastewater at optimum size and dosage of the adsorbent.

**Table XXVIII:** Transmittance of acid black 48 at optimum size and dosage

| Dye concentration | Transmittance for different adsorbents | | |
|---|---|---|---|
| | **Powdered activated carbon** | **Peanut hull** | **Onion peel** |
| Low concentration | 96 | 78.2 | 80.1 |
| Medium concentration | 97.3 | 72.8 | 75.6 |
| High concentration | 97.2 | 69.4 | 62.4 |

Table 28 gives an idea about transmittance of combined dye and coffee wastewater using different adsorbents. We can observe from the table that powdered activated carbon has the highest transmittance values beyond 90%. The maximum transmittance achieved using peanut hull at low concentration of acid black 48 with 100ppm of coffee is 78.2%. The maximum transmittance achieved using onion peel at low concentration of acid black 48 with 100 ppm of coffee is 89.1%

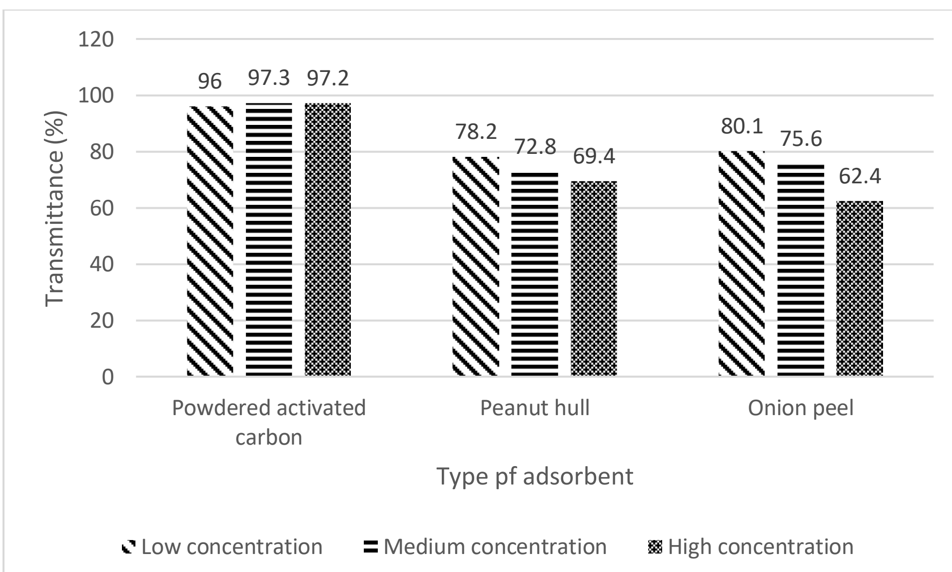


**Figure 1:** Transmittance of acid black 48 at optimum size and dosage

**Table XXIX:** Transmittance of crystal violet at optimum size and dosage

| Dye concentration | Transmittance for different adsorbents | | |
|---|---|---|---|
| | **Powdered activated carbon** | **Peanut hull** | **Onion peel** |
| Low concentration | 95.4 | 68.3 | 79.8 |
| Medium concentration | 96.8 | 71.8 | 75.4 |
| High concentration | 93.1 | 44.7 | 72.9 |

Table 29 gives an idea about transmittance of combined dye and coffee wastewater using different adsorbents. We can observe from the table that powdered activated carbon has the highest transmittance values beyond 90%. The maximum transmittance achieved using peanut hull at medium concentration of crystal violet, certified with 100ppm of coffee is 78.2%. The maximum transmittance achieved using onion peel at low concentration of crystal violet certified with 100 ppm of coffee is 79.8%.

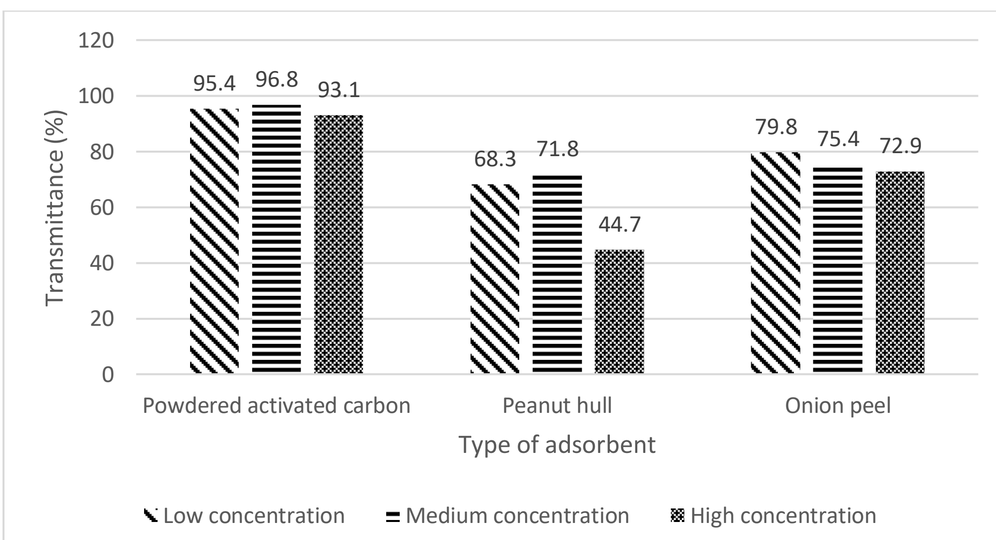


**Figure 2:** Transmittance of crystal violet at optimum size and dosage

**Table XXX:** Transmittance of disperse yellow 3 at optimum size and dosage

| Dye concentration | Transmittance for different adsorbents | | |
|---|---|---|---|
| | Powdered activated carbon | Peanut hull | Onion peel |
| Low concentration | 96.8 | 78.9 | 82.4 |
| Medium concentration | 95.3 | 75.9 | 73.9 |
| High concentration | 94.2 | 67.4 | 64.8 |

Table 30 gives an idea about transmittance of combined dye and coffee wastewater using different adsorbents. We can observe from the table that powdered activated carbon has the highest transmittance values beyond 90%. The maximum transmittance achieved using peanut hull at medium concentration of disperse yellow 3 with 100ppm of coffee is 78.9%. The maximum transmittance achieved using onion peel at low concentration of disperse yellow 3 with 100 ppm of coffee is 82.4%.

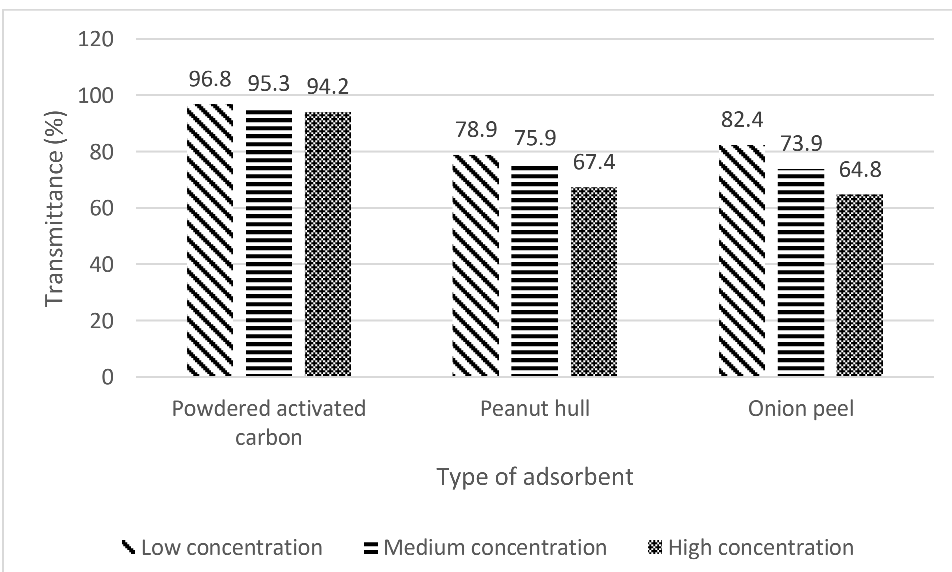


**Figure 3:** Transmittance of disperse yellow 3 at optimum size and dosage.

**Table XXXI:** NPOC of combined acid black 48 and coffee wastewater.

| Coffee wastewater concentration (ppm) | Powdered activated carbon | Onion peel | Peanut hull |
|---|---|---|---|
| | 4.61 | 8.49 | 12.47 |
| | 4.87 | 8.74 | 12.75 |
| | 5.14 | 8.84 | 12.72 |
| | 5.32 | 9.62 | 13.06 |
| | 5.94 | 9.41 | 14.14 |
| 100 | 6.07 | 9.95 | 13.16 |
| | 11.48 | 14.46 | 19.21 |
| | 11.67 | 15.54 | 19.98 |
| | 12.09 | 15.47 | 20.72 |
| | 12.87 | 16.64 | 20.95 |
| | 12.52 | 16.81 | 21.61 |
| 150 | 12.39 | 16.06 | 21.79 |
| | 17.21 | 20.44 | 29.24 |
| | 17.64 | 20.63 | 29.44 |
| | 17.94 | 21.45 | 31.62 |
| | 18.42 | 22.96 | 31.77 |
| | 17.96 | 23.32 | 32.43 |
| 200 | 18.51 | 22.76 | 30.74 |
| | 23.94 | 28.03 | 37.61 |
| | 24.43 | 29.84 | 37.52 |
| | 24.78 | 29.64 | 38.76 |
| | 24.95 | 29.43 | 38.94 |
| | 25.31 | 32.48 | 37.52 |
| 250 | 25.67 | 30.67 | 38.44 |
| | 29.65 | 35.42 | 41.47 |
| | 30.54 | 39.64 | 41.66 |
| | 30.21 | 36.18 | 42.79 |
| | 30.86 | 36.84 | 42.61 |
| | 30.43 | 37.81 | 43.49 |
| 300 | 30.66 | 37.62 | 42.78 |

Table 31 represents the NPOC of acid black 48 mixed with coffee wastewater treated with three different adsorbents including PAC, peanut hull, onion peel. From the table it is observed that peanut hull has maximum NPOC value of 43.49 mg/L, orange peel and powdered activated carbon has 39.64 and 30.66 mg/L respectively.

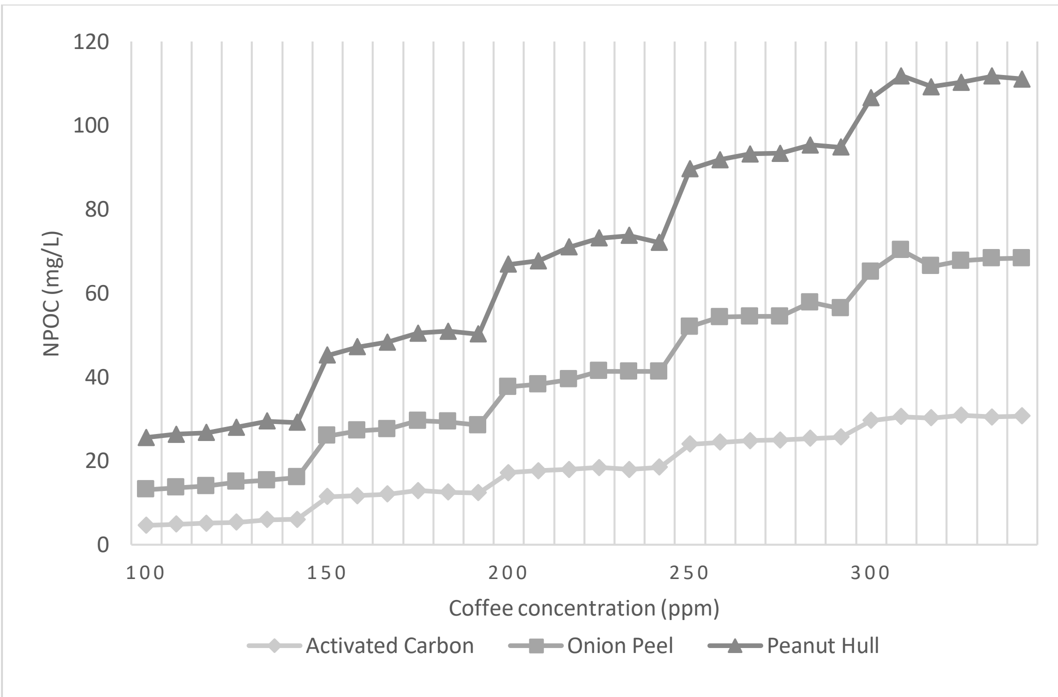


**Figure 4:** NPOC of high concentration acid black with three adsorbents.

**Table XXXII:** NPOC of combined crystal violet and coffee wastewater.

| Coffee wastewater concentration (ppm) | Powdered activated carbon | Onion peel | Peanut hull |
|---|---|---|---|
| | 2.48 | 4.51 | 6.15 |
| | 2.75 | 4.31 | 6.34 |
| | 2.98 | 4.27 | 6.94 |
| | 2.54 | 4.95 | 6.37 |
| | 2.76 | 5.07 | 6.88 |
| 100 | 2.77 | 5.16 | 7.64 |
| | 5.39 | 7.15 | 8.14 |
| | 5.75 | 7.38 | 8.31 |
| | 5.51 | 7.81 | 8.46 |
| | 5.26 | 8.24 | 8.76 |
| | 5.87 | 8.57 | 9.06 |
| 150 | 5.41 | 8.96 | 9.55 |
| | 8.95 | 11.72 | 16.48 |
| | 8.71 | 11.63 | 16.64 |
| | 8.64 | 11.54 | 16.44 |
| | 8.72 | 11.75 | 16.87 |
| | 8.04 | 11.84 | 16.18 |
| 200 | 9.67 | 12.93 | 16.94 |
| | 9.16 | 15.31 | 27.59 |
| | 9.64 | 15.47 | 27.43 |
| | 9.84 | 15.91 | 27.67 |
| | 9.71 | 15.42 | 28.42 |
| | 9.42 | 16.17 | 28.64 |
| 250 | 9.91 | 16.84 | 27.43 |
| | 12.24 | 20.16 | 34.31 |
| | 12.81 | 21.94 | 34.92 |
| | 12.56 | 21.46 | 34.15 |
| | 12.51 | 21.71 | 35.48 |
| | 12.91 | 21.62 | 35.22 |
| 300 | 12.55 | 21.83 | 36.87 |

Table 32 represents the NPOC of crystal violet, certified mixed with coffee wastewater treated with three different adsorbents including PAC, peanut hull, onion peel. From the table it is observed that peanut hull has maximum NPOC value of 36.87 mg/L, orange peel and powdered activated carbon has 21.94 and 12.91 mg/L respectively.

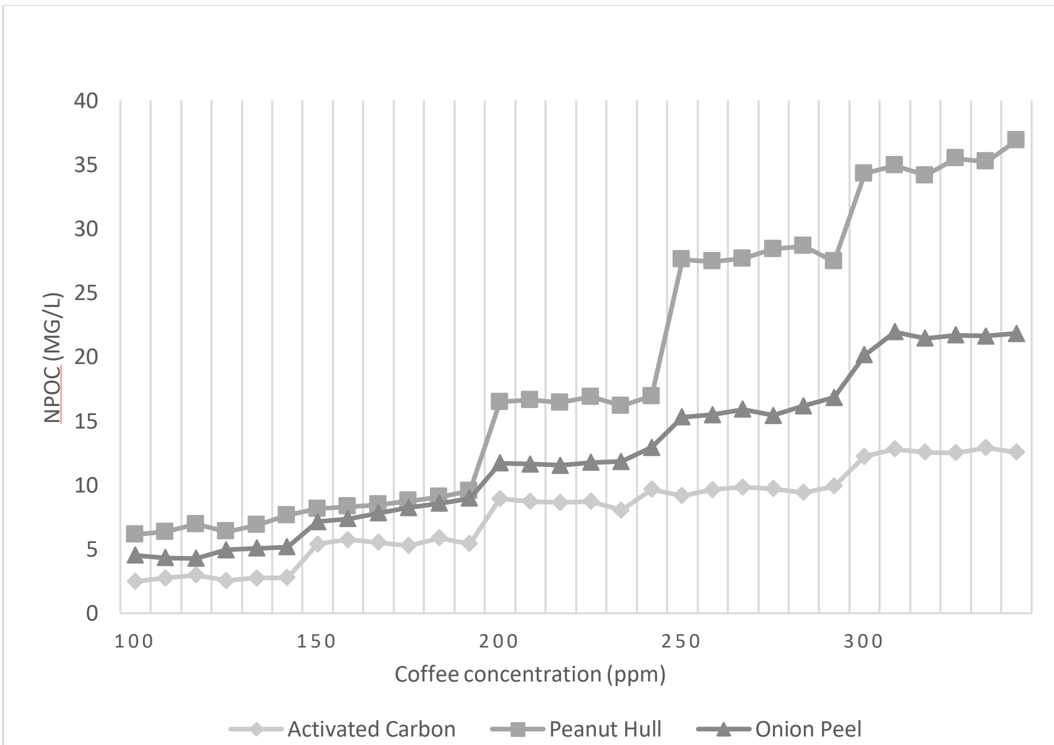


**Figure 5:** NPOC of high concentration crystal violet with three adsorbents.

**Table XXXIII:** NPOC of combined disperse yellow 3 and coffee wastewater.

| Coffee wastewater concentration (ppm) | Powdered activated carbon | Onion peel | Peanut hull |
|---|---|---|---|
| | 6.43 | 7.53 | 7.98 |
| | 6.36 | 7.47 | 7.93 |
| | 6.63 | 7.16 | 8.77 |
| | 6.99 | 7.27 | 8.13 |
| | 6.38 | 7.64 | 8.93 |
| 100 | 6.18 | 7.93 | 8.77 |
| | 9.75 | 11.24 | 14.87 |
| | 9.29 | 11.89 | 14.1 |
| | 9.55 | 11.87 | 14.4 |
| | 9.69 | 11.5 | 14.51 |
| | 9.95 | 11.67 | 14.15 |
| 150 | 9.82 | 11.88 | 14.3 |
| | 11.16 | 15.16 | 18.96 |
| | 11.9 | 15.13 | 19.2 |
| | 11.35 | 15.54 | 19.47 |
| | 11.23 | 15.38 | 19.22 |
| | 11.87 | 15.81 | 19.39 |
| 200 | 11.8 | 15.7 | 19.93 |
| | 13.3 | 17.59 | 21.47 |
| | 13.94 | 17.86 | 21.76 |
| | 13.26 | 17.1 | 21.65 |
| | 13.16 | 17.22 | 21.61 |
| | 13.1 | 17.71 | 21.88 |
| 250 | 13.23 | 17.53 | 21.78 |
| | 15.43 | 20.19 | 24.42 |
| | 15.1 | 20.5 | 25.65 |
| | 15.6 | 20.61 | 25.37 |
| | 15.44 | 20.15 | 25.21 |
| | 15.19 | 21.92 | 25.63 |
| 300 | 15.31 | 20.59 | 25.21 |

Table 33 represents the NPOC of Disperse yellow 3 mixed with coffee wastewater treated with three different adsorbents including PAC, peanut hull, onion peel. From the table it is observed that peanut hull has maximum NPOC value of 25.65 mg/L, orange peel and powdered activated carbon has 20.61 and 12.91 mg/L respectively.

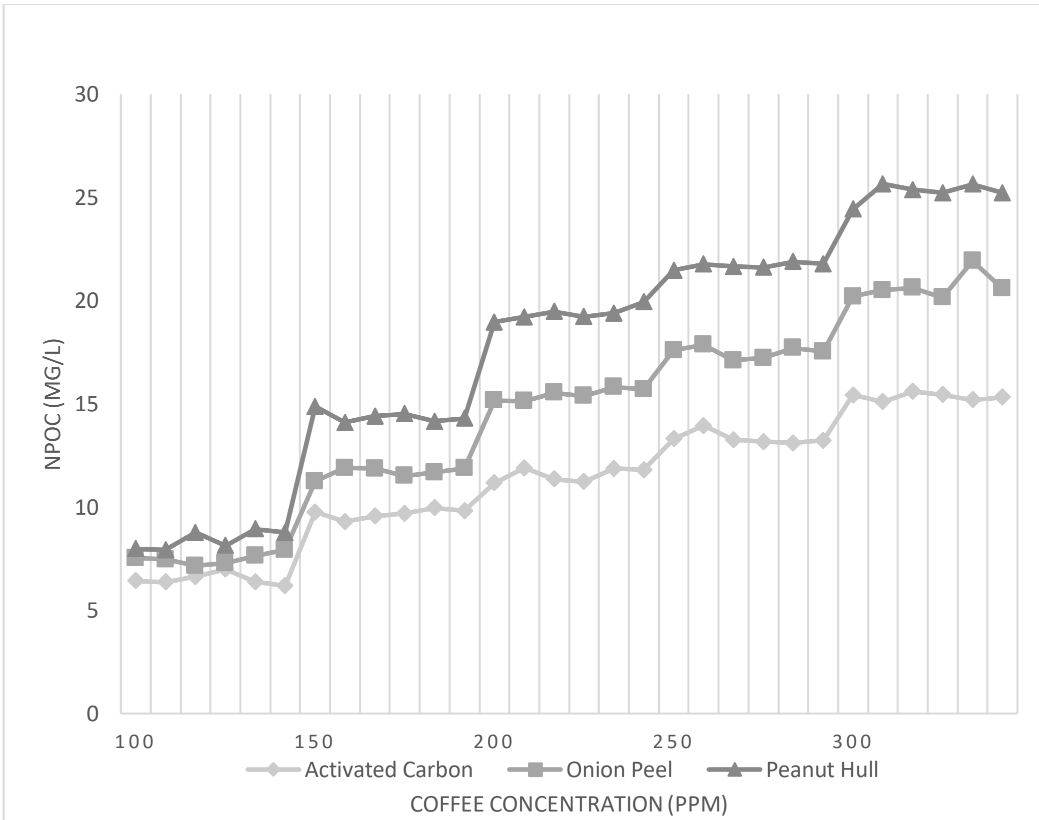


**Figure 6:** NPOC of high concentration disperse yellow 3 with three adsorbents.

**4.2 Results on effects of pH**

The pH observed with the three dyes i.e. Acid black 48, crystal violet certified, disperse yellow 3 is (5.5,4.9,3.7), (7.2,8.2,7.7) and (6.5,7.3,8.1) respectively. In the dye adsorption process pH factor plays an important role because the magnitude of electrostatic attraction between dye and adsorbent change with change in pH. The rate of adsorption not only depends on active spots of the adsorbent to get sorbed but also on pH.

For example, cationic dyes have less adsorption rate because of the presence of excess H+ ions at low pH. In contrast the anionic dyes have more adsorption at low pH.

### 4.3 Results of isotherms and isotherm coefficients

Freundlich isotherm is the best fit for Acid black 48 with the optimum dosage of low cost adsorbent being orange peel. The linear equation is y = 2.1873x - 0.0339 and coefficient of determination $R^2$ = 0.7338, coefficient of Freundlich isotherm, $K_f$ = 0.9122

Langmuir isotherm is the best fit for crystal violet certified with the optimum dosage of low cost adsorbent being peanut hull. The linear equation is y = 0.0079x - 0.0013 and coefficient of determination $R^2$ = 0.9465, coefficient of Langmuir isotherm, $K_L$= 796.23

Langmuir isotherm is the best fit for Disperse yellow 3 with optimum dosage of low cost adsorbent being orange peel. The linear equation is y = 82.423x + 0.0078 and the coefficient of determination $R^2$ = 0.946, coefficient of Langmuir isotherm $K_L$ = 128.20

### 4.4 Discussion on effects of parameters on color removal

The two-major parameter in color removal which are used to distinguish the water quality are absorbance and transmittance. The highest color removal and the efficiency of the adsorption process is represented by maximum transmittance and minimum absorbance. Since the batch adsorption process is conducted in laboratory constant temperature is maintained. pH factor is also considered but usually adsorption is done at tertiary treatment process. NPOC is another factor where organic carbon is removed which represent treatment efficiency.

# CHAPTER V

# CONCLUSION

## 5.1 Conclusions based on the research

1. Acid Black 48 has best treatment in terms of transmittance 78.2% and 89.1% with peanut hull at optimum size of (0.6-0.425 mm) and onion peel with optimum dosage of 1.2 g respectively.
2. Crystal Violet certified has best treatment in terms of transmittance is 71.8% and 79.8% with peanut hull at optimum size of (<0.425 mm) and onion peel with optimum dosage of 2 g respectively.
3. Disperse Yellow 8 has best treatment in terms of transmittance is 78.9% and 82.4% with peanut hull at optimum size (2.362-0.6 mm) and optimum dosage of 1.2 g respectively.
4. Powdered Activated Carbon has the best transmittance values of more than 90% and hence we considered PAC as reference in the comparison of transmittance with low-cost adsorbents.
5. Color removal and treatment is better for the combined dye and coffee wastewater because of the dilution involved.

6. NPOC of Acid black 48, crystal violet, certified and disperse yellow 3 has high values with peanut hull. Powdered activated carbon, onion peel has reduced NPOC values after treatment when compared to before treatment.

### 5.2 Significance and application

The significance of the adsorption process is to treat dye wastewater as a tertiary treatment before releasing it in to the surface water. The effluent should maintain EPA wastewater standard as per NPDES permit under Clean Water Act. The two-stage treatment of adsorption and micro-filtration has proved to be an effective treatment process to remove dye and coffee color from the wastewater. Textile and coffee industries being highly polluting because of high BOD and COD in the effluent require pre-treatment of the wastewater. Adsorption using low-cost adsorbents is an economical way to treat binary mixture of dye and coffee wastewater. The engineering significance of the treatment process is about being efficient and economical.

### 5.3 Recommendations for future research

1. Every dye reacts differently with various adsorbents. More investigations should be carried out with different types of adsorbents to understand the efficient removal of dye and coffee waste in the wastewater to maintain surface water quality.
2. More economical treatment methods such as biosorption and electrochemical oxidation must be studied using low-cost adsorbents for effective removal of dyes in wastewater.

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## APPENDIX A: Tables

**Table XXXIV:** Transmittance of acid black 48 with PAC at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 54.7 | 62.7 | 55 | 86.1 | 58.7 | 83.5 | 56.7 | 96.4 | 56.6 | 95.5 | 58.3 | 95.3 |
| **100** | 72.9 | 74.3 | 69 | 96 | 73 | 94.6 | 73.4 | 94.3 | 76.3 | 95.4 | 73 | 94.2 |
| **150** | 68.3 | 72.9 | 70.1 | 91.4 | 69.6 | 93.5 | 69.8 | 92.8 | 68.7 | 93.9 | 69.7 | 93.4 |
| **200** | 68.2 | 72.4 | 68.1 | 90 | 69.4 | 92.4 | 69 | 92.9 | 67.4 | 93 | 68.3 | 93.1 |
| **250** | 67.8 | 69.9 | 67.9 | 88 | 67.5 | 90.3 | 67 | 91.7 | 67.2 | 93 | 67.4 | 92.9 |
| **300** | 67.2 | 69.7 | 67.9 | 87.8 | 67.7 | 89.9 | 65.4 | 91.2 | 67 | 92.4 | 66.2 | 90.7 |

**Table XXXV:** Transmittance of acid black 48 with PAC at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 32.2 | 57.3 | 32 | 89.5 | 31.9 | 89.5 | 31.2 | 92.1 | 31.1 | 95.4 | 30.8 | 98.9 |
| **100** | 49.2 | 63.7 | 48.9 | 87 | 49 | 95.6 | 50.9 | 91.3 | 50.1 | 97.3 | 49.8 | 99.2 |
| **150** | 48.5 | 62.4 | 48.5 | 86.3 | 48.6 | 86.6 | 49.8 | 90.1 | 48.9 | 92.1 | 49 | 94.1 |
| **200** | 48.4 | 61.8 | 48.3 | 89.1 | 48.3 | 79.4 | 48.2 | 98.5 | 47.7 | 92 | 49.5 | 94.1 |
| **250** | 47.7 | 60.3 | 47.7 | 85.3 | 47.2 | 78.9 | 47.7 | 92.3 | 47.5 | 93.5 | 48.2 | 99.4 |
| **300** | 46.4 | 59.7 | 46.2 | 74 | 46.6 | 76.7 | 46.3 | 91.6 | 46.5 | 92.2 | 46.4 | 97.4 |

**Table XXXVI:** Transmittance of acid black 48 with PAC at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 10.8 | 40.9 | 11 | 83.7 | 11.9 | 96.4 | 11.4 | 98.2 | 12.3 | 99.8 | 11.3 | 98.4 |
| 100 | 31.5 | 55.6 | 30.3 | 73.5 | 33.6 | 95 | 30.7 | 97.3 | 34.3 | 96.2 | 31.8 | 98.2 |
| 150 | 29.7 | 54.2 | 29.4 | 70.1 | 29 | 94.6 | 29.9 | 93.2 | 30.6 | 94.9 | 28.8 | 95.4 |
| 200 | 28.3 | 53.9 | 28.2 | 64.7 | 28.4 | 89.7 | 29.4 | 90.5 | 27.5 | 94.8 | 28.3 | 95 |
| 250 | 27.3 | 51.8 | 27.7 | 62.9 | 26.9 | 87.9 | 27.3 | 89.8 | 27.3 | 92.6 | 29.9 | 94.4 |
| 300 | 25.5 | 50.4 | 27.1 | 58.9 | 27 | 78.9 | 27.2 | 92.8 | 27 | 90.2 | 24.9 | 92.9 |

**Table XXXVII:** Transmittance of acid black 48 with peanut hull at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 54.7 | 62.7 | 55 | 66.1 | 58.7 | 69.5 | 56.7 | 70.2 | 56.6 | 69.9 | 58.3 | 70.8 |
| 100 | 72.9 | 74.3 | 69 | 75.9 | 73 | 76.8 | 73.4 | 75.6 | 76.3 | 78.2 | 73 | 74.1 |
| 150 | 68.3 | 72.4 | 70.1 | 74.6 | 69.6 | 75.4 | 69.8 | 74.9 | 68.7 | 77.3 | 69.7 | 73.2 |
| 200 | 68.2 | 69.7 | 68.1 | 73.7 | 69.4 | 74.3 | 69 | 73.2 | 67.4 | 76.8 | 68.3 | 72.8 |
| 250 | 67.8 | 72.9 | 67.9 | 71.8 | 67.5 | 72.7 | 67 | 71.8 | 67.2 | 75.4 | 67.4 | 70.9 |
| 300 | 67.2 | 69.9 | 67.9 | 70.9 | 67.7 | 71.6 | 65.4 | 70.6 | 67 | 74.3 | 66.2 | 69.8 |

**Table XXXVIII:** Transmittance of acid black 48 with peanut hull at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 32.2 | 40.9 | 32 | 53.9 | 31.9 | 52.6 | 31.2 | 61.6 | 31.1 | 65.4 | 30.8 | 67.6 |
| **100** | 49.2 | 55.6 | 48.9 | 66.8 | 49 | 67.8 | 50.9 | 71.9 | 50.1 | 72.8 | 49.8 | 70.2 |
| **150** | 48.5 | 54.2 | 48.5 | 65.4 | 48.6 | 66.4 | 49.8 | 70.5 | 48.9 | 71.3 | 49 | 69.5 |
| **200** | 48.4 | 53.9 | 48.3 | 64.3 | 48.3 | 65.8 | 48.2 | 69.7 | 47.7 | 70.4 | 49.5 | 68.2 |
| **250** | 47.7 | 51.8 | 47.7 | 63.9 | 47.2 | 64.3 | 47.7 | 68.4 | 47.5 | 69.7 | 48.2 | 67.6 |
| **300** | 46.4 | 50.4 | 46.2 | 62.5 | 46.6 | 63.2 | 46.3 | 67.3 | 46.5 | 68.1 | 46.4 | 65.9 |

**Table XXXIX:** Transmittance of acid black 48 with peanut hull at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.632 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 10.8 | 54.7 | 11 | 46.2 | 11.9 | 48.9 | 11.4 | 50.3 | 12.3 | 52.7 | 11.3 | 51.6 |
| **100** | 31.5 | 61.4 | 30.3 | 67.8 | 33.6 | 67.9 | 30.7 | 68.7 | 34.3 | 69.4 | 31.8 | 68.7 |
| **150** | 29.7 | 60.1 | 29.4 | 66.2 | 29 | 68.6 | 29.9 | 67.8 | 30.6 | 68.6 | 28.8 | 67.5 |
| **200** | 28.3 | 59.8 | 28.2 | 65.4 | 28.4 | 67.4 | 29.4 | 66.2 | 27.5 | 67.3 | 28.3 | 66.7 |
| **250** | 27.3 | 58.5 | 27.7 | 64.3 | 26.9 | 66.9 | 27.3 | 65.4 | 27.3 | 66.8 | 29.9 | 65.4 |
| **300** | 25.5 | 57.6 | 27.1 | 62.9 | 27 | 65.5 | 27.2 | 63.1 | 27 | 65.4 | 24.9 | 64.1 |

**Table XL:** Transmittance of acid black 48 with onion peel at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 54.7 | 62.7 | 55 | 63.2 | 58.7 | 67.4 | 56.7 | 69.2 | 56.6 | 63.4 | 58.3 | 61.5 |
| **100** | 72.9 | 74.3 | 69 | 76.4 | 73 | 78.6 | 73.4 | 80.1 | 76.3 | 78.4 | 73 | 75.1 |
| **150** | 68.3 | 72.4 | 70.1 | 75.1 | 69.6 | 77.4 | 69.8 | 79.4 | 68.7 | 77.2 | 69.7 | 73.2 |
| **200** | 68.2 | 69.7 | 68.1 | 74.6 | 69.4 | 76.2 | 69 | 78.1 | 67.4 | 76.4 | 68.3 | 71.7 |
| **250** | 67.8 | 72.9 | 67.9 | 73.2 | 67.5 | 75.7 | 67 | 77.5 | 67.2 | 74.5 | 67.4 | 69.4 |
| **300** | 67.2 | 69.9 | 67.9 | 72.4 | 67.7 | 74.1 | 65.4 | 76.9 | 67 | 72.8 | 66.2 | 68.4 |

**Table XLI:** Transmittance of acid black 48 with onion peel at medium concentration

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 32.2 | 40.9 | 32 | 55.4 | 31.9 | 58.1 | 31.2 | 67.5 | 31.1 | 63.8 | 30.8 | 51.6 |
| **100** | 49.2 | 55.6 | 48.9 | 62.7 | 49 | 67.2 | 50.9 | 75.6 | 50.1 | 67.6 | 49.8 | 57.9 |
| **150** | 48.5 | 54.2 | 48.5 | 60.8 | 48.6 | 65.7 | 49.8 | 73.1 | 48.9 | 65.1 | 49 | 55.4 |
| **200** | 48.4 | 53.9 | 48.3 | 59.1 | 48.3 | 64.1 | 48.2 | 71.7 | 47.7 | 64.8 | 49.5 | 53.1 |
| **250** | 47.7 | 51.8 | 47.7 | 57.6 | 47.2 | 62.7 | 47.7 | 70.2 | 47.5 | 62.9 | 48.2 | 51.7 |
| **300** | 46.4 | 50.4 | 46.2 | 56.1 | 46.6 | 61.2 | 46.3 | 68.5 | 46.5 | 60.7 | 46.4 | 50.4 |

**Table XLII:** Transmittance of acid black 48 with onion peel at high concentration

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 10.8 | 54.7 | 11 | 45.7 | 11.9 | 41.2 | 11.4 | 51.7 | 12.3 | 45.6 | 11.3 | 42.7 |
| **100** | 31.5 | 61.4 | 30.3 | 47.1 | 33.6 | 54.6 | 30.7 | 62.4 | 34.3 | 54.7 | 31.8 | 47.6 |
| **150** | 29.7 | 60.1 | 29.4 | 46.4 | 29 | 53.7 | 29.9 | 60.7 | 30.6 | 53.1 | 28.8 | 45.4 |
| **200** | 28.3 | 59.8 | 28.2 | 44.8 | 28.4 | 52.1 | 29.4 | 58.7 | 27.5 | 52.7 | 28.3 | 44.1 |
| **250** | 27.3 | 58.5 | 27.7 | 43.1 | 26.9 | 50.7 | 27.3 | 57.6 | 27.3 | 51.6 | 29.9 | 43.7 |
| **300** | 25.5 | 57.6 | 27.1 | 41.9 | 27 | 49.5 | 27.2 | 55.2 | 27 | 49.7 | 24.9 | 41.6 |

**Table XLIII:** Transmittance of crystal violet with PAC at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 12.9 | 17.25 | 13 | 92.6 | 14.3 | 94.7 | 13.9 | 95.4 | 13.3 | 95.9 | 14.9 | 96.8 |
| **100** | 34.4 | 44.2 | 34.3 | 91.7 | 34.4 | 92.5 | 34.5 | 93.2 | 33.3 | 94.1 | 36.4 | 95.4 |
| **150** | 33.6 | 42.5 | 33.7 | 90.8 | 33.7 | 91.6 | 33.9 | 92.8 | 35.7 | 93.2 | 36 | 94.1 |
| **200** | 32.7 | 42.2 | 33.6 | 89.9 | 34.8 | 90.3 | 35.5 | 91.7 | 34.9 | 91.8 | 35 | 93.8 |
| **250** | 32.2 | 40.5 | 31.6 | 87.5 | 32.2 | 89.8 | 33.5 | 90.2 | 33.9 | 90.7 | 34.3 | 92.9 |
| **300** | 33.4 | 42 | 32.4 | 86.3 | 32.2 | 88.7 | 33 | 89.6 | 36.4 | 90.5 | 33 | 92.5 |

**Table XLIV:** Transmittance of crystal violet with PAC at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 8.8 | 16.3 | 8.6 | 94.6 | 8.7 | 95.1 | 8.9 | 96.3 | 8.8 | 96.3 | 9.1 | 97 |
| 100 | 35.4 | 44.8 | 35.6 | 92.9 | 35.7 | 94.8 | 35.2 | 94.8 | 35.4 | 95.2 | 35.7 | 96.8 |
| 150 | 34.3 | 43.6 | 34.2 | 91.2 | 34.3 | 93.2 | 34.2 | 93.9 | 34.3 | 94.2 | 34.6 | 95.2 |
| 200 | 33.9 | 42.9 | 33.7 | 90.6 | 33.8 | 91.6 | 33.5 | 92.6 | 33.9 | 93.7 | 33.2 | 94.7 |
| 250 | 33.2 | 41.3 | 33.5 | 89.7 | 33.6 | 90.4 | 33.1 | 91.8 | 33.2 | 92.8 | 32.8 | 93.5 |
| 300 | 32 | 41.1 | 31.7 | 87.2 | 31.8 | 89.6 | 31.5 | 90.7 | 32 | 91.3 | 31.7 | 92.4 |

**Table XLV:** Transmittance of crystal violet with PAC at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 0.4 | 5.3 | 0.4 | 84.6 | 0.5 | 86.3 | 0.4 | 86.4 | 0.5 | 89.7 | 0.4 | 90.6 |
| 100 | 6 | 6.7 | 6.1 | 89.3 | 6.2 | 90.7 | 6.7 | 91.5 | 6.4 | 92.8 | 7.1 | 93.1 |
| 150 | 5.5 | 6.2 | 5.2 | 87.2 | 5.6 | 88.6 | 5.5 | 90.4 | 5.2 | 91.2 | 5.5 | 92.7 |
| 200 | 5.3 | 6.7 | 5.5 | 85.4 | 5.4 | 86.5 | 5.3 | 88.9 | 4.9 | 90.6 | 5.3 | 91.5 |
| 250 | 4.8 | 5.3 | 4.9 | 84.6 | 5.8 | 85.9 | 5.4 | 87.1 | 5.1 | 89.5 | 5.4 | 89.4 |
| 300 | 5.1 | 5.9 | 4.9 | 83.4 | 5.4 | 84.6 | 5.5 | 85.7 | 5.4 | 87.6 | 4.8 | 87.3 |

**Table XLVI:** Transmittance of crystal violet with peanut hull at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.362 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 12.9 | 17.25 | 13 | 70.9 | 14.3 | 69.1 | 13.9 | 67.4 | 13.3 | 83.7 | 14.9 | 84 |
| **100** | 34.4 | 44.2 | 34.3 | 68.3 | 34.4 | 63.3 | 34.5 | 59.2 | 33.3 | 61.4 | 36.4 | 67 |
| **150** | 33.6 | 42.5 | 33.7 | 66.2 | 33.7 | 64 | 33.9 | 58.3 | 35.7 | 65.6 | 36 | 61.9 |
| **200** | 32.7 | 42.2 | 33.6 | 61.2 | 34.8 | 61.5 | 35.5 | 52.2 | 34.9 | 66.1 | 35 | 64.5 |
| **250** | 32.2 | 40.5 | 31.6 | 58.6 | 32.2 | 60.1 | 33.5 | 52 | 33.9 | 65.5 | 34.3 | 52.2 |
| **300** | 33.4 | 42 | 32.4 | 66.3 | 32.2 | 54.7 | 33 | 60.9 | 36.4 | 50.9 | 33 | 62.9 |

**Table XLVII:** Transmittance of crystal violet with peanut hull at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 8.8 | 16.3 | 8.6 | 59.2 | 8.7 | 58.1 | 8.9 | 57.4 | 8.8 | 56.7 | 9.1 | 56.2 |
| **100** | 35.4 | 44.8 | 35.6 | 67.9 | 35.7 | 68.7 | 35.2 | 69.1 | 35.4 | 70.07 | 35.7 | 71.8 |
| **150** | 34.3 | 43.6 | 34.2 | 65.2 | 34.3 | 67.4 | 34.2 | 68.7 | 34.3 | 69.8 | 34.6 | 70.2 |
| **200** | 33.9 | 42.9 | 33.7 | 64.1 | 33.8 | 65.9 | 33.5 | 66.9 | 33.9 | 68.4 | 33.2 | 69.4 |
| **250** | 33.2 | 41.3 | 33.5 | 63.7 | 33.6 | 64.6 | 33.1 | 65.3 | 33.2 | 67.3 | 32.8 | 68.5 |
| **300** | 32 | 41.1 | 31.7 | 62.4 | 31.8 | 63.2 | 31.5 | 64.2 | 32 | 65.7 | 31.7 | 66.6 |

**Table XLVIII:** Transmittance of crystal violet with peanut hull at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 0.4 | 5.3 | 0.4 | 45.8 | 0.5 | 41.6 | 0.4 | 38 | 0.5 | 32.7 | 0.4 | 31.4 |
| 100 | 6 | 6.7 | 6.1 | 37.6 | 6.2 | 44.7 | 6.7 | 41.2 | 6.4 | 36.6 | 7.1 | 34.3 |
| 150 | 5.5 | 6.2 | 5.2 | 37.2 | 5.6 | 38.5 | 5.5 | 39.9 | 5.2 | 32.4 | 5.5 | 31.2 |
| 200 | 5.3 | 6.7 | 5.5 | 35.6 | 5.4 | 37.3 | 5.3 | 36.3 | 4.9 | 31.4 | 5.3 | 30.1 |
| 250 | 4.8 | 5.3 | 4.9 | 31.9 | 5.8 | 36.3 | 5.4 | 34.1 | 5.1 | 31.5 | 5.4 | 30.2 |
| 300 | 5.1 | 5.9 | 4.9 | 30.7 | 5.4 | 30.9 | 5.5 | 34.9 | 5.4 | 33.6 | 4.8 | 30.5 |

**Table XLIX:** Transmittance of crystal violet with onion peel at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 12.9 | 20.2 | 13 | 74.7 | 14.3 | 76.7 | 13.9 | 78.9 | 13.3 | 80.7 | 14.9 | 82.4 |
| 100 | 34.4 | 37.1 | 34.3 | 72.9 | 34.4 | 75.8 | 34.5 | 77.2 | 33.3 | 78.1 | 36.4 | 79.8 |
| 150 | 33.6 | 36.8 | 33.7 | 71.6 | 33.7 | 74.6 | 33.9 | 76.4 | 35.7 | 77.6 | 36 | 78.4 |
| 200 | 32.7 | 35.4 | 33.6 | 71.3 | 34.8 | 73.8 | 35.5 | 75.9 | 34.9 | 76.9 | 35 | 77.6 |
| 250 | 32.2 | 33.9 | 31.6 | 70.1 | 32.2 | 72.3 | 33.5 | 73.1 | 33.9 | 74.5 | 34.3 | 76.3 |
| 300 | 33.4 | 33.5 | 32.4 | 69.7 | 32.2 | 70.8 | 33 | 72.8 | 36.4 | 73.2 | 33 | 74.9 |

**Table L:** Transmittance of crystal violet with onion peel at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 8.8 | 15.4 | 8.6 | 69.4 | 8.7 | 71.9 | 8.9 | 73.1 | 8.8 | 74.6 | 9.1 | 76.9 |
| **100** | 35.4 | 36.2 | 35.6 | 68.8 | 35.7 | 70.8 | 35.2 | 72.8 | 35.4 | 73.2 | 35.7 | 75.4 |
| **150** | 34.3 | 35.3 | 34.2 | 67.5 | 34.3 | 69.1 | 34.2 | 71.9 | 34.3 | 72.5 | 34.6 | 74.6 |
| **200** | 33.9 | 34.7 | 33.7 | 66.4 | 33.8 | 67.8 | 33.5 | 70.2 | 33.9 | 71.8 | 33.2 | 73.9 |
| **250** | 33.2 | 33.9 | 33.5 | 63.9 | 33.6 | 66.2 | 33.1 | 69.8 | 33.2 | 70.9 | 32.8 | 72.1 |
| **300** | 32 | 32.7 | 31.7 | 62.8 | 31.8 | 64.9 | 31.5 | 67.5 | 32 | 68.6 | 31.7 | 70.8 |

**Table LI:** Transmittance of crystal violet with onion peel at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 0.4 | 5.3 | 0.4 | 65.6 | 0.5 | 67.4 | 0.4 | 69.5 | 0.5 | 71.9 | 0.4 | 73.2 |
| **100** | 6 | 6.7 | 6.1 | 64.2 | 6.2 | 66.5 | 6.7 | 68.2 | 6.4 | 69.3 | 7.1 | 72.9 |
| **150** | 5.5 | 6.2 | 5.2 | 63.8 | 5.6 | 64.9 | 5.5 | 67.5 | 5.2 | 68.4 | 5.5 | 71.8 |
| **200** | 5.3 | 6.7 | 5.5 | 62.9 | 5.4 | 63.2 | 5.3 | 66.7 | 4.9 | 67.7 | 5.3 | 70.6 |
| **250** | 4.8 | 5.3 | 4.9 | 60.6 | 5.8 | 62.1 | 5.4 | 65.3 | 5.1 | 65.9 | 5.4 | 69.5 |
| **300** | 5.1 | 5.9 | 4.9 | 59.2 | 5.4 | 60.8 | 5.5 | 63.8 | 5.4 | 64.6 | 4.8 | 68.2 |

**Table LII:** Transmittance of disperse yellow 3 with PAC at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying powdered activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 49.1 | 57.1 | 48.7 | 96.5 | 48.7 | 97.5 | 49.3 | 96.3 | 48.6 | 97.7 | 47.8 | 97.7 |
| **100** | 67.3 | 73.2 | 67.2 | 95.3 | 67.4 | 96.1 | 67.8 | 95.2 | 67.3 | 96.4 | 67.9 | 96.8 |
| **150** | 65.4 | 72.8 | 65.4 | 94.2 | 65.8 | 95.3 | 65.6 | 94.1 | 65.2 | 95.9 | 65.3 | 95.1 |
| **200** | 63.9 | 71.9 | 63.7 | 93.8 | 63.2 | 94.4 | 63.8 | 93.7 | 63.9 | 94.5 | 63.7 | 94.5 |
| **250** | 62.1 | 70.4 | 62.8 | 92.1 | 62.8 | 93.8 | 62.6 | 92.9 | 62.5 | 93.2 | 62.6 | 93.2 |
| **300** | 61 | 69.3 | 61.4 | 87.1 | 61.5 | 89.3 | 61.9 | 88.6 | 61.3 | 91.4 | 61.4 | 92.6 |

**Table LIII:** Transmittance of disperse yellow 3 with PAC at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying powdered activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 28.8 | 35.4 | 29.1 | 92.1 | 27.5 | 93.1 | 28.7 | 93.8 | 28.3 | 95.6 | 27.3 | 96.4 |
| **100** | 47.6 | 54.1 | 47.8 | 91.7 | 46.4 | 92.6 | 47.2 | 92.9 | 47.1 | 94.2 | 47.6 | 95.3 |
| **150** | 46.3 | 53.7 | 46.1 | 90.3 | 46.2 | 91.4 | 46.4 | 91.7 | 46.8 | 93.3 | 46.1 | 94.7 |
| **200** | 45.8 | 52.9 | 45.4 | 89 | 45.3 | 90 | 45.3 | 91.2 | 45.5 | 92.1 | 45.2 | 93.8 |
| **250** | 44.2 | 51.6 | 44.2 | 88.8 | 44.1 | 89.7 | 44.5 | 90.4 | 44.2 | 91.7 | 44 | 92.5 |
| **300** | 43 | 50.3 | 43.1 | 87.4 | 43.6 | 88.9 | 43.8 | 89.8 | 43.4 | 90.2 | 43.4 | 91.9 |

**Table LIV:** Transmittance of disperse yellow 3 with PAC at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying powdered activated carbon dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.2 | | 0.4 | | 0.6 | | 0.8 | | 1 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 13.7 | 27.4 | 14.9 | 87.9 | 13.4 | 89.7 | 13.9 | 91.5 | 13.9 | 93.2 | 13.4 | 95.2 |
| **100** | 37.1 | 45.6 | 37.8 | 86.7 | 37.1 | 88.2 | 37.5 | 90.7 | 37.8 | 92.1 | 37.2 | 94.2 |
| **150** | 36.4 | 44 | 36.5 | 85.4 | 36 | 87.7 | 36.6 | 89 | 36.2 | 91.7 | 36.1 | 93.1 |
| **200** | 35.7 | 43.9 | 35.1 | 84.3 | 35.7 | 86.5 | 35.4 | 88.2 | 35 | 90.8 | 35.2 | 92.7 |
| **250** | 34.6 | 42.1 | 34.4 | 83.2 | 34.6 | 85.3 | 34.7 | 87.8 | 34.1 | 89.2 | 34.7 | 91.8 |
| **300** | 33.1 | 41.4 | 33.6 | 82.1 | 33.1 | 84.2 | 33.3 | 86.5 | 33.8 | 88.7 | 33.6 | 90.7 |

**Table LV:** Transmittance of disperse yellow 3 with peanut hull at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 49.1 | 54.5 | 48.7 | 65.4 | 48.7 | 67.8 | 49.3 | 70.8 | 48.6 | 66.3 | 47.8 | 65.6 |
| **100** | 67.3 | 73.9 | 67.2 | 74.1 | 67.4 | 73.4 | 67.8 | 78.9 | 67.3 | 73.7 | 67.9 | 72.9 |
| **150** | 65.4 | 72.4 | 65.4 | 73.2 | 65.8 | 72.2 | 65.6 | 77.5 | 65.2 | 72.4 | 65.3 | 71.4 |
| **200** | 63.9 | 71.7 | 63.7 | 72.6 | 63.2 | 71.9 | 63.8 | 76.2 | 63.9 | 71.5 | 63.7 | 70.8 |
| **250** | 62.1 | 70.1 | 62.8 | 71.1 | 62.8 | 70.8 | 62.6 | 75.9 | 62.5 | 70.6 | 62.6 | 69.3 |
| **300** | 61 | 69.3 | 61.4 | 70.4 | 61.5 | 69.2 | 61.9 | 74.3 | 61.3 | 69.8 | 61.4 | 68.2 |

**Table LVI:** Transmittance of disperse yellow 3 with peanut hull at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 28.8 | 35.2 | 29.1 | 65.3 | 27.5 | 72.2 | 28.7 | 70.4 | 28.3 | 69.2 | 27.3 | 67.2 |
| 100 | 47.6 | 53.8 | 47.8 | 69.4 | 46.4 | 69.3 | 47.2 | 75.9 | 47.1 | 75.7 | 47.6 | 65.7 |
| 150 | 46.3 | 52.6 | 46.1 | 68.6 | 46.2 | 74.9 | 46.4 | 74.8 | 46.8 | 74.5 | 46.1 | 64.5 |
| 200 | 45.8 | 51.7 | 45.4 | 67.6 | 45.3 | 73.1 | 45.3 | 73.5 | 45.5 | 73.3 | 45.2 | 63.2 |
| 250 | 44.2 | 50.9 | 44.2 | 66.9 | 44.1 | 72.4 | 44.5 | 72.3 | 44.2 | 72.8 | 44 | 62.4 |
| 300 | 43 | 49.8 | 43.1 | 65.1 | 43.6 | 71.3 | 43.8 | 71.9 | 43.4 | 71.4 | 43.4 | 61.7 |

**Table LVII:** Transmittance of disperse yellow 3 with peanut hull at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying peanut hull size (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 3.327-2.38 | | 2.38-2.362 | | 2.362-0.6 | | 0.6-0.425 | | <0.425 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| 0 | 13.7 | 22.7 | 14.9 | 38.6 | 13.4 | 43.2 | 13.9 | 48.2 | 13.9 | 46.2 | 13.4 | 47.2 |
| 100 | 37.1 | 43.2 | 37.8 | 54.1 | 37.1 | 62.4 | 37.5 | 67.4 | 37.8 | 64.8 | 37.2 | 65.8 |
| 150 | 36.4 | 42.7 | 36.5 | 53.7 | 36 | 61.3 | 36.6 | 66.2 | 36.2 | 63.6 | 36.1 | 64.2 |
| 200 | 35.7 | 41.8 | 35.1 | 52.1 | 35.7 | 60.1 | 35.4 | 65.1 | 35 | 62.7 | 35.2 | 63.1 |
| 250 | 34.6 | 40.4 | 34.4 | 51.4 | 34.6 | 59.7 | 34.7 | 64.3 | 34.1 | 61.4 | 34.7 | 62.9 |
| 300 | 33.1 | 39.9 | 33.6 | 50.6 | 33.1 | 58.4 | 33.3 | 63.7 | 33.8 | 60.9 | 33.6 | 61.5 |

**Table LVIII:** Transmittance of disperse yellow 3 with onion peel at low concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 49.1 | 55.2 | 48.7 | 63.2 | 48.7 | 65.4 | 49.3 | 68.7 | 48.6 | 64.8 | 47.8 | 58.3 |
| **100** | 67.3 | 73.7 | 67.2 | 74.1 | 67.4 | 78.9 | 67.8 | 82.4 | 67.3 | 73.9 | 67.9 | 67.9 |
| **150** | 65.4 | 72.3 | 65.4 | 73.3 | 65.8 | 77.4 | 65.6 | 81.8 | 65.2 | 72.4 | 65.3 | 66.8 |
| **200** | 63.9 | 71.5 | 63.7 | 72.8 | 63.2 | 76.6 | 63.8 | 80.2 | 63.9 | 74.6 | 63.7 | 65.4 |
| **250** | 62.1 | 70.8 | 62.8 | 71.7 | 62.8 | 75.3 | 62.6 | 79.9 | 62.5 | 73.3 | 62.6 | 64.6 |
| **300** | 61 | 69.6 | 61.4 | 70.6 | 61.5 | 74.7 | 61.9 | 78.5 | 61.3 | 72.2 | 61.4 | 63.3 |

**Table LIX:** Transmittance of disperse yellow 3 with onion peel at medium concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 28.8 | 35.4 | 29.1 | 59.8 | 27.5 | 60.2 | 28.7 | 65.7 | 28.3 | 63.9 | 27.3 | 59.7 |
| **100** | 47.6 | 53.7 | 47.8 | 63.3 | 46.4 | 67.3 | 47.2 | 73.9 | 47.1 | 67.5 | 47.6 | 57.9 |
| **150** | 46.3 | 52.9 | 46.1 | 62.1 | 46.2 | 66.5 | 46.4 | 72.3 | 46.8 | 66.2 | 46.1 | 56.3 |
| **200** | 45.8 | 51.8 | 45.4 | 61.4 | 45.3 | 65.6 | 45.3 | 71.2 | 45.5 | 65.5 | 45.2 | 55.2 |
| **250** | 44.2 | 50.2 | 44.2 | 60.7 | 44.1 | 64.1 | 44.5 | 70.4 | 44.2 | 64.2 | 44 | 54.6 |
| **300** | 43 | 49.1 | 43.1 | 59.8 | 43.6 | 63.8 | 43.8 | 69.9 | 43.4 | 63.8 | 43.4 | 53.2 |

**Table LX:** Transmittance of disperse yellow 3 with onion peel at high concentration.

| Coffee concentration (ppm) | Transmittance (%) results with varying onion peel dosage (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 0.4 | | 0.8 | | 1.2 | | 1.6 | | 2 | |
| | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT | BT | AT |
| **0** | 13.7 | 21.9 | 14.9 | 45.4 | 13.4 | 41.1 | 13.9 | 65.4 | 13.9 | 61.7 | 13.4 | 52.5 |
| **100** | 37.1 | 45.3 | 37.8 | 52.1 | 37.1 | 57 | 37.5 | 64.8 | 37.8 | 60.1 | 37.2 | 57.9 |
| **150** | 36.4 | 44.6 | 36.5 | 51.2 | 36 | 56.2 | 36.6 | 63.5 | 36.2 | 59.4 | 36.1 | 58.6 |
| **200** | 35.7 | 43.5 | 35.1 | 50.3 | 35.7 | 55.1 | 35.4 | 62.9 | 35 | 58.5 | 35.2 | 57.4 |
| **250** | 34.6 | 42.8 | 34.4 | 49.05 | 34.6 | 54.4 | 34.7 | 61.6 | 34.1 | 57.6 | 34.7 | 56.7 |
| **300** | 33.1 | 41.7 | 33.6 | 48.2 | 33.1 | 53.7 | 33.3 | 60.3 | 33.8 | 55.2 | 33.6 | 55.3 |

## APPENDIX B: FIGURES

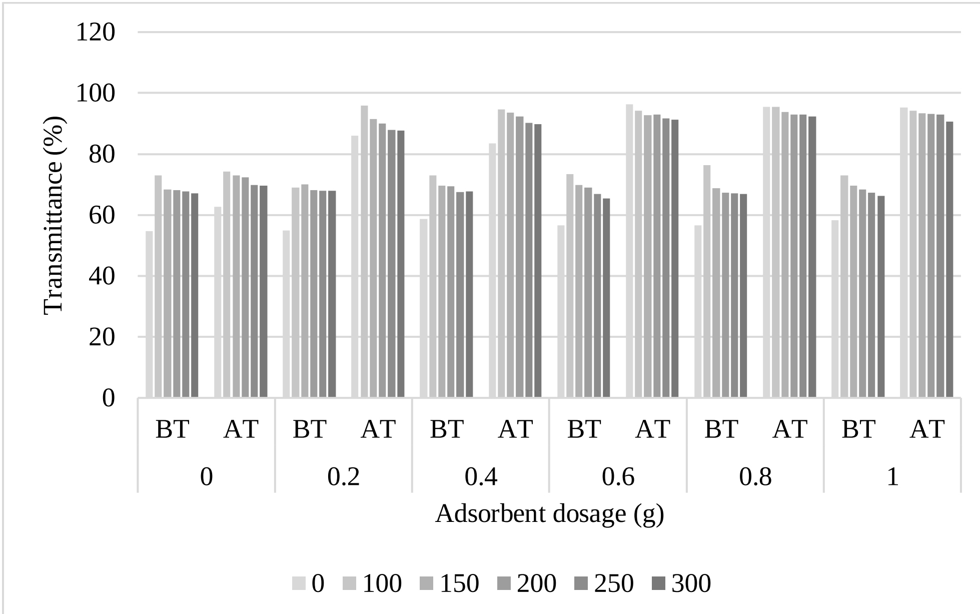


**Figure 7:** Comparison of transmittance before and after treatment in low concentration acid black 48

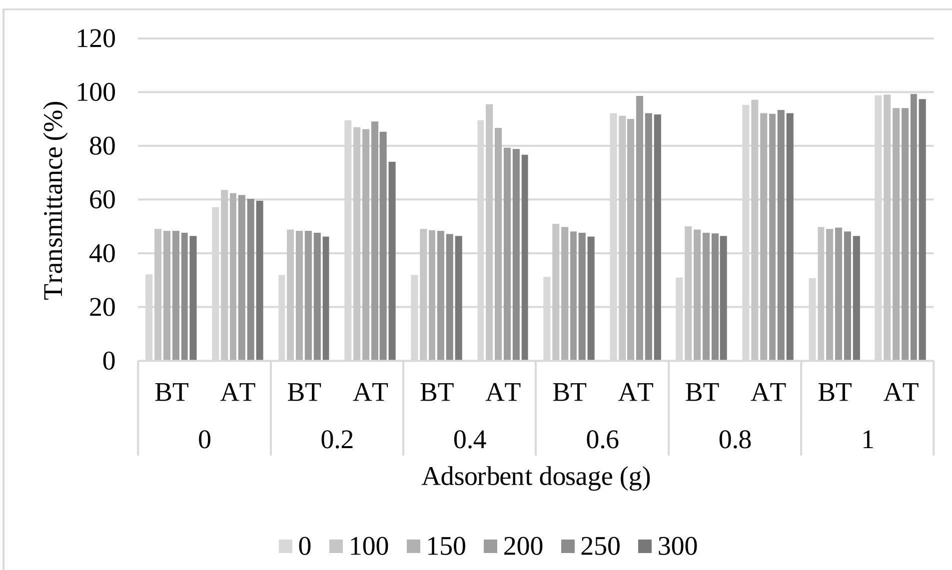


**Figure 8:** Comparison of transmittance before and after treatment in medium concentration acid black 48.

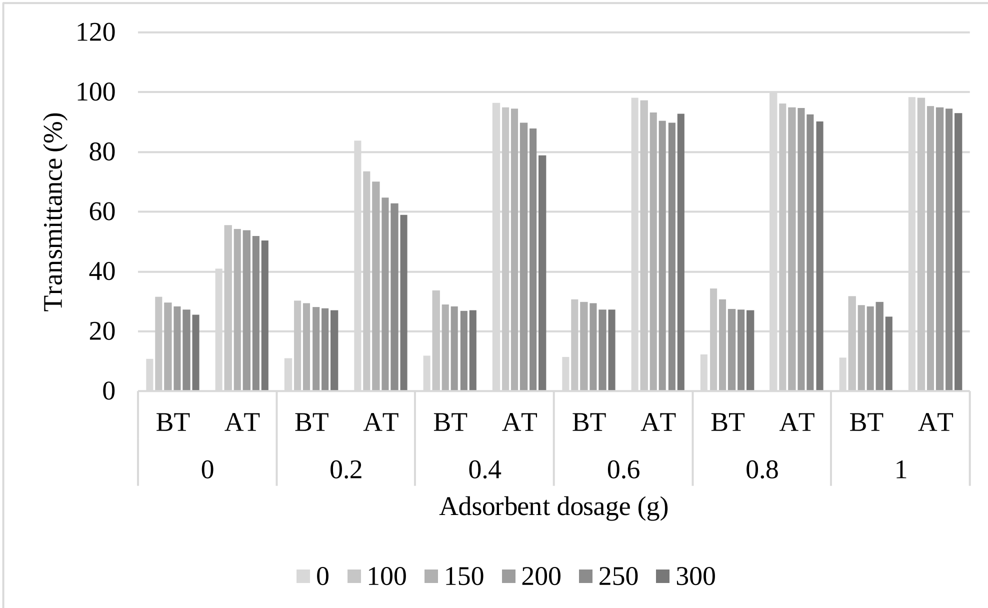


**Figure 9:** Comparison of transmittance before and after treatment in high concentration acid black 48.

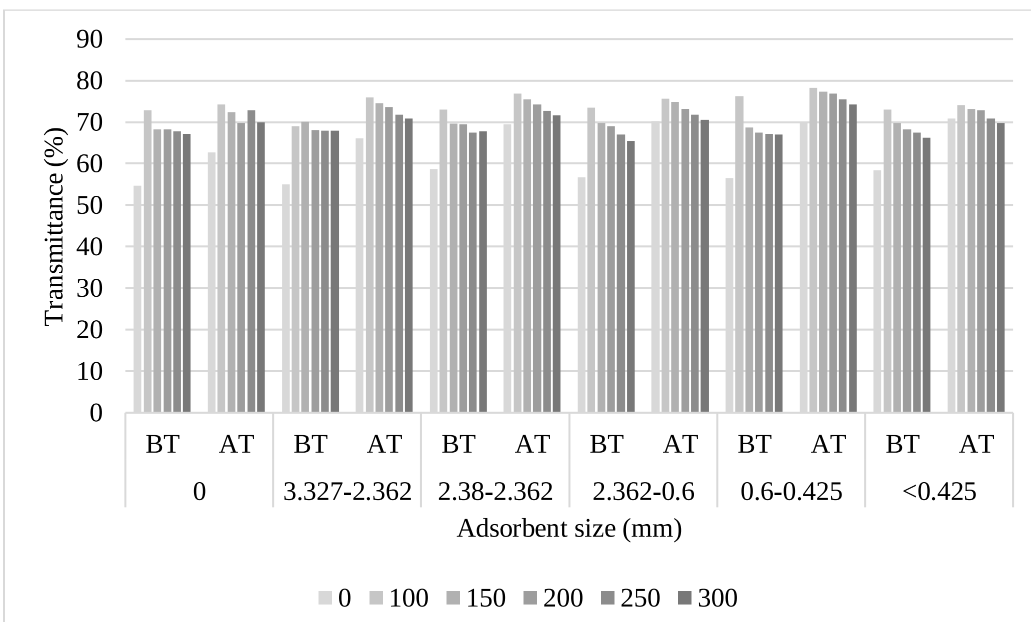


**Figure 10:** Comparison of transmittance before and after treatment in low concentration acid black 48.

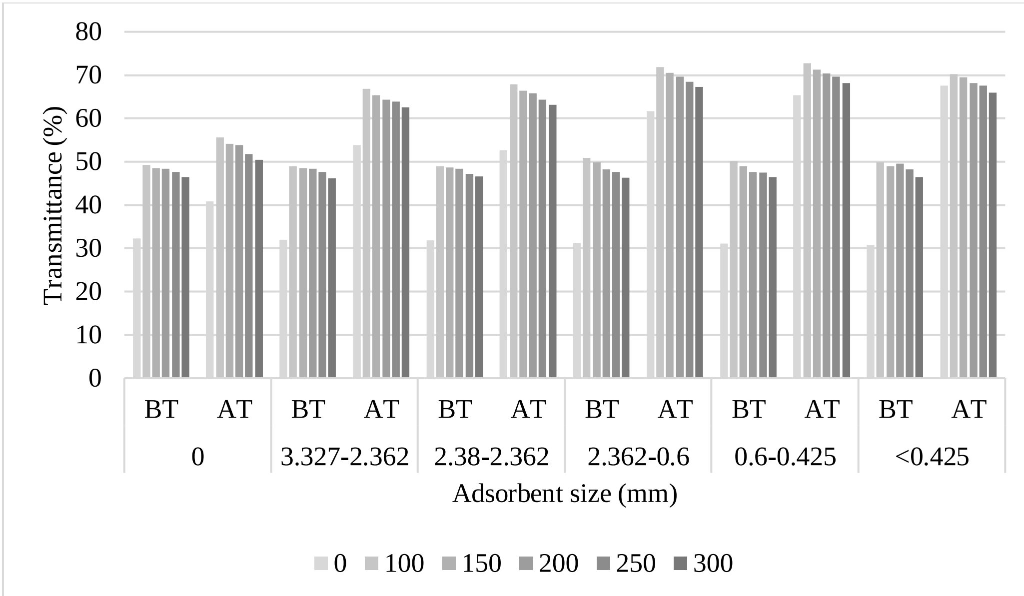


**Figure 11:** Comparison of transmittance before and after treatment in medium concentration acid black 48.

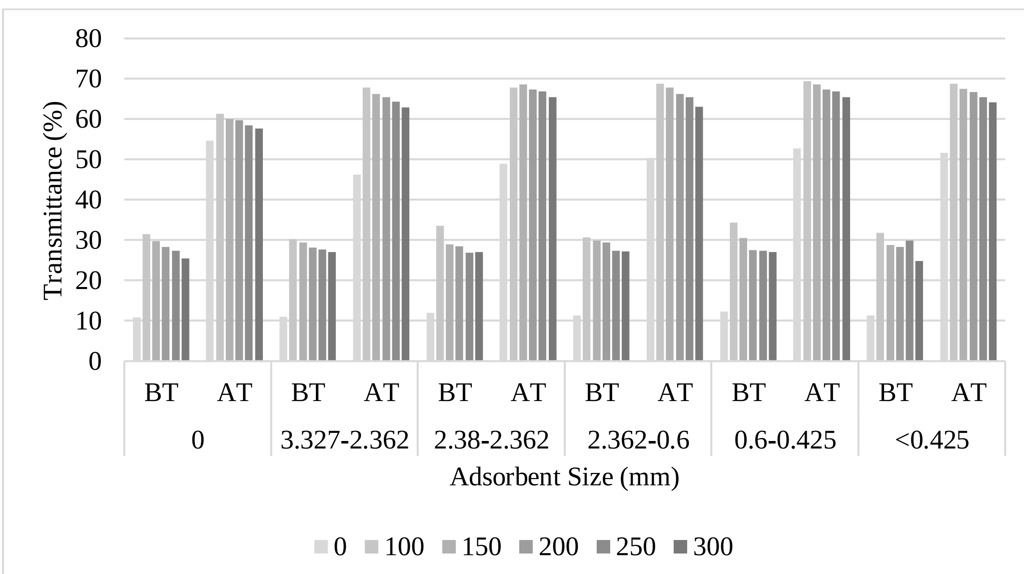


**Figure 12:** Comparison of transmittance before and after treatment in high concentration acid black 48.

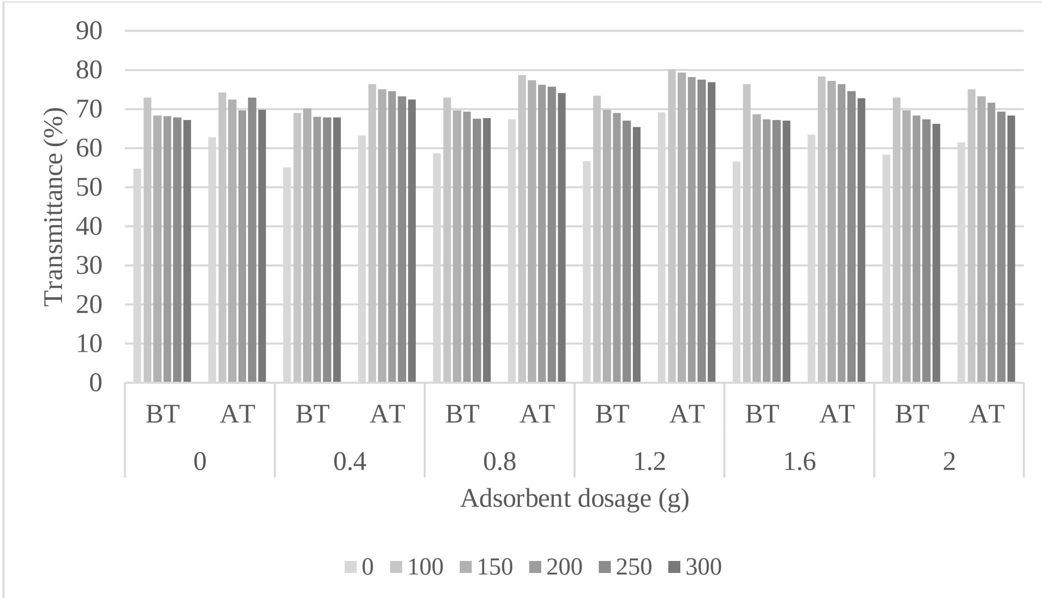


**Figure 13:** Comparison of transmittance before and after treatment in low concentration acid black 48.

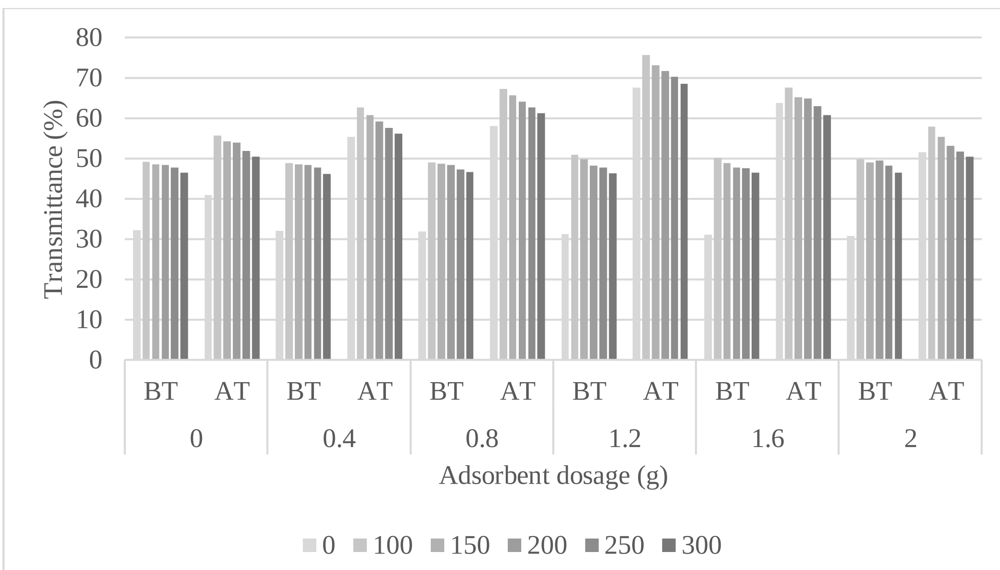


**Figure 14:** Comparison of transmittance before and after treatment in medium concentration acid black 48.

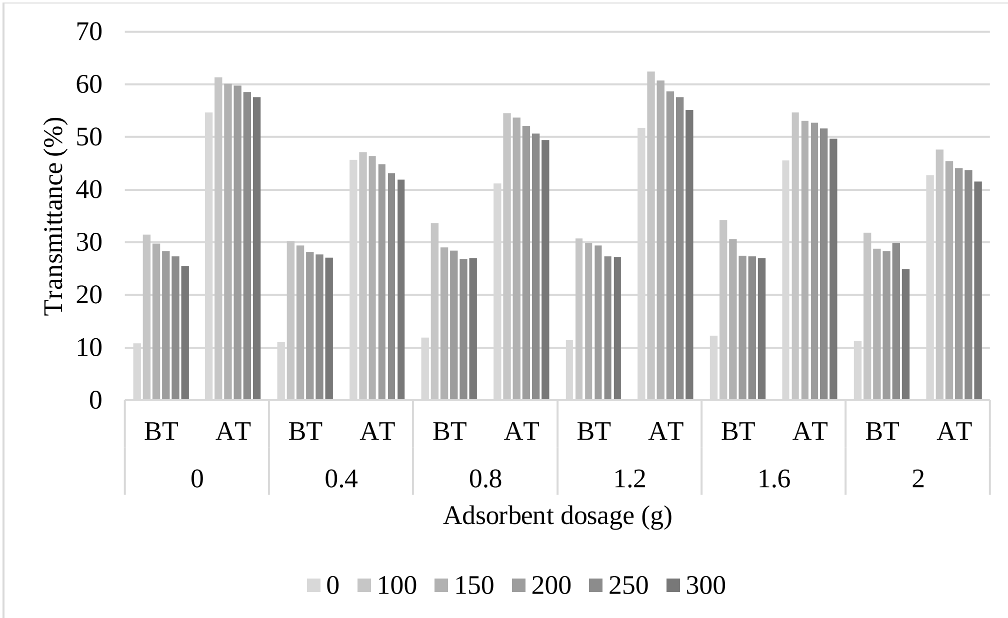


**Figure 15:** Comparison of transmittance before and after treatment in high concentration acid black 48.

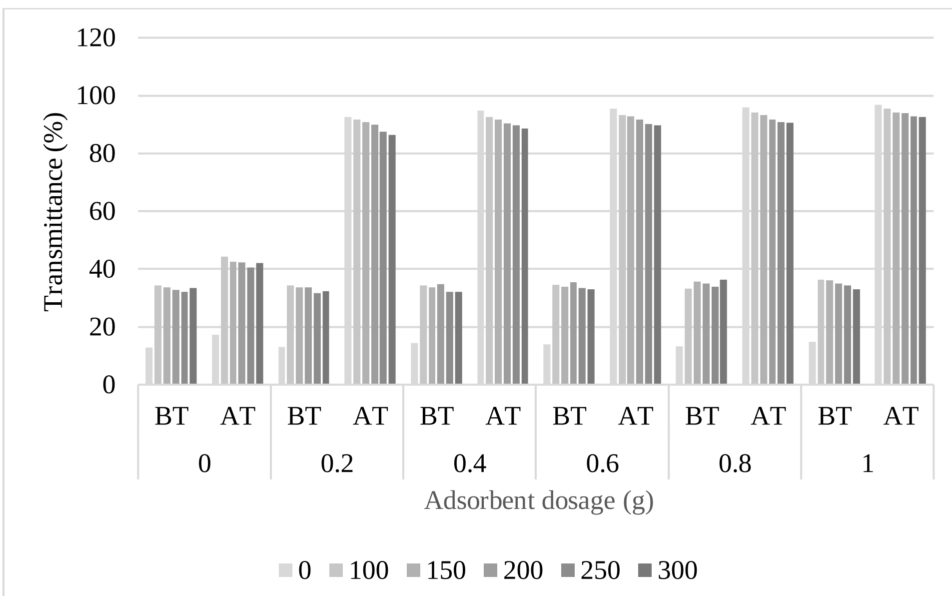


**Figure 16:** Comparison of transmittance before and after treatment in low concentration crystal violet.

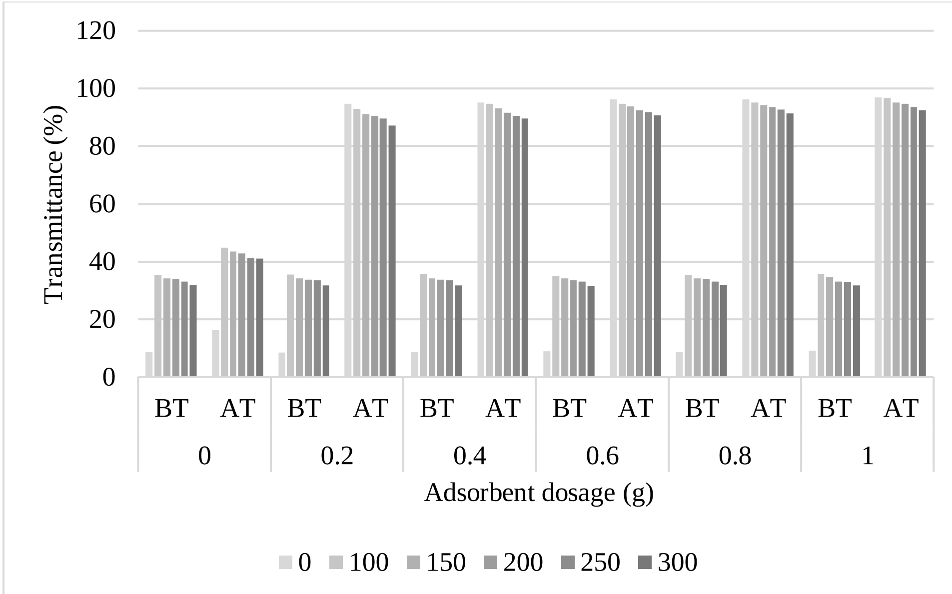


**Figure 17:** Comparison of transmittance before and after treatment in medium concentration crystal violet.

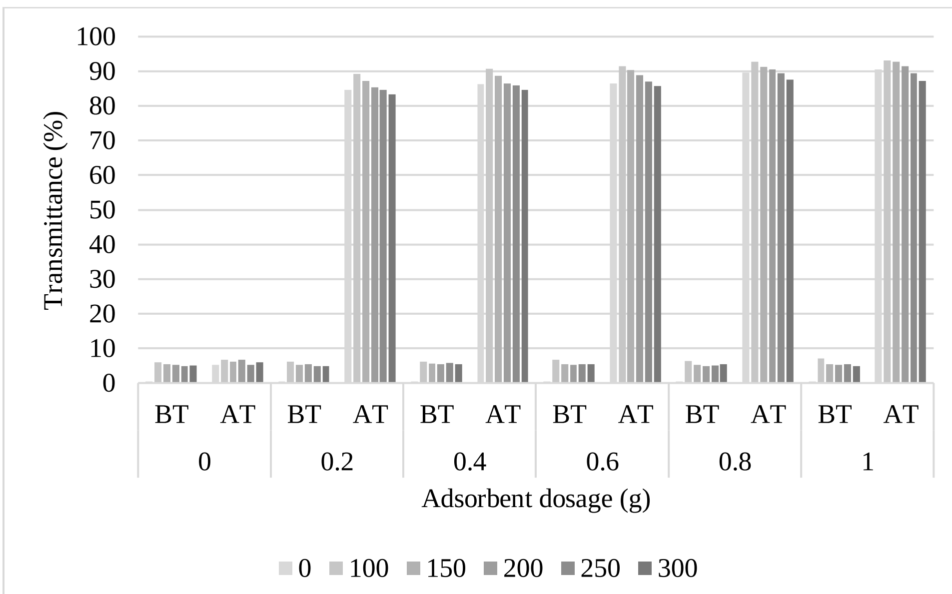


**Figure 18:** Comparison of transmittance before and after treatment in high concentration crystal violet.

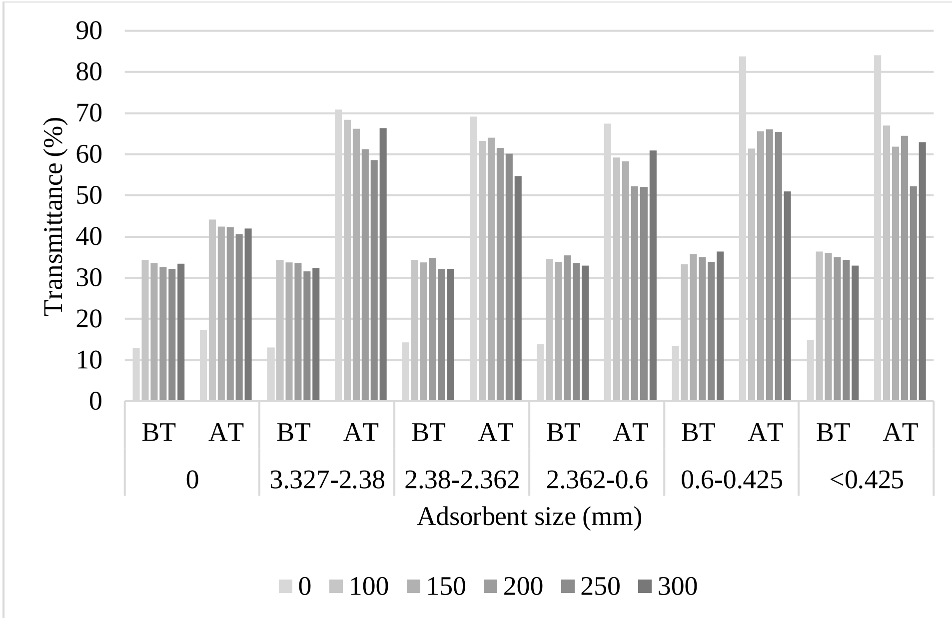


**Figure 19:** Comparison of transmittance before and after treatment in low concentration crystal violet.

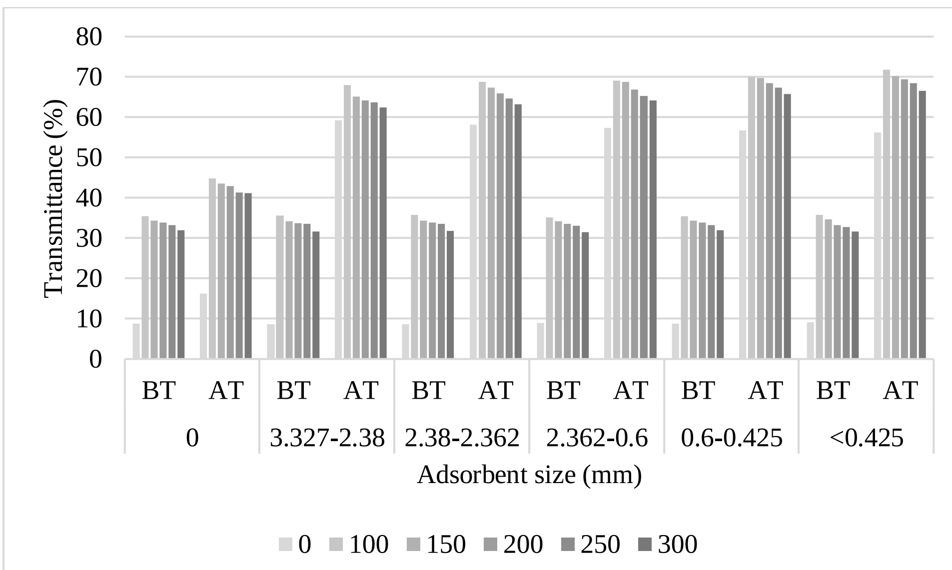


**Figure 20:** Comparison of transmittance before and after treatment in medium concentration crystal violet.

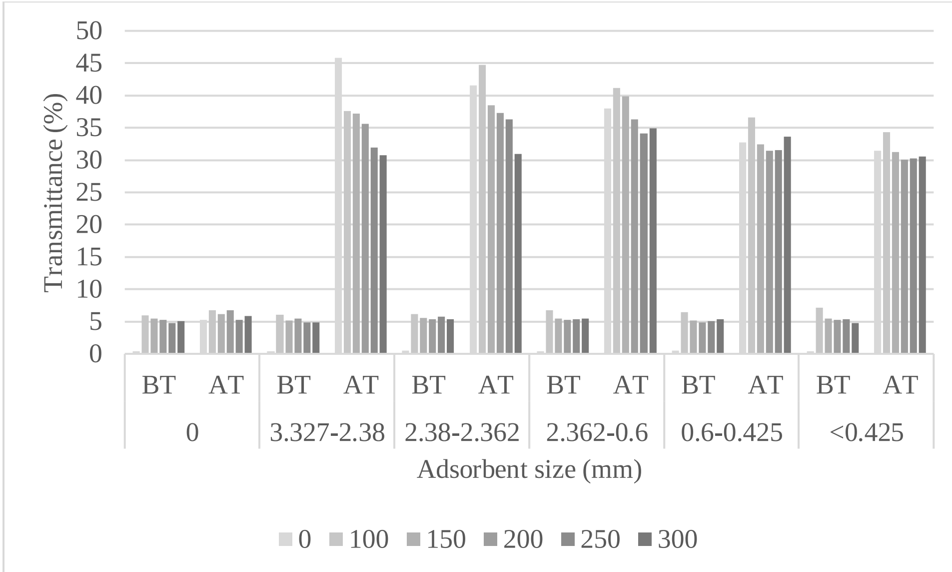


**Figure 21:** Comparison of transmittance before and after treatment in high concentration crystal violet.

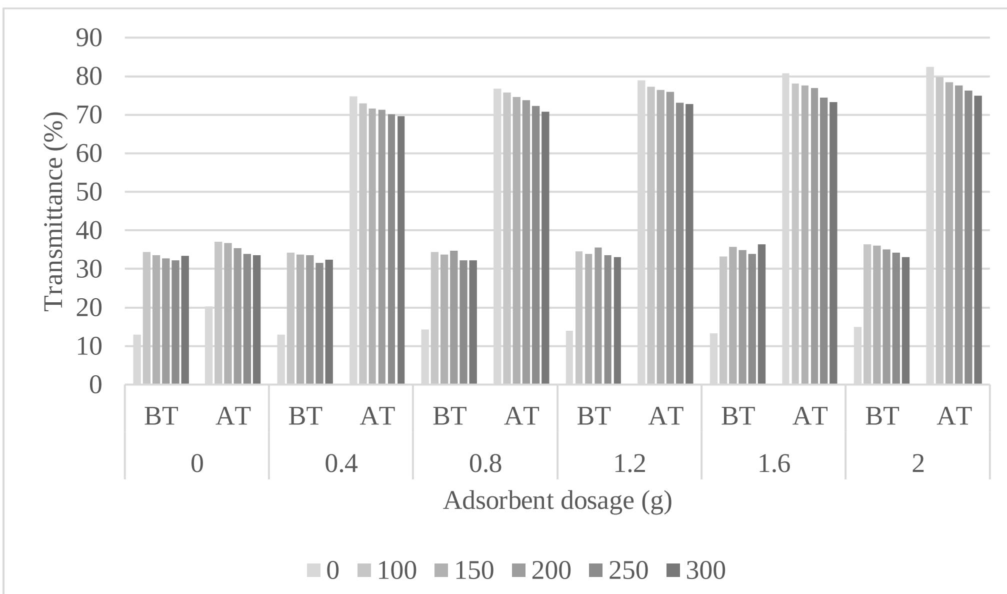


**Figure 22:** Comparison of transmittance before and after treatment in low concentration crystal violet.

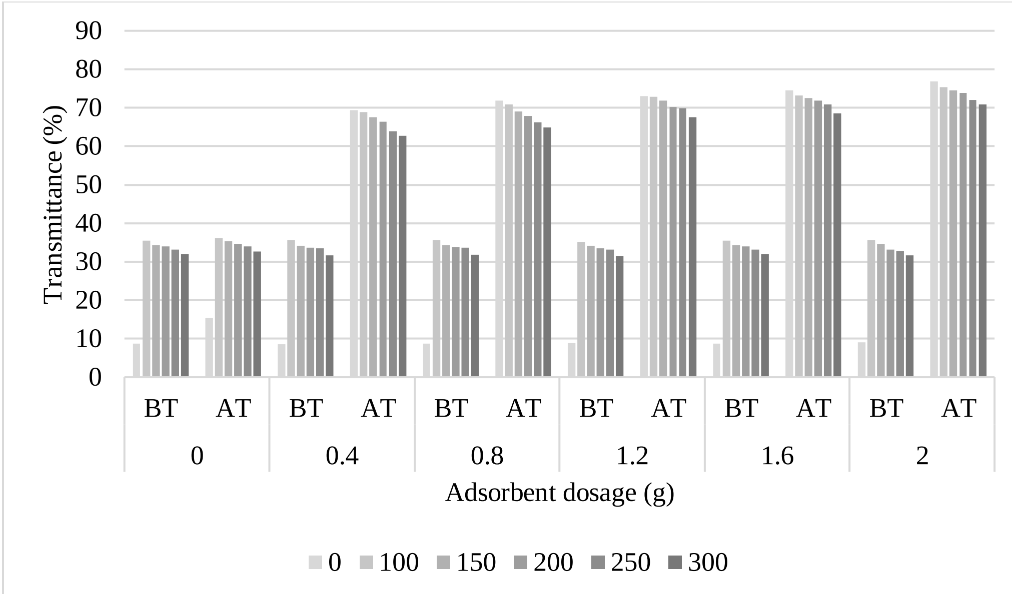


**Figure 23:** Comparison of transmittance before and after treatment in medium concentration crystal violet.

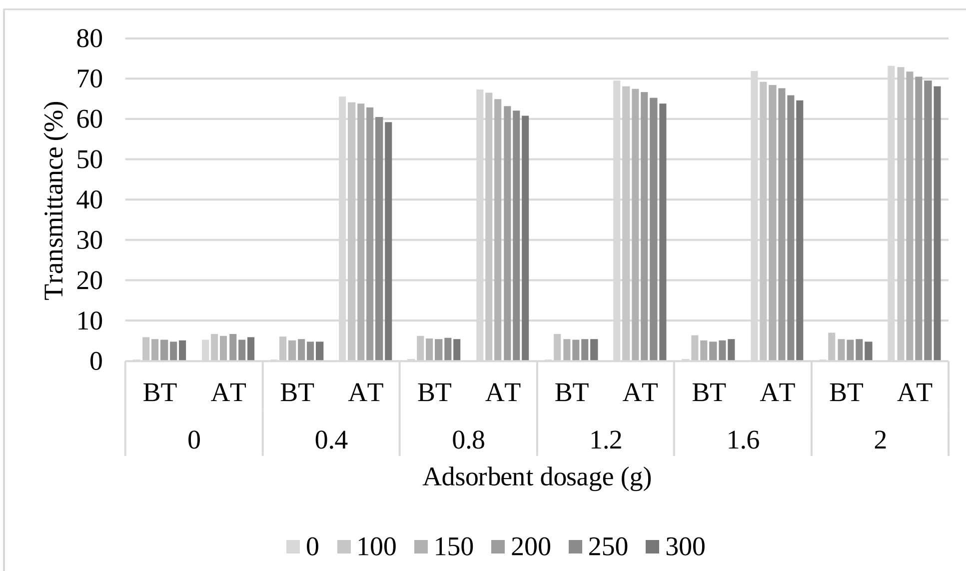


**Figure 24:** Comparison of transmittance before and after treatment in high concentration crystal violet.

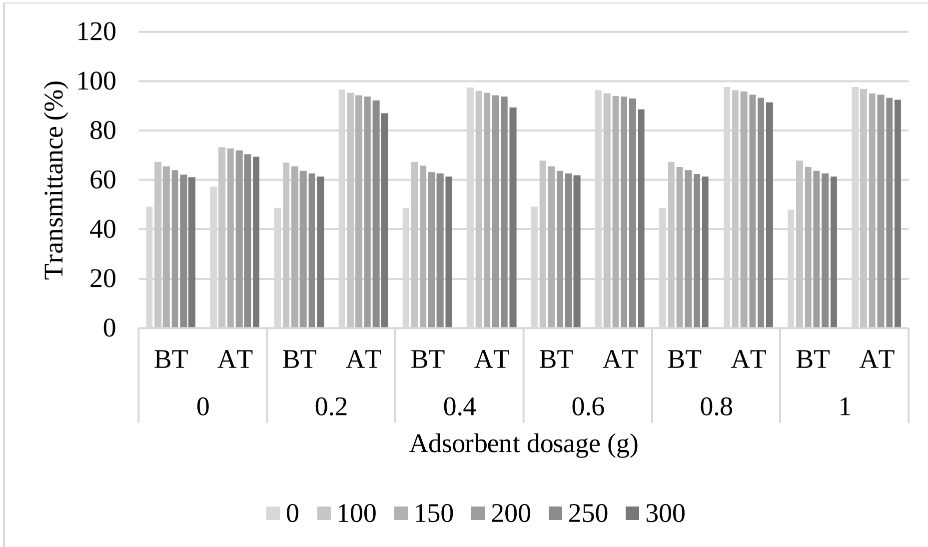


**Figure 25:** Comparison of transmittance before and after treatment in low concentration disperse yellow 3.

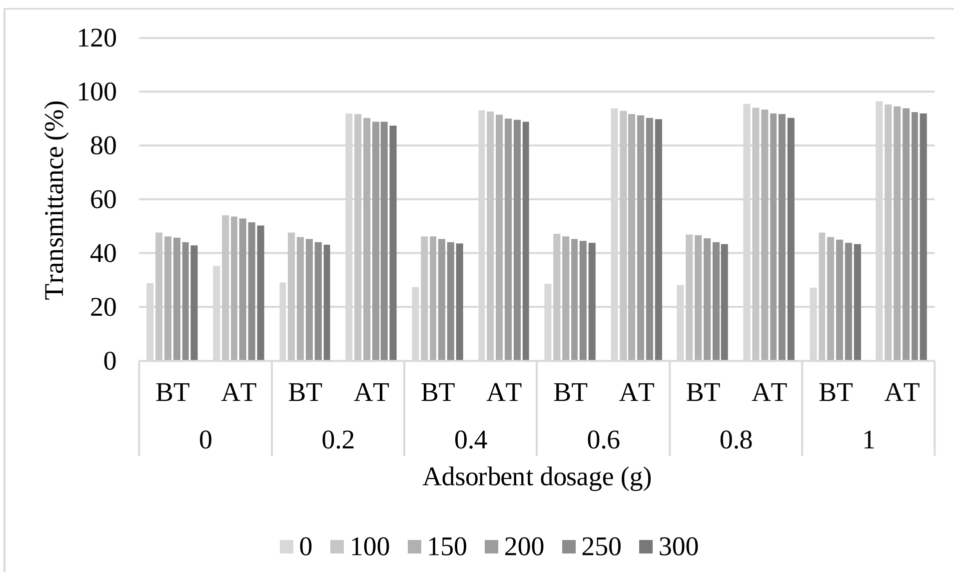


**Figure 26:** Comparison of transmittance before and after treatment in medium concentration disperse yellow 3.

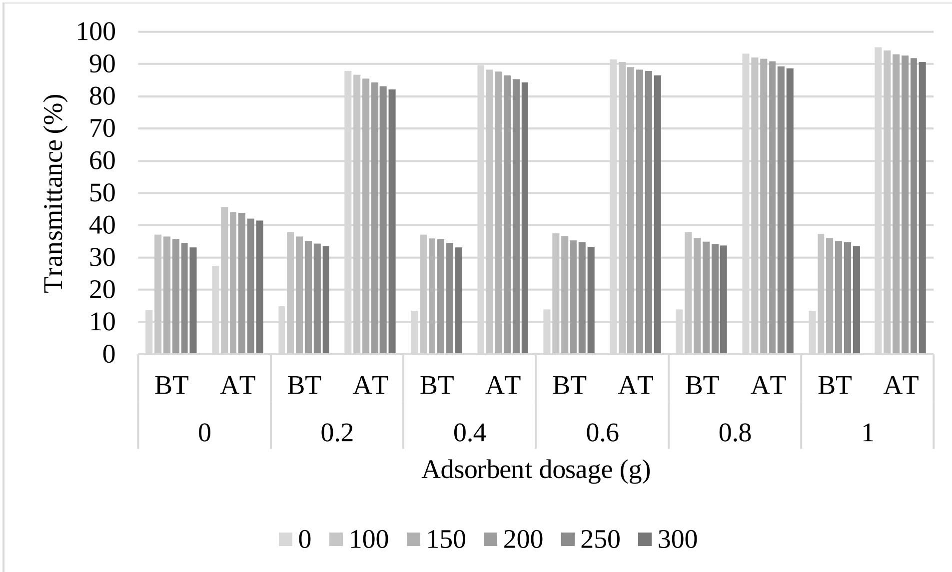


**Figure 27:** Comparison of transmittance before and after treatment in high concentration disperse yellow 3.

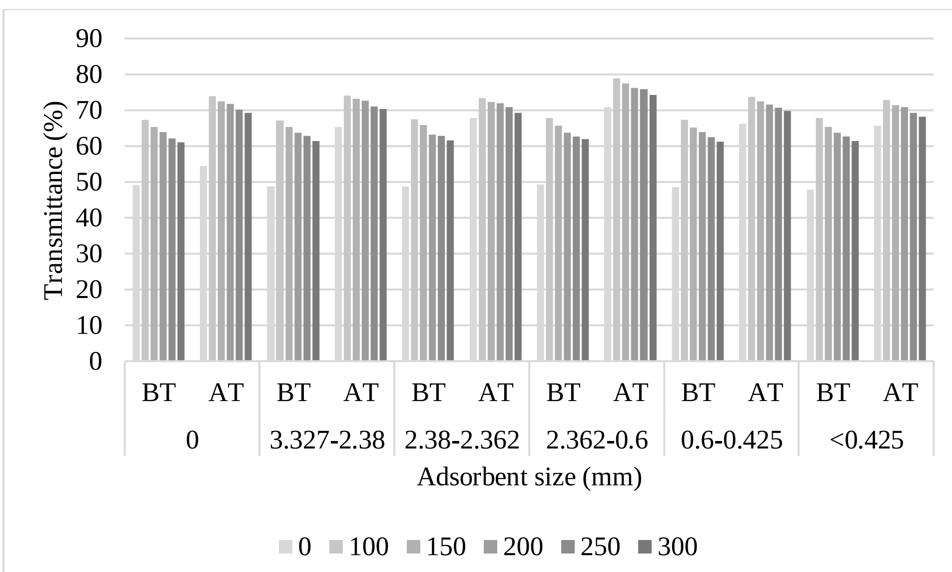


**Figure 28:** Comparison of transmittance before and after treatment in low concentration disperse yellow 3.

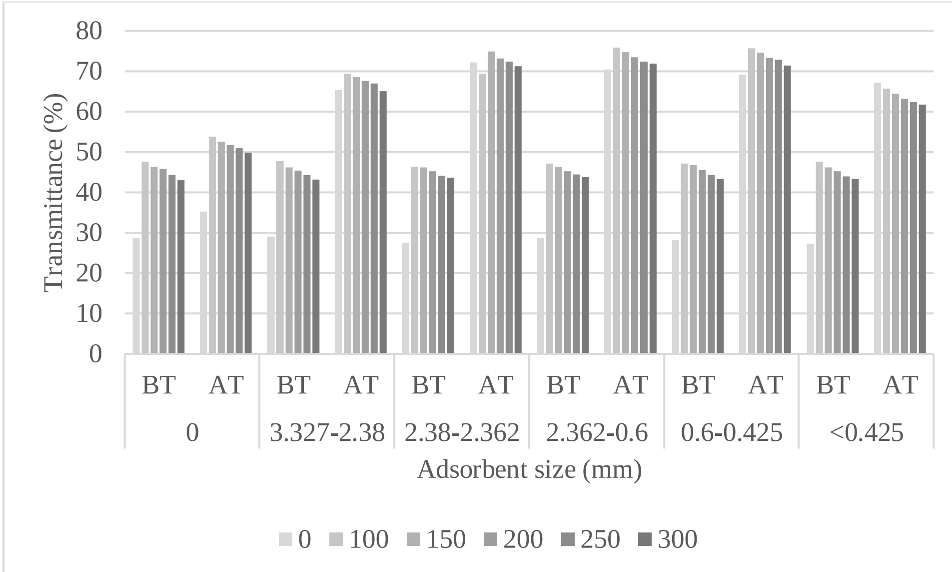


**Figure 29:** Comparison of transmittance before and after treatment in medium concentration disperse yellow 3.

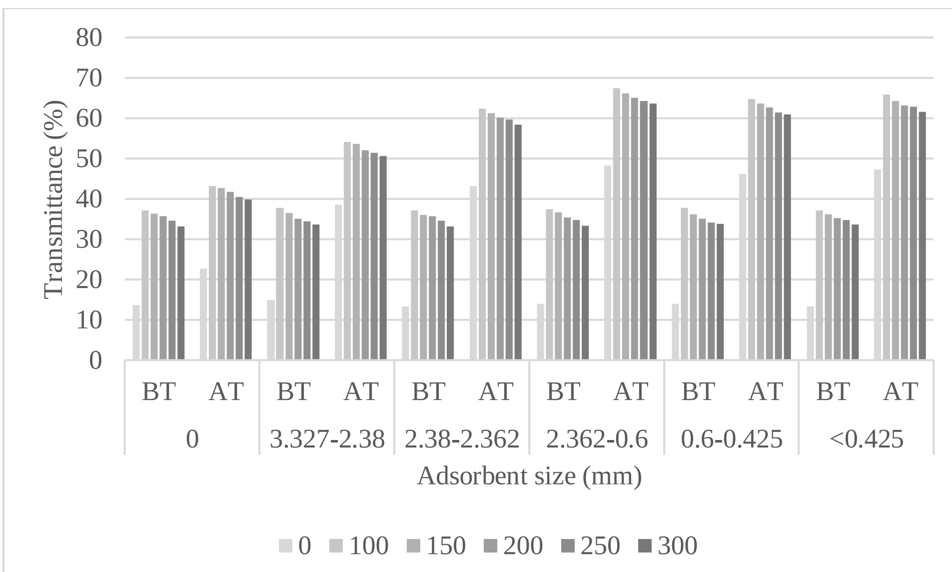


**Figure 30:** Comparison of transmittance before and after treatment in high concentration disperse yellow 3.

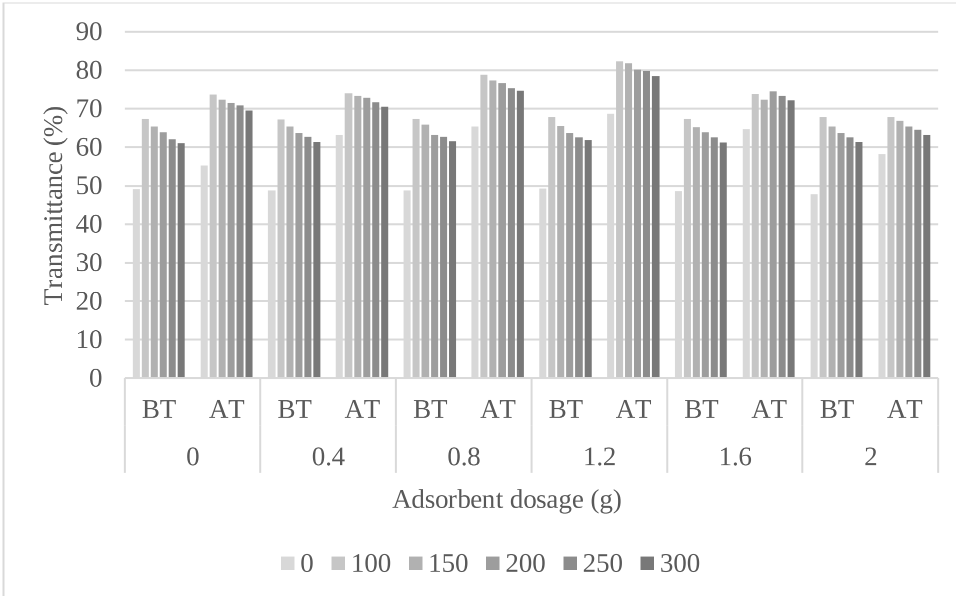


**Figure 31:** Comparison of transmittance before and after treatment in low concentration disperse yellow 3.

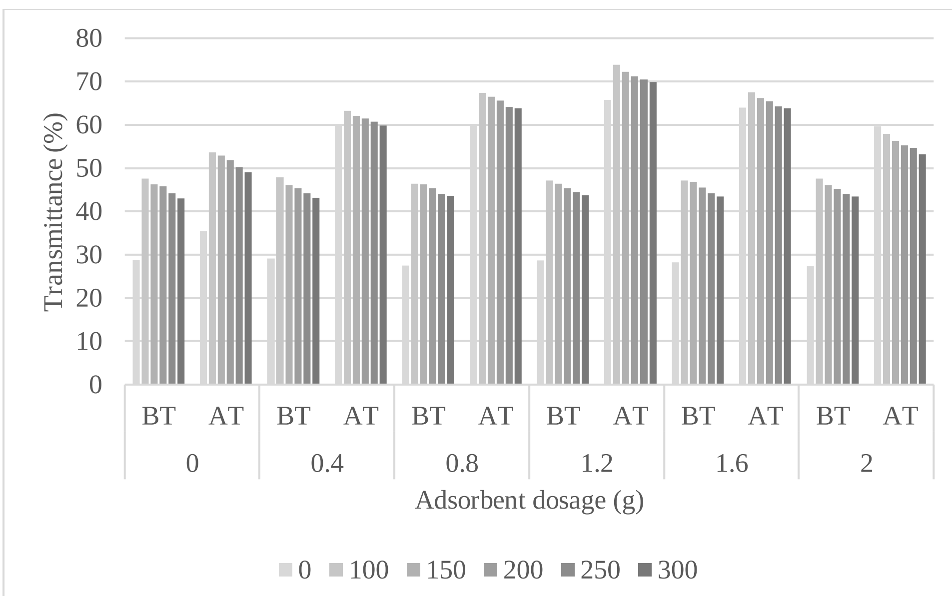


**Figure 32:** Comparison of transmittance before and after treatment in medium concentration disperse yellow 3.

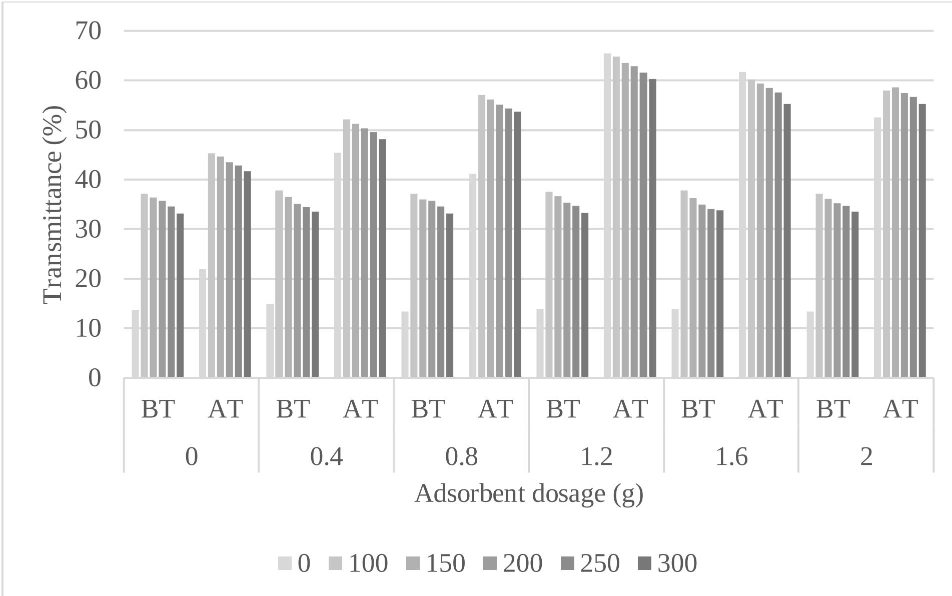


**Figure 33:** Comparison of transmittance before and after treatment in high concentration disperse yellow 3.

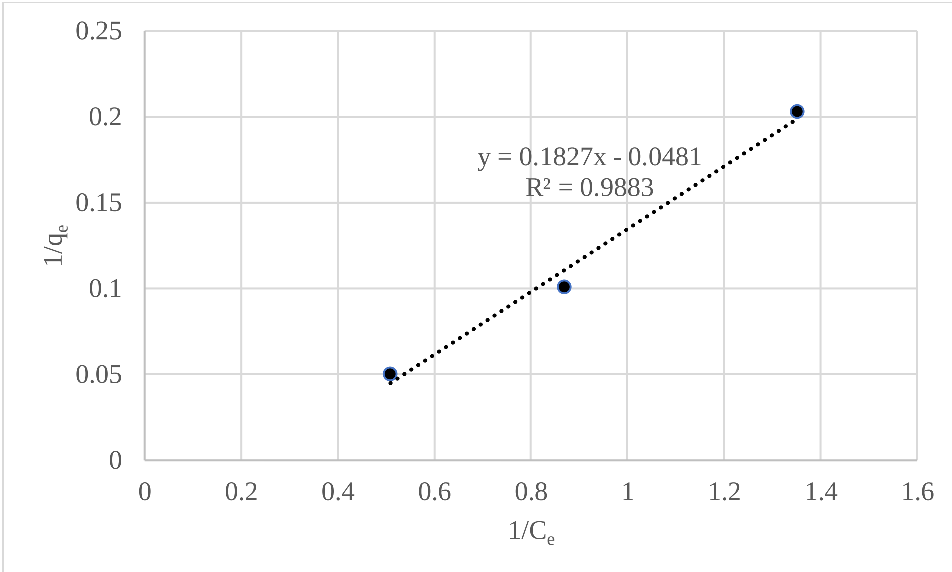


**Figure 34:** Langmuir isotherm model of acid black 48 adsorption on PAC.

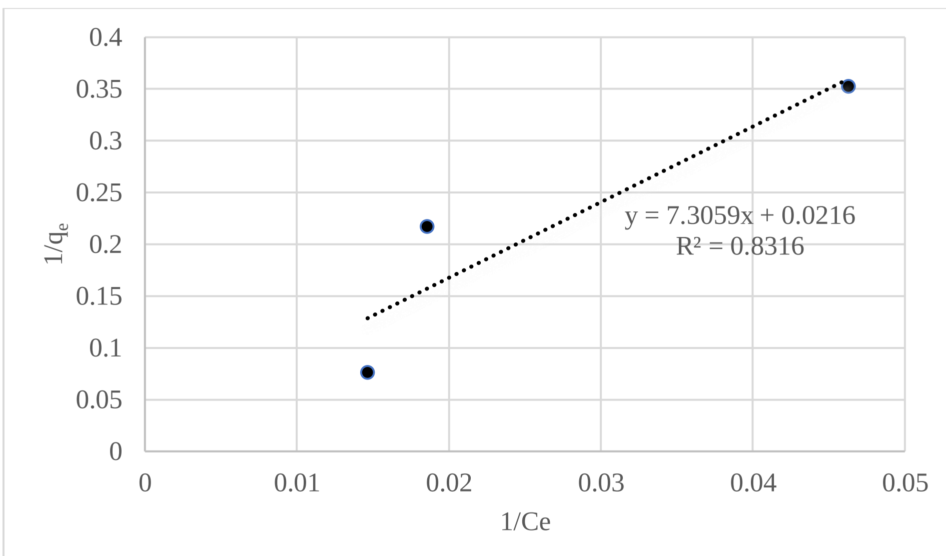


**Figure 35:** Langmuir isotherm model of acid black 48 adsorption on peanut hull.

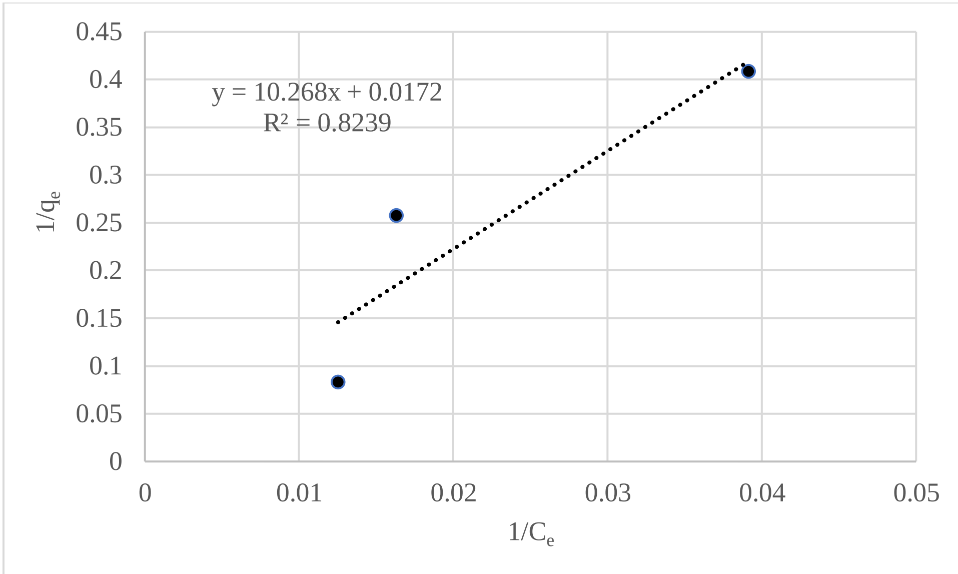


**Figure 36:** Langmuir isotherm model of acid black 48 adsorption on onion peel.

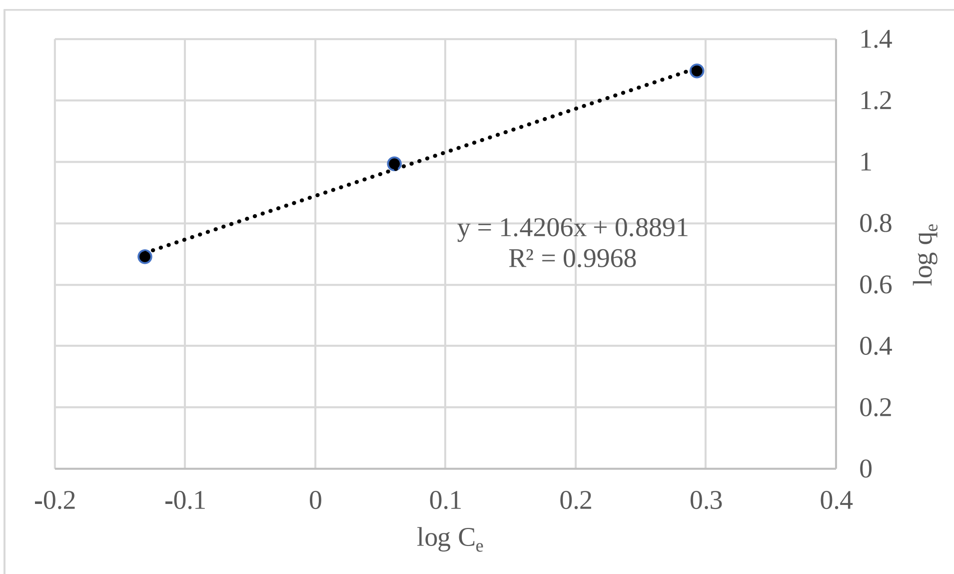


**Figure 37:** Freundlich isotherm model of acid black 48 adsorption on PAC.

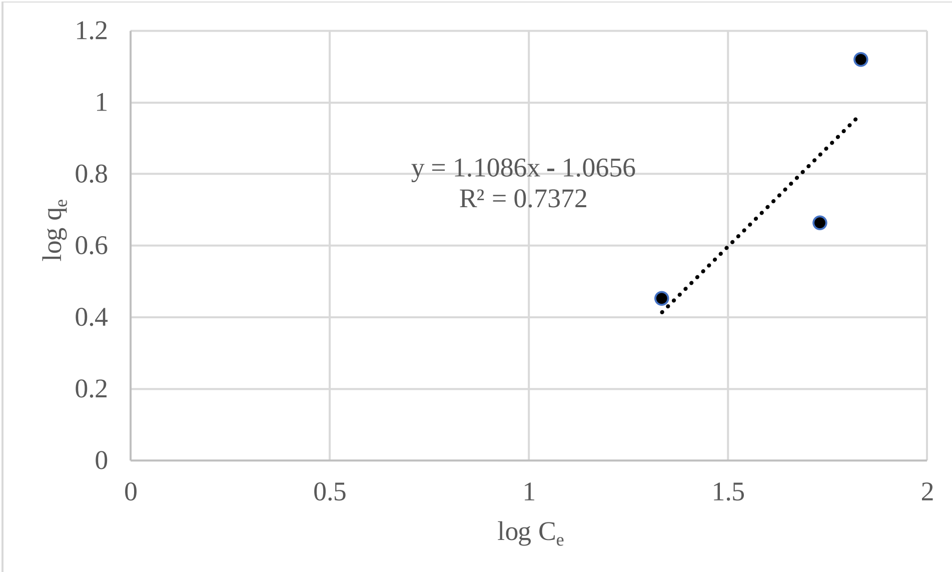


**Figure 38:** Freundlich isotherm model of acid black 48 adsorption on peanut hull.

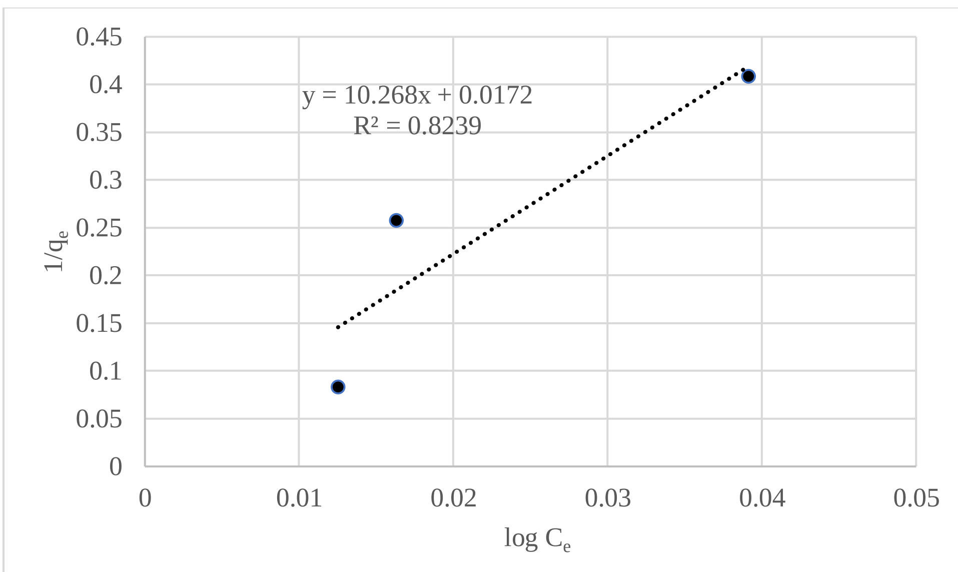


**Figure 39:** Freundlich isotherm model of acid black 48 adsorption on onion peel.

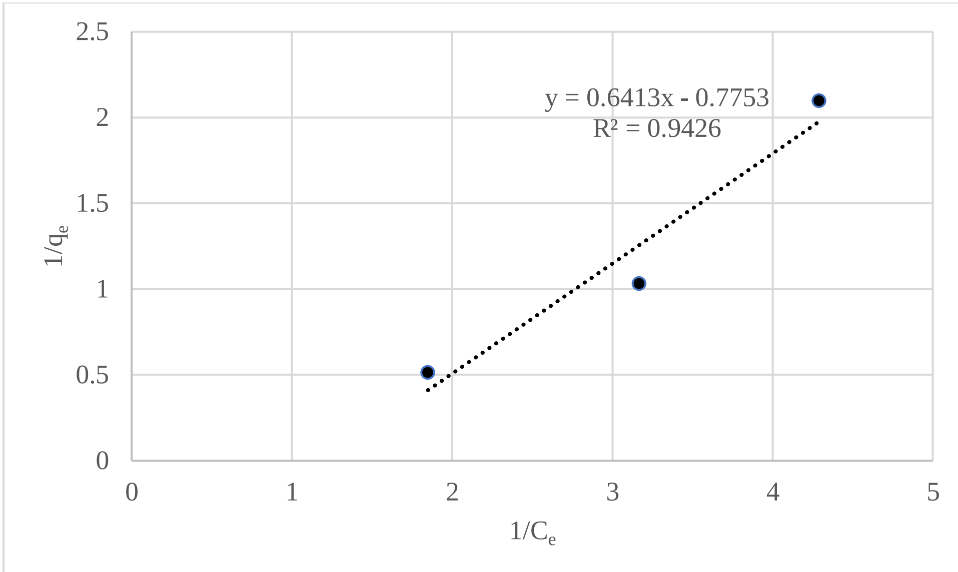


**Figure 40:** Langmuir isotherm model of crystal violet adsorption on PAC.

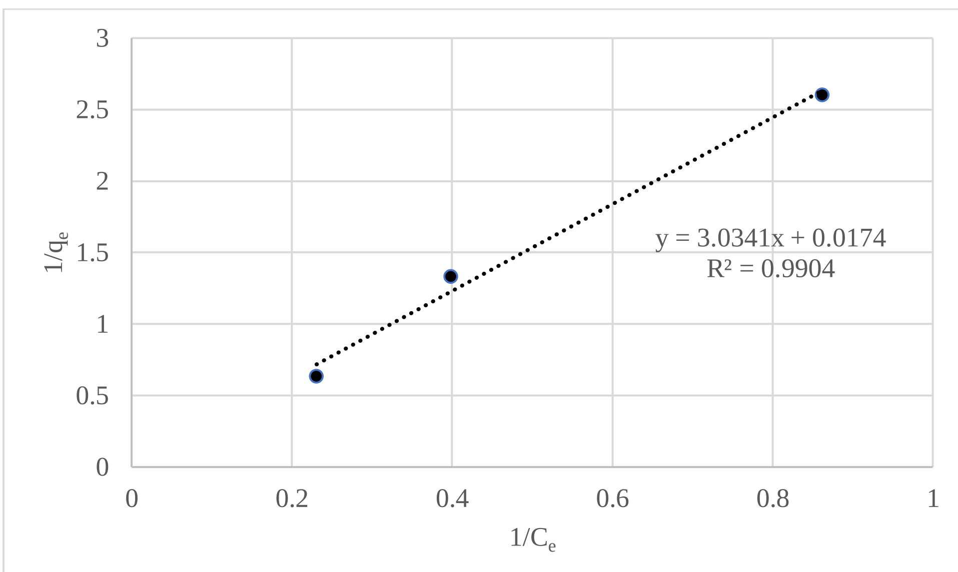


**Figure 41:** Langmuir isotherm model of crystal violet adsorption on peanut hull.

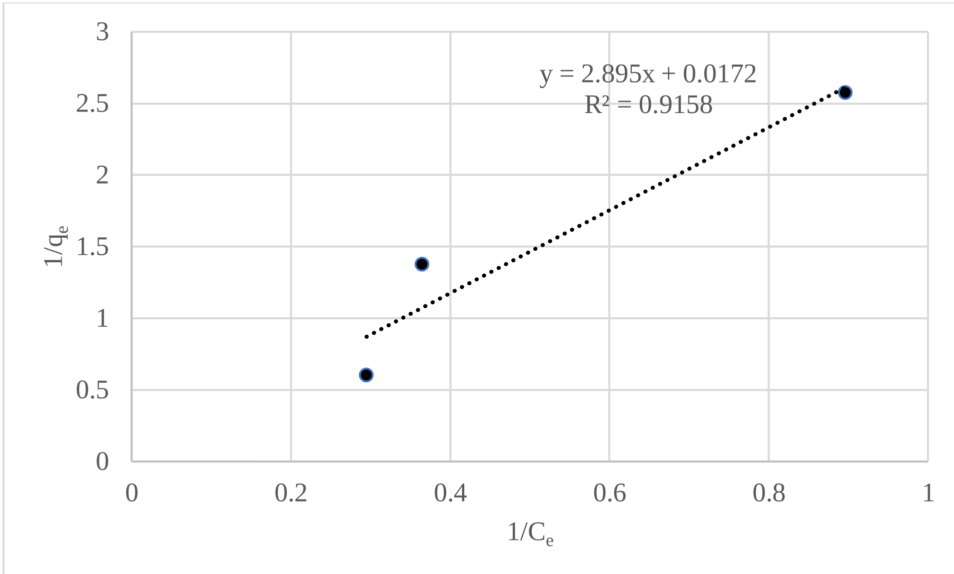


**Figure 42:** Langmuir isotherm model of crystal violet adsorption on onion peel.

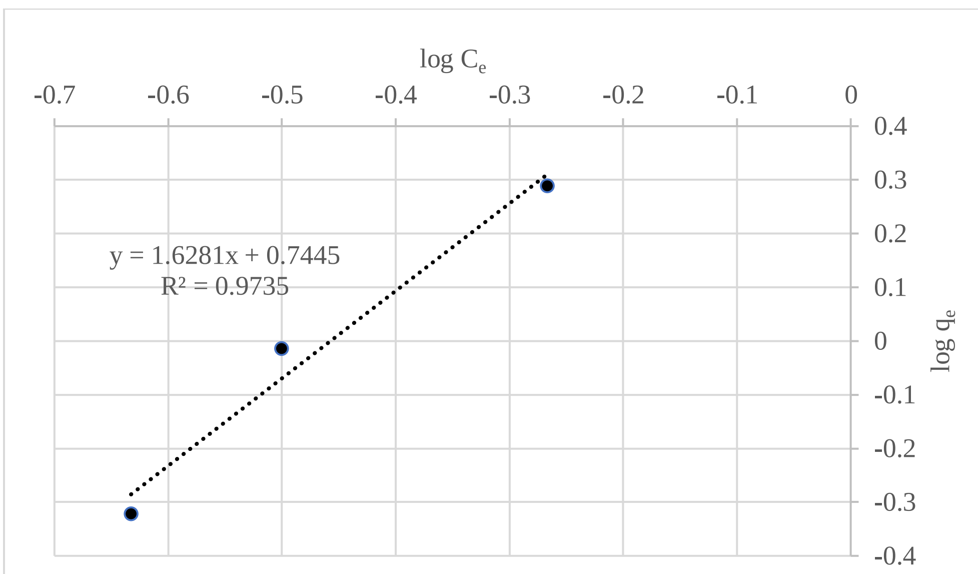


**Figure 43:** Freundlich isotherm model of crystal violet adsorption on PAC.

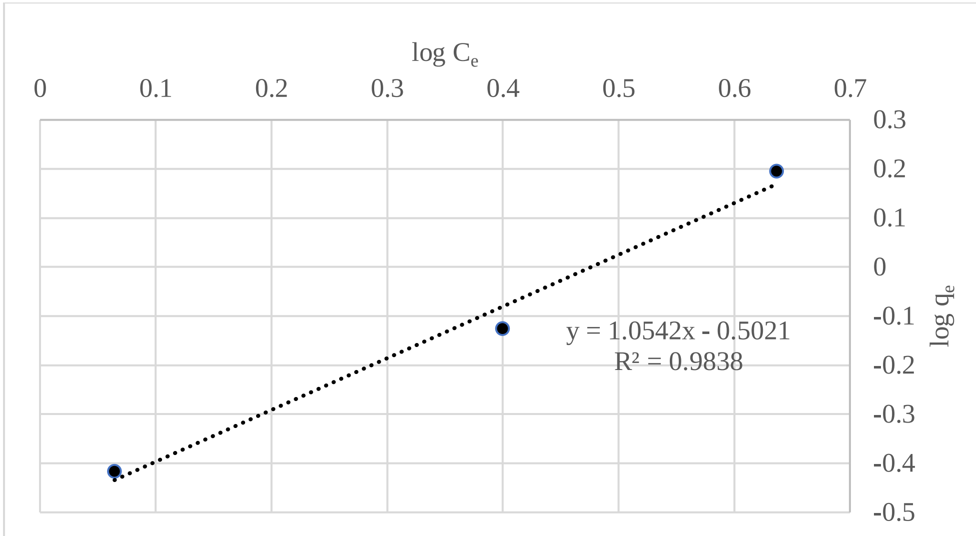


**Figure 44:** Freundlich isotherm model of crystal violet adsorption on peanut hull.

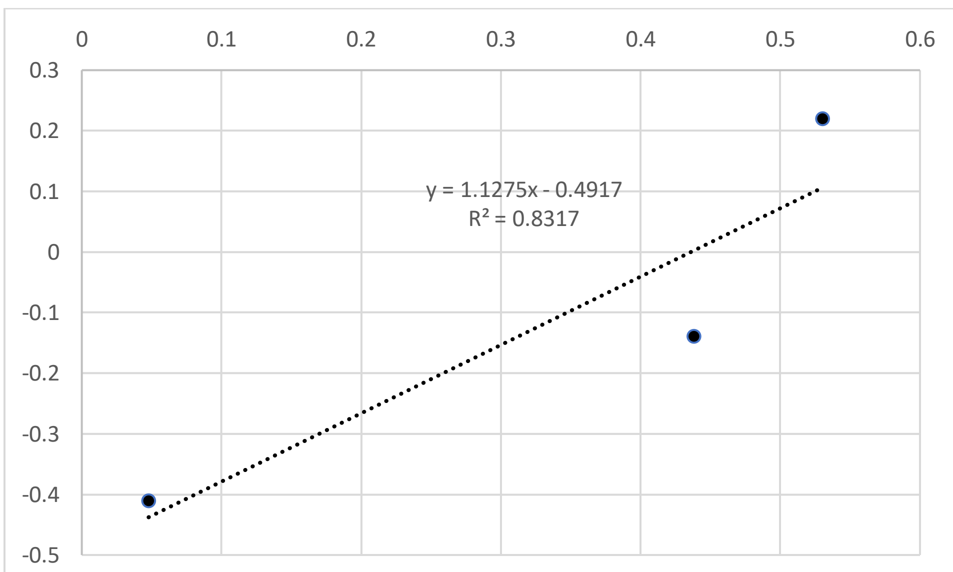


**Figure 45:** Freundlich isotherm model of crystal violet adsorption on onion peel.

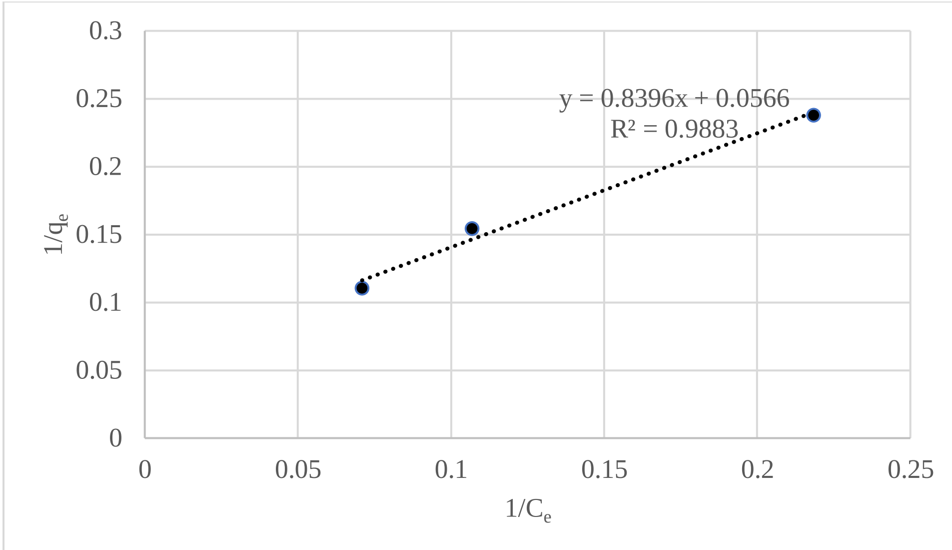


**Figure 46:** Langmuir isotherm model of disperse yellow 3 adsorption on PAC.

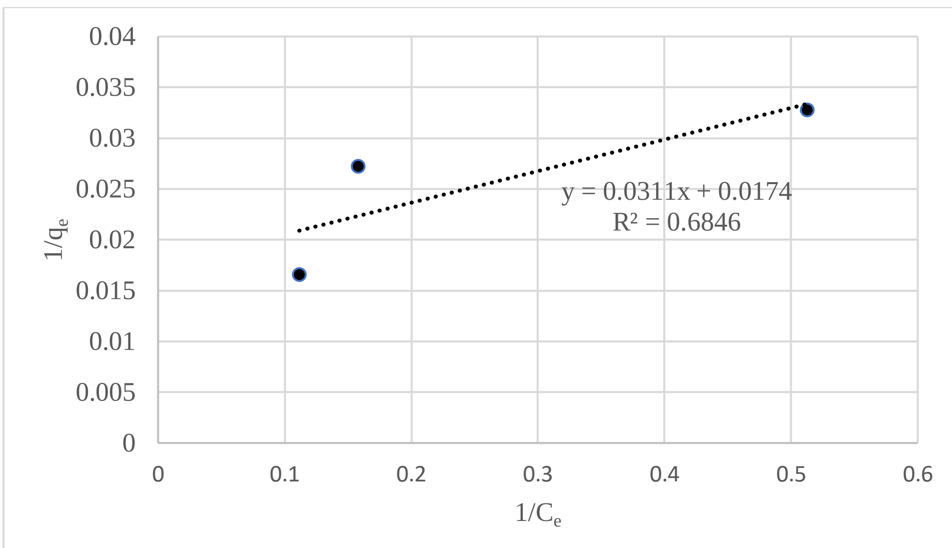


**Figure 47:** Langmuir isotherm model of disperse yellow 3 adsorption on peanut hull.

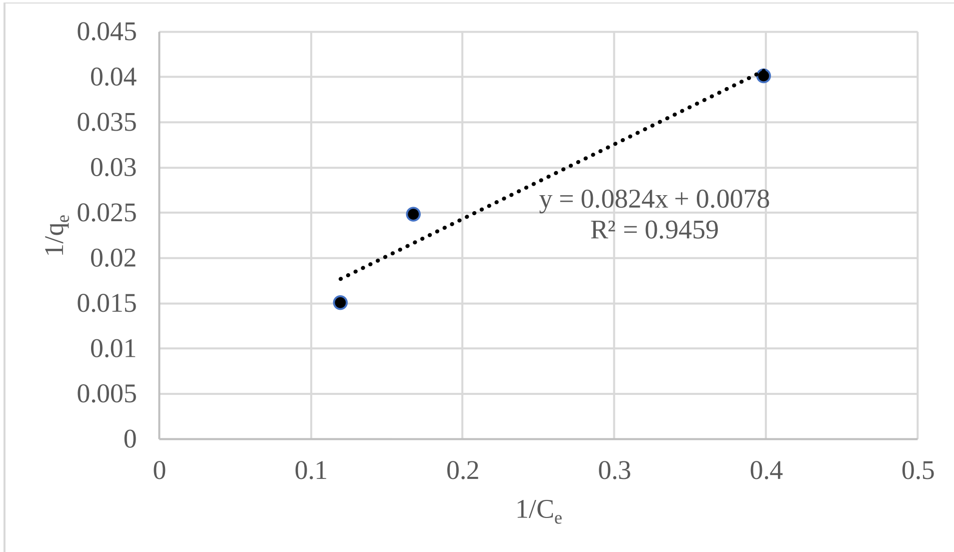


**Figure 48:** Langmuir isotherm model of disperse yellow 3 adsorption on onion peel.

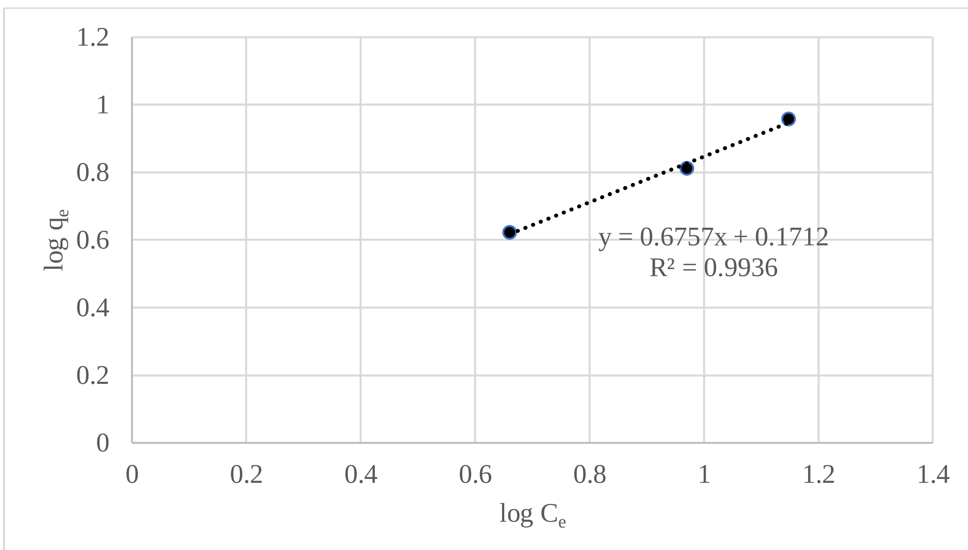


**Figure 49:** Freundlich isotherm model of disperse yellow 3 adsorption on PAC.

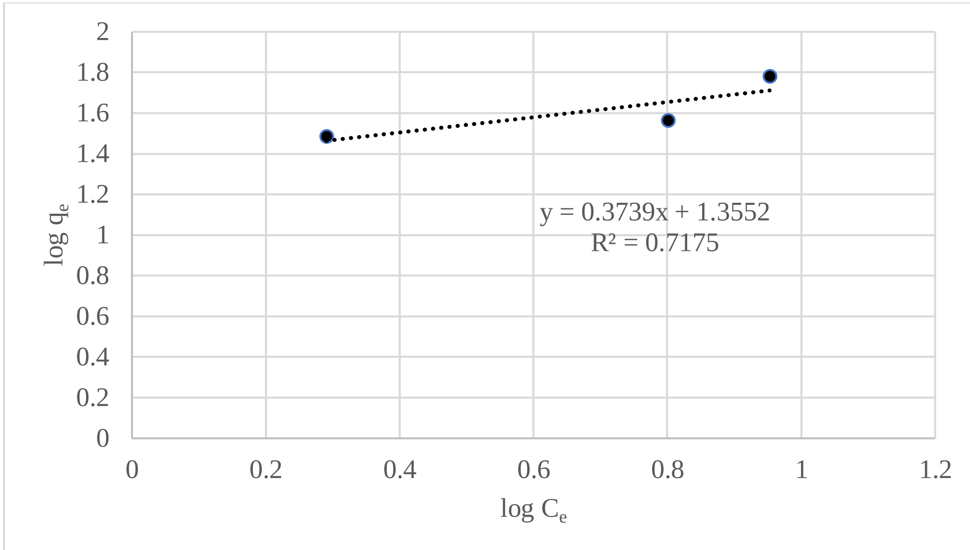


**Figure 50:** Freundlich isotherm model of disperse yellow 3 adsorption on peanut hull.

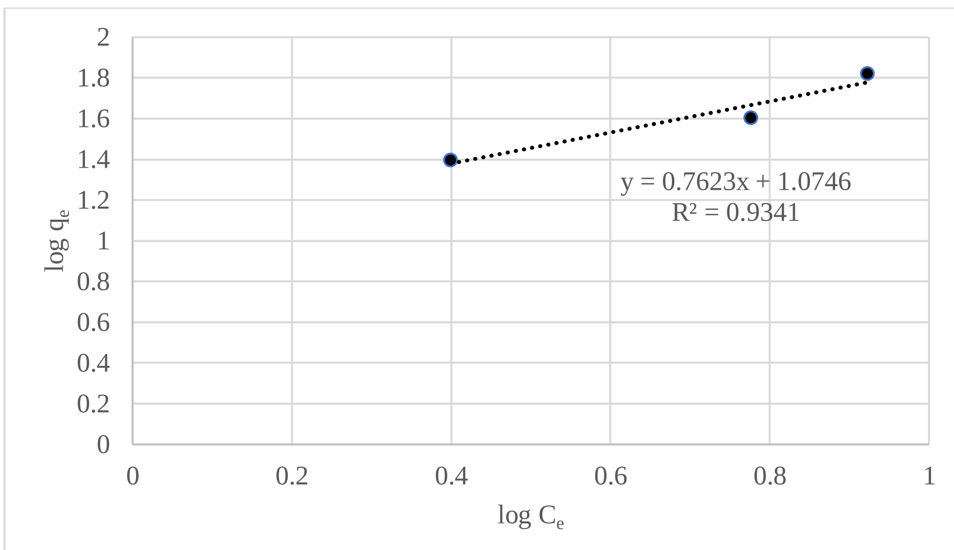


**Figure 51:** Freundlich isotherm model of disperse yellow 3 adsorption on onion peel.

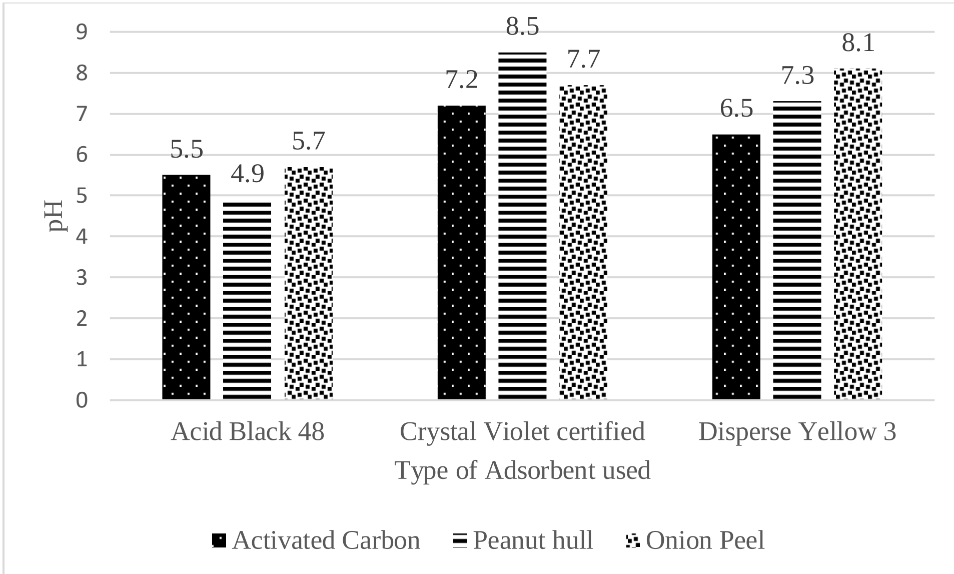


**Figure 52:** Plot of pH with varying adsorbents used in the color removal.