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COLOR REMOVAL FROM COMBINED DYE AND FRUIT NECTAR
WASTEWATER USING ADSORPTION AND MICROFILTRATION

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Bachelor of Science in Chemical Engineering

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May 2013

Submitted in partial fulfillment of requirements for the degree
MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING

at

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May 2018

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DEDICATION

This thesis is dedicated to the Almighty God, My parents, Mr. Ife Akinwande and Mrs. Bolanle Akinwande, and my future generation.

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WASTEWATER USING ADSORPTION AND MICROFILTRATION
OLUWATOBILOBA ANUOLUWAPO AKINWANDE

ABSTRACT

Pollution of the waterways is a great challenge of the 21st century. Textile effluents contain compounds which have the capacity to cause more harm when ingested. There are many dye removal technologies like coagulation, photo oxidation which help to remove color from dye wastewater. The use of adsorption to remove color from dye wastewater has been used for many centuries. Activated carbon can efficiently remove color from dye wastewater but it is very expensive and so different researches have been conducted to get the adsorption capacity of different forms of adsorbents. These adsorbents can be gotten from agricultural waste, biomass, and industrial waste and even household materials like paper.

In this research, agricultural adsorbents like orange peel, banana peel and onion peel are being used as adsorbents to treat dyes like Acid red 88, Direct blue 15 and Rhodamine 6G. The amount of adsorbent dose and dye concentration is being varied to know at what dye concentration or adsorbent dose effectively removes color from dye wastewater.

In this study, the treatment of a binary mixture of dye wastewater with fruit drink of different concentrations, low (10ppm), medium (50ppm) and high (100ppm). The dye waste water was prepared in the laboratory while the fruit drink was bought from a local grocery store. Color removal efficiency was investigated for the three adsorbents; orange

peel, banana peel, onion peel. Transmittance and Absorbance values were used to determine the removal efficiency of the adsorption process

Keywords: dye, adsorption, water, transmittance, absorbance

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CHAPTER I

INTRODUCTION

1.1 Introduction

Saving water to preserve the earth should be everyone's focus right now. The increasing demand for fresh water due to the increase in the growth of people in the world today especially in sectors like the agricultural, industrial, and domestic consuming about 70,22 and 8% of the existing fresh water, respectively and this has led to the release of enormous amount of wastewater (1,2,3) containing many pollutants and these pollutants make the water unusable for both human and animal consumption. One of the many pollutants is dyes. Due to the synthetic origin and very intricate molecular structure of the dye, this makes the dye very stable and very tough to be biodegradable (4,5). Dyes enter the wastewater stream primarily through the manufacturing and fabric finishing of textiles (6). Chemicals, auxiliaries, salts, surfactants, heavy metals, minerals, oils, organic dyes are all constituents of textile finishing wastewater. The pH, COD, BOD and AOX are very astronomical values in textile dye wastewater and the wastewater is very colored (7).

Public water supplies are greatly affected by textile effluents and diseases like such as diarrhea, cholera, typhoid fever, e-coli infections and diphtheria can be gotten

from drinking water that is infected with textile effluents. Some of the few heavy metals gotten from textile wastewater effluents is mercury, lead and organic contamination (benzene, phenol, PCB) of the water. One of the effects of these dyes is deterioration in human's health. Some of these dyes are toxic, mutagenic and carcinogenic in nature (8). Hence, it is important to treat dye wastewater before it is discharged into the river. The problem of finding a cost-effective method of treating dye wastewater has led to many researches on cost-effective methods of treating dye wastewater. There are many methods currently used to treat dye wastewater. This method is further explained in this literature, including filtration, flocculation, chemical precipitation, ion exchange, membrane separation and adsorption (9). The adsorption process is the most effective way of removal of dyes from dye waste water (10). Activated carbon is very expensive and preparation of activated carbon in the laboratory is accompanied by several problems such as combustion at elevated temperature, pore blocking, hygroscope etc. (11)

Dyes are substances that when introduced to a material it gives the material its color. Dyes contain ionic aromatic organic compounds with structures including aryl rings, which have delocalized electron rings

1.2. Objective

In terms of providing a statement of objective for this thesis to highlight its objective would be in the following form. Observing and studying the color removal of different low-cost aqueous dyes against different low-cost adsorbents

In lieu of the above statement, the following objectives are to be considered

1)The main aim of this project is to find a cheaper and less expensive way of removing dye from textile effluents.

2) Evaluation of the removal of color from dye waste water samples through transmittance readings and comparing it with varying dosages of adsorbents and varying of sugar samples.

3) Studying the extent of the color removal through the transmission results and further. Calculating the percentage removal and plotting the percentage removal against the dosages of adsorbent and sugar of which are three categories, low, medium, and high.

4) Considering a secondary treatment to improve the results and achieve high removal percentage with adsorption. Thus, the treatment is expected to produce high quality results

CHAPTER II

LITERATURE REVIEW

2.1 Dyes in Water Pollution

Dyes are chemical combinations that impart color to surfaces or fabrics by attaching themselves to fabrics or clothes. Most dyes are made up of complex organic molecules and are made to be resistant to many substances such as detergents. Synthetic dyes are used mostly in different areas of advanced technology for example in numerous types of textile (12), paper (13), leather tanning (14), food processing, plastics, cosmetics, rubber, printing and dye manufacturing industries (15-17). Synthetic dyes are also used in ground water tracing (18) for the determination of specific surface area of activated sludge (19), sewage (20) and waste-water treatment (21). The textile effluents pollute the hydrosphere because of the recalcitrance nature of the dye. This leads to the unpleasant color of the water body which will diminish the penetration of the sun rays and resist photochemical and biological attacks to aquatic life (22). There are approximately more than 100,000 commercial dyes are known with an annual production of over 7×10^5 tonnes/year (23). The total dye consumption in the textile industry worldwide is more than 10,000 tonnes/year and approximately 100 tonnes /year of dyes is discharged into water streams (24). The amount of dyes released from various processes from the textile

manufacturing processes is unknown. The release of these harmful synthetic dyes has caused considerable damage to the environment.

2.2 Adsorption Role

The word adsorption means the accumulation of a substance at the interface between two phases (liquid -solid interface or gas-solid interface. The substance that accumulates at the interface is called adsorbate and the solid on which adsorption occurs is adsorbent (25). Adsorption can be classified into types: chemical sorption and physical adsorption. Chemical adsorption or chemisorption is illustrated by the formation of strong chemical associations between molecules or ions of adsorbate to adsorbent surface, which is generally due to the exchange of electrons (26). And thus, chemical sorption generally is irreversible. Physical adsorption or physisorption is characterized by weak van der Waals intraparticle bonds between adsorbate and adsorbent and thus reversible in most cases (26). Adsorption on most of the adsorbent and are thus reversible in most cases. Adsorption on most of the adsorbent with some exception of chemisorption. The many factors affecting adsorption on most of the adsorbent and thus reversible in most cases (26). Adsorption on most of the adsorbent including agricultural by-products is controlled by physical forces with some exception of chemisorption. The main physical forces controlling adsorption are van der waals forces, hydrogen bonds. polarity, dipole-dipole etc. (27). This process provides an attractive alternative for the treatment of polluted waters, especially if the sorbent is inexpensive and does not require an additional pretreatment step before its application(28).As for environmental remediation purpose, adsorption techniques are widely used to remove certain classes of chemical contaminates from waters, especially those that are widely used to remove certain classes

of chemical contaminants from waters, especially those that are practically unaffected by conventional biological wastewater treatment (28,29). Adsorption has been found to be superior to other techniques in terms of flexibility and simplicity of design, initial cost, insensitivity to toxic pollutants and ease of operation. Factors that influence the adsorption efficiency include adsorbate-adsorbent interaction, adsorbent surface area adsorbent to adsorbate ratio, adsorbent particle size, temperature and contact time (30,29).

2.3 Definition of dye

Dyes are chemicals which give color to materials when they bind with it. Dyes are ionic, aromatic organic compounds with structures including aryl rings, which have delocalized electron systems. Dyes are made up of two vital components: the chromophores which oversee creating the color, and the auxochromes, which can not only supplement the chromophore but also make the molecule dissolve in water efficiently and increase the affinity (to attach) toward the fibers. Dyes display considerable structural diversity and are classified in many ways. These can be categorized based on their solubility: soluble dyes which include acid, mordant, metal complex, direct, basic, and reactive dyes: and insoluble dyes including azoic, sulfur, vat and disperse dyes. Besides this, either a major azo linkage or an anthraquinone unit also characterizes dyes chemically. It is important to note that the azo dyes are used across the world and it comprises of 65-70% of the dyes made. Though the grouping of dyes according to their structure is an appropriate system and has many advantages, like it readily identifies dyes as belonging to a group and having characteristic properties e.g., azo dyes are generally known to be strong, cost effective and have all round properties

and anthraquinone dyes (weak, expensive), there are a manageable number of chemical groups (about a dozen). Both the synthetic dye chemist and the dye technologist effectively use this grouping generally. In the color index method of grouping dyes, most of the dyes are grouped according to their application or their C.I. name/number. In this system of grouping the dye, the dyes are given C.I. numbers, the purity and the exact chemical constitution may also vary depending upon the name.

Some distinguishing factors of dyes according to their usage are discussed below
(31)

2.4 Classification of dyes

2.4.1 Acid dye

Are mainly used in industries that produce nylon, wool, silk, modified acrylics and sometimes paper, leather, ink-jet printing, food, and cosmetics. This dye is water-soluble. The main chemical groups of these dyes are azo (including premetallized), anthraquinone, triphenylmethane, azine, Xanthene, nitro, nitroso.

2.4.2 Cationic (Basic Dyes)

Are also mainly used in industries that produce paper, polyacrylonitrile, modified nylons, modified polyesters, cation dyeable polyethylene terephthalate and to some extent in medicine too. This dye was used formally for silk, wool, and tannin-mordanted cotton. Colored cation is formed in solution because these dyes are water-soluble in nature. The main divisions of these dyes are dia-zahemicyanine, triarylmethane, cyanine, hemicyanine, thiazine, oxazine and acridine.

2.4.3 Disperse Dyes

Are commonly used in industries that make use of polyester and sometimes on nylon, cellulose, cellulose acetate, and acrylic fibers. These are sustainably water-insoluble nonionic dyes that are used for hydrophobic fibers from aqueous dispersion. These dyes most of the time contain azo, anthraquinone, styryl nitro, and benzodifuranone groups.

2.4.4 Direct Dyes

Is mostly used for dyeing cotton and rayon, paper, leather and sometimes nylon. These dyes are water-soluble anionic dyes in nature and when dyed from aqueous solution in the presence of electrolytes that have a strong bond to cellulosic fibers. Most of the time, these dyes in this category are polyazo compounds, along with some stilbenes, phthalocyanines and oxazines.

2.4.5 Reactive Dyes

Are used in industries that make use of cotton and other cellulosic but are also used to an extent on wool and nylon. These dyes create a covalent bond with the fiber and include chromophore groups embedded in it groups such as azo, anthraquinone, triarylmethane, phthalocyanine, formazan, oxazine etc. Their chemical structure is simpler, absorption spectra show narrower absorption bands and the dyeings are brighter making them advantageous over direct dyes.

2.4.6 Solvent Dyes

Are generally used for plastics, gasoline, lubricants, oils and waxes. These dyes are solvent soluble in nature (water-insoluble) and are generally nonpolar or little polar i.e, lacking polar solubilizing groups such as sulfonic acid, carboxylic acid, or quaternary

ammonium. The main chemical classes are azo and anthraquinone, but phthalocyanine and triarylmethane are also used

2.4.7 Sulfur Dyes

Used mainly in cotton and rayon and have restricted usage with polyamide fibers, silk, leather, paper, and wood. They have intermediate structures and though they form a relatively tiny class of dyes that have low cost and have good wash fastness properties making this class as important from a cost-effective point of view.

2.4.8 Vat Dyes

Used mainly for cotton to cellulosic fibers as soluble leuco salts and for rayon and wool too. These water-insoluble dyes are with the main principal chemical class containing anthraquinone (including polycyclic quinones) and indigoids.

Besides these, there are some groups too like azoic having azo classes being used in cotton and other cellulosic materials; fluorescent brighteners having stilbene, pyrazoles, coumarin and naphthalimides used mainly for soaps and detergents, fibers, oils, paints and plastics and mordant having azo and anthraquinone used for wool leather, natural fibers after pretreating with metals and anodized aluminum.

At present there are 100,000 more commercial dyes with a rough estimated production of 7×10^5 .

2.5 Factors Affecting Adsorption of Dye

Solution pH, temperature and initial dye concentration are examples of factors that affect the adsorption of dye concentration. Optimization of these conditions will enhance the development of industrial-scale dye removal treatment process. The factors affecting adsorption are explained further.

2.5.1 Effects Of Solution Ph

Solution pH is one of the most crucial factors affecting the capacity of adsorbent in wastewater treatment. The efficiency of adsorption is dependent on the solution pH, since variation in pH leads to the variation in the degree of ionization of the adsorptive molecule and the surface properties of the adsorbent (32). Chowdhury et al (33) studied the effect of solution pH on the adsorption of Basic Green 4 dye by Ananas comosus leaf powder and they noticed that at a pH range from 2 to 10, the dye removal ratio was maximum at pH 10. Dawood and Sen (34) studied the effect of the solution pH on the adsorption of Congo red by pine cone and they noticed that the adsorption was maximum at Ph 3.5. Ibrahim et al (35) studied the adsorption of RB4 dye by modified barley straw and they found that RB4 dye by modified barley straw and they found that RB4 gives a complete removal of 100% at pH 3 and decreased value below 50% as the Ph was increased with increase in solution pH on dye adsorption

2.5.2 Effect of Initial Dye Concentration

One of the many crucial factors affecting the amount of dye removal is the initial dye concentration. The effects of initial dye concentration are dependent on the immediate relation between the dye concentration and the existing sites on an adsorbent surface. An increase in initial dye concentration can lead to a rise in the capacity of the adsorbent and this leads to a high driving force for mass transfer at a high initial dye concentration (36).

2.5.3 Effect of Temperature

Temperature is another parameter that will change the adsorption capacity of the adsorbent (37). In a situation where by the amount of adsorption increases with

increasing temperature then the adsorption is called an endothermic process. Factors affecting adsorption may be due to the increasing movement of the dye molecules and a rise in the number of active sites for the adsorption with increasing temperature. A decrease in the adsorption capacity with an increase in temperature indicates that the adsorption is an exothermic process. This may be because of adding more temperature while reducing the adsorption forces between the dye species and the active sites on the adsorbent forces between the dye species and the active sites on the adsorbent surface because of decreasing the amount of adsorption (38).

2.5.4 Effect of Amount Of Adsorbent

Adsorbent dosage is a vital process parameter to indicate the capacity of an adsorbent for a given amount of the adsorbent at the operating conditions. Normally the percentage of dye removal rises with increasing the adsorbent dosage, where the amount of sorption sites at the surface of adsorbent will raise more by adding more quantities of adsorbent.

2.6 History of Dyes

Dyes has been used for a very long time by man and the first original known use of a colorant is known to be by Neanderthal man about 1,800,000 years ago. It should be noted that the first known use of organic colorant was known nearly 4000 years ago, the blue indigo was discovered in the wrappings of mummies in Egyptian tombs (39). Plants, insects, mollusks were the main sources of dyes and it was generally made on a small scale. It was after in 1856 that Perkin's historic discovery (40, 41) of the first man-made dye, mauveine, that dyes were manufactured artificially and on a small scale.

2.7 Available Technologies for Dye Removal

There are many methods of dye removal. The three broad categories of removing dyes from effluents are: biological methods, chemical methods, and physical methods (42). However, all these processes have advantages and disadvantages. Due to the excessive cost and disposal challenges, many of the old methods of treating dye wastewater have not been used at a large scale in the textile and paper industries (43). Currently, there is no way of eliminating color from dye wastewater due to the complex nature of the effluents (44,45). Despite the availability of many techniques to remove these pollutants from wastewater as legal requirements, such as coagulation, chemical oxidation, membrane separation process, electrochemical and aerobic and anaerobic microbial degradation, these methods are not very successful due to suffering from restrictions (46). Among this method, adsorption has been preferred due to its cheapness and the high-quality of the treated effluents especially for well-designed sorption processes (47). One of the effective ways of treating dye waste water is be adsorption using activated carbon. Methods of treating wastewater can generally be classified into four categories: (i) Physical (ii) chemical (iii) biological (iv) acoustical, radiation and electrical processes. Some of the methodologies are discussed below.

2.7.1 Sedimentation

Is the simplest form of primary treatment used at most municipal and industrial-wastewater treatment facilities (48) . There are many alternatives of process options available to increase the gravity settling ability of suspended particles including chemical flocculants, sedimentation basins, and clarifiers.

2.7.2 Filtration Technology

Is a vital part of drinking water and wastewater treatment applications which includes microfiltration, ultrafiltration, nanofiltration and reverse-osmosis. It has been tried for color removal by many individuals (48,49). Each membrane process works best for a water treatment function (48). Microfiltration is usually not used for wastewater treatment because of its large pore size and although ultrafiltration and nanofiltration (48;50) methods are effective for the removal of all classes of dyestuffs, dye molecules are usually bottlenecks of the membrane pores thereby making the separation systems to be of limited use for textile effluent treatment. The major hindrances are high working pressure, significant energy consumption, increasing cost of membrane and little membrane life which makes their use short for treating dye wastewater. Reverse osmosis adds more force to water under pressure through a membrane that is impermeable to most impurities. The membrane effectively rejects salts better than it is at rejecting non-ionized weak acids and bases and smaller organic molecules generally molecular weight below 200. Reverse Osmosis (51; 52; 53) helps to decolorize and desalt processes against the most various ranges of dye wastes and has been used for recycling. The water gotten by reverse osmosis will be close to pure H₂O.

2.7.3 Chemical Treatment of Dye Wastewater With A Coagulating/Flocculating

Chemical treatment of dye wastewater with a coagulating/flocculating agent (54;55;56) is one of the many ways of removing color from dye wastewater. This process includes adding agents, such as aluminum (Al³⁺), calcium (Ca²⁺) or ferric (Fe³⁺) ions, to the dye wastewater and it causes flocculation. Besides these other agents (57, 58, 59) has been used for this process. Sometimes a combination (60) of the two enhances the

process. Generally, the process is not usually expensive due to the price of chemicals) with satisfactory removal of sulfur, disperse and vat dyes. However, the main hindrance of the process is a thick sludge made in large quantity also; this process is also pH dependent. (61,62). This technique is not as effective in highly soluble dyes and the result with azo, reactive acid and the result with azo, reactive, acid and also the basic dyes (63,64).

2.7.4 Oxidation

This is a way by which wastewater is treated by using oxidizing agent. There are two known ways of treating by oxidization. Chemical oxidation and UV assisted oxidation using chlorine, hydrogen peroxide, Fenton's reagent, ozone, or potassium permanganate are used for treating effluents especially those obtained from primary treatment(sedimentation). These methods are examples of the frequently used decolorization processes whereby it requires low quantities and short reaction time. The methods are used to degrade the dyes partly or wholly (In most cases to lower molecular weight species such as aldehydes, carboxylates, sulfates, and nitrogen).

However, an entire oxidation can diminish the intricate molecules to carbon dioxide and water. pH and catalyst play vital roles in oxidation processes.

Chlorine is a common and strong oxidizing agent used and may also be applied as calcium hypochlorite and sodium hypochlorite. it is popularly known as a disinfectant to remove color t for water treatment, it is majoring used in disinfectant for water treatment. It is used for the reduction of color like pulp and textile bleaching, Reactive, acid, direct and metal complex dyes, which are water soluble are decolorized readily by hypochlorite but water-insoluble disperse and vat dyes are harder to remove color in this process

(65,66). It has been realized that decolorization of reactive dyes need long reaction times, while the nature of the metal complex dye solution remains partially colored even after an extended period of treatment. Dyes (67) having amino acids or substituted amino groups on a naphthalene ring are more prone to chlorine and remove color more easily than other dyes. Oxidation can boost using pH and catalyst e.g. in the decomposition of metal complex dyes metals like iron, copper, nickel, and chromium are liberated and these metals have an inert catalytic effect that increases decolorization. Using chlorine gas to remove color from in dye waste-water is a low-cost method. This method causes unavoidable side reactions, making organochlorine compounds including toxic trihalomethane, thereby adding more adsorbable organic halogens content of the treated water, also the liberation of metals in metal complex dyes may cause corrosion in metallic vessels.

Hydrogen peroxide (H_2O_2) is a pale blue liquid substance which looks colorless in a dilute solution, slightly more gelatinous than water. It has strong oxidizing properties and is powerful bleaching agent that can be used for paper and pulp bleaching. (68) It is also a necessary raw material for producing peroxidase enzymes, which is used for the removal of color from dyes (69). However, the process is pH dependent and produces a lot of sludge.

Another substance widely known to oxidize dye wastewater is Fenton reagent which is a solution of hydrogen peroxide and iron catalyst and is stronger than hydrogen peroxide. In most cases it is effective (70) in the removal of color of both dyes that are soluble and insoluble in water examples are acid, reactive, direct, and metal complex dyes although some dyes like vat and disperse are found to be unaffected to it example of

these dyes are (71) palanil blue 3RT which was unaffected to fenton's reagent. Dyes like remazol brilliant blue B, sirrus supra blue BBR, has being observed that color have been removed from it. It has been studied over the years that the removal of color from dye has led to the reduction in chemical oxygen demand values (COD) except for reactive dyes, pH, total organic carbon, and toxicity have drastically reduced in values due to the removal of color. This process can also be used in substances that have high suspended solid concentration and is also used most times in wastewater treatment when a municipality allows the release of Fenton's sludge into the sewage. The quality of the sludge is also better, but the phosphates can also be removed. It should be noted that that within a narrow pH range of less than 3.5, this process is not as effective (72). This process involves sludge generation and takes a longer reaction time.

Another method used in many industries to remove color from textile waste water effluent is zonation by using ozone. The use of ozone to remove color from dye wastewater has been studied by workers and has been found to be an effective way of removing color from dye waste water (73,74,75,76) have done extensive study on the ozonation of color removal (reactive dyes) and discovered that color removal of the effluent can be realized in 5mins of the absorbent being in contact with the yellow and blue shades at an ozone consumption of 37.5 and 36mg/l, respectively and many individuals recommend that ozonation is great at removing color of exhausted dye bath effluents in which it main ingredients are conventional reactive dyes. The removal of a popular dye called aqueous C.I reactive blue was studied by a researcher by the name Wu et al.(2008b) (77) in a reactor called the semi-batch reactor in which the process can be referred to as a pseudo-first order reaction when compared to the dye. After the research

was done, it was discovered that ozonation is also an effective way of removing chemical oxygen demand (COD) but some researchers (78,79) disagree with this claim. They claim that color was effectively removed but not COD. In a study, to discover the different ways of reusing of reactive dye bath for the addition of color to fabric after removal of color. Many other cold brand reactive dyes such as red 5MR and golden yellow MR were used, and the oxidation was achieved by using ozone. Some authors have had studies that prove that ozonation is an effective way of removing color and chemical oxygen demand (COD) and is effective for reusing water even in conditions that are critical as the addition of color with light ones.

Another method commonly used to remove color from dye wastewater is Electrochemical methodology (80) (81). This way of treatment is used to remove color. The removal of color can be done by electro oxidation with non-soluble anodes or by electro-coagulation by the aid of consumable materials. Some examples of anode materials like iron aids in conducting polymer a boron doped diamond electrode etc., with different experimental conditions has been used successfully in the electro-degradation of dyes (82) (83) (84). It was observed that the color removed (85) of 83%-100% was removed from the dye, Direct Red 80 by using three types of electrodes which are iron polypyrrole doped with chromium and boron doped diamond electrode. This method has efficiently removed color from soluble and insoluble dyes with reduction of COD. Many other factors affect the rate of color and organic load removal depends on. The most crucial factors are the anode's material and the working potential. The factors that hinder are high electricity cost and sludge production and pollution from chlorinated organics, heavy metals due to indirect oxidation.

2.7.5 *Advanced Oxidation Process (Aops)*

In this technique, more than one oxidation process is used simultaneously. The reason being that one oxidation process cannot be used to efficiently to degrade the dyes. Techniques such as Fenton's reagent oxidation, ultra-violet (UV), photolysis and sonolysis are all reactions that involve the quick making of the hydroxyl free radical, which are very reactive. Dyes can be degraded through the processes of sonolysis and photolysis. The reactions can reduce the dye at room temperature and pressure. It also has an advantage over biological treatment for waste streams containing toxic or bio-inhibitory contaminants. The core attraction of advanced oxidation processes is that organic contaminants are commonly transformed to carbon dioxide. There is diverse range of advanced oxidation processes usually available for example chemical oxidation processes using ozone, combined ozone and peroxide, ultra-violent enhanced oxidation such as UV/hydrogen peroxide, UV/ozone, UV/ air wet air oxidation and catalytic wet air oxidation (In this method, air is the oxidant). In a particular study by Namboodri(86) it stated that UV process is used alone, only 10-20% color removal was realized but when the process is used with peroxide, the process of color removal was increased by 90%.

2.7.6 *Photo-Fenton Process*

The use of both UV light, the so-called photo-Fenton reaction has proven to increase the efficiency of the Fenton process and has been found to be very effective in treating dye wastewater (87). Muruganandham and Swaminathan (88) studied the photochemical removal of color of chlorotriazine reactive azo dye reactive orange 4 by Fenton and photo-Fenton processes. The effects of solution pH applied H₂O₂, Fe²⁺ dose, UV light intensity was studied and is found that there is an increase in original dye

concentration which therefore reduces the removal rate. Many authors have made suggestions that under optimum conditions the photo-Fenton process is more efficient than Fenton process.

2.7.7 Photocatalysis

Is one of the series of advanced oxidation processes for treating pollutants (88,89,90,91, 92, 93). In this process, light energy gotten from a light source makes an electron from the valence band of the catalyst to the conduction band with a series of reaction which brings about the making of hydroxyl radicals. These radicals have a large oxidizing potential and can attack most organic structures causing oxidation. Some substances called the chalcogenides- these are oxides like TiO₂, ZnO, ZrO₂, CeO₂ etc or sulfides such as CdS, ZnS, etc) have also being utilized as photocatalyst in the photocatalytic process and the process is used for a different groups of dyes that include the direct, reactive, vat and disperse. More information about the catalytic dyes can be seen in a review (89). The authors discussed about the breaking down of dyes and it depends on many factors like pH, catalyst concentration, substrate concentration, substrate concentration and the existence of electron acceptors for example hydrogen peroxide and ammonium sulphate.

2.8 Low Cost Adsorbent For Effective Dye Removal

The selection of a great adsorbent depends on so many factors. The factors are that it should be freely available, reasonably priced, and non-hazardous in nature. There has been much research on various kinds of adsorbent and the adsorption capacity. Cost is one of the factors used to compare different adsorbents. It is generally known that an adsorbent is referred to as low-cost when little processing is required and is found

everywhere, or waste material from another industry which has lost its value or is a byproduct or further processing values. There are many low-cost adsorbents that has been used for the removal of dyes. There are many ways of removing dyes using low-cost adsorbent. By-products of industrial, agricultural industries and bio sorbent are very helpful in removing dyes from waste water. Most of these adsorbents have been tested and tried for dye removal. The use of waste material for adsorption has multiple benefits such as water treatment and waste management.

2.8.1 *Agricultural Waste*

There is so much research undergoing to find cost effective adsorbent to effectively treat dye wastewater which according to the physic-chemical characteristics and low-cost they may be great adsorbents (94). A huge amount of waste is generated due to large agricultural production. One of the many properties of agricultural waste is that it is made up of lignocellulosic material that consists of three important structural components which are lignin, cellulose, and hemicellulose. Some of these properties contribute to the mass and have enormous molecular weights. The properties of lignocellulosic materials are that they contain extractive structural components which have a smaller molecular size (95). Much research has been done on using agricultural adsorbents produced from agricultural waste to effectively treat dye wastewater. Sectors like the agricultural and industrial sector pollute land, air and water and can cause adverse effects on the ecosystem with the untreated waste produced from these sectors. It has also been realized that improper treatment of these waste cause bigger challenges to the society. Therefore, more laws should be created to stop the illegitimate disposal of hazardous material to other areas (96).

Many ideas have been brought up on how to effectively get rid of agricultural waste for example using the waste as adsorbent that have high adsorption capacity to remove color from dye waste water (97). Agricultural waste is known for being renewable, huge quantities can be found everywhere and very reasonably priced compared to other materials used as adsorbent. Agricultural adsorbent is greatly preferred as adsorbent because it requires little processing (washing, drying, and grinding) therefore reduces overall production cost and energy cost due to thermal energy are eliminated (98). Oil palm is one of the many adsorbent being used in many industrial fields and therefore waste is generated from these industries and a lot of research is done on its by-products as dye adsorbent such as palm kernel fiber (99,100), Palm shell (101) and palm kernel shell (102). The agricultural product, coconut is grown in 80 countries of the world and its products are used in food industries and because of this waste is generated from these industries and is used intently for dye absorption studies such as empty coconut bunch (103) coconut husk (104) coconut coir dust (105) and coconut tree sawdust (106).

2.8.2 Industrial By-Products

Metal hydroxide sludge fly ash, red mud, biosolids and waste slurry are examples of low-cost adsorbent and locally available materials.

2.8.2.1 Metal Hydroxide Sludge

Metal hydroxide sludge possesses the ability to remove azo dyes. One of the many constituents are insoluble metal hydroxide and salts. A research by Netpradit et al (107) discusses the reactive dye removal by electroplating industry hydroxide sludge and discovered that the maximum adsorption capacity of 45.37 and 61.73 mg/g for reactive

red 120 and reactive red 2 respectively at 30 degree centigrade and at a pH of 8-9. It was also discovered that pH has a key role to play in the adsorption and formation of dye-metal complexes. Golder et al(108) also researched the adsorption of Congo red dye by metal hydroxide sludge as adsorbent and the reported maximum adsorption capacity of 270.8mg/g at 30 degree centigrade and a starting pH of 10.4. Santos et al.(109) also studied the metal hydroxides as a low-cost adsorbent which is used to remove the reactive dye Remazol Brilliant blue in solution and it was discovered that at a particular temperature of 25 degree centigrade and pH 7, a maximum monolayer adsorption capacity of 91.0 mg/g.

2.8.2.2 *Fly Ash*

Is also one of the many industrial solid wastes used to adsorb dyes (110,111,112). It was estimated that the global production of fly ash was 67.5 million tonnes per year in 2010 (113). In the burning processes of waste material fly ash is produced. One of the main constituents of fly ash is some hazardous heavy metals (113).

CHAPTER III

MATERIALS AND METHODS

3.1 Dyes

The following dyes were used in the experiment.

3.1.1 *Direct blue 15*

The dye “Direct blue 15” is part of a group of dyes widely known as azo dyes. It is also known for its color which is deep purple to dark blue microcrystalline (Reference 1 Its solutions have a high concentration and have its solutions have a high concentration and have the tendency to appear blue-black. Azo dyes belong to a very important class of dye which is majorly used for various industrial applications. It is also used for various industrial applications. It’s majorly used for dyeing in textile industries. It’s used majorly because of different spectrum of shades; shared bonding to the fibers, very easy application, beautiful colors, and little energy is consumed.

Surveying 10,000 dyes with the all world-wide production of 7×10^5 in a year, it is concluded that 50% are widely known as azo dyes, having the characteristic chromophore azo dyes group (-N=N-).

According to, the global making and use of dyeing of textile and paper when it enters the environment through various waste streams. If it gets to the atmosphere, the

ionic state of Direct blue 15, it produces a substance that is non-volatile, and this compound will belong solely in the particle phase in air. The process of wet and dry deposition can physically remove particulate-phase direct blue. If it enters the soil, Direct blue 15 is expected to have slight mobility which is based on the retention of the dye in soil by micro-organisms by ion-exchange process particularly on clay surfaces. The process of volatilization from moist soil is not expected because the compound sometimes exists as an ion and ions do not volatilize. Using the process of activated sludge inoculum. The dye, direct blue 15 did not breakdown on over 41 days in the aerobic static test indicating that biodegradation is not a vital environmental fate process in soil or water. However due to the complete breakdown of direct blue 15 was reported within 7 days with the use of sludge inoculum incubated under aerobic conditions. If released into the atmosphere, it is expected to adsorb the suspended solids and sediment due to the ionic state; adsorption therefore increases with decreasing pH. Direct blue 15 will only exist entirely in the ion form at pH values of 5 to 9 and therefore lead to the volatilization from water surfaces and bio-concentration are not expected to be important fate processes. The process of hydrolysis is not only expected to be an important fate process. The process of hydrolysis is not expected to be an environmental fate process since this compound does not have any functional groups that hydrolyze environmental conditions (pH 5 to 9).

Occupational exposure to Direct blue 15 may occur when inhaled and through dermal contact with this compound at the workplace where direct blue is made and tested.

3.1.2 *Acid Red 88*

Acid red 88 is classified as an azo dye which has a red color in very high concentrations solutions. Azo dyes which have a red color that appears to be black in color in very high concentrations solutions. Azo dyes are dyes that have the functional group $R-N=N-R'$ in which R and R' are usually made up of aryl groups. The Azo dyes are used to treat textiles, leather and some food substances.

Azo dyes are generally classified as solids. Most are known as salts, the colored component being the anion usually, although some cationic azo dyes are known. Most proteins are cationic in nature; thus, the dyeing of leather and wool is best known as the ion-exchange reaction. The anionic dye adheres to these particles through the forces of electrostatic. Cationic azo dyes contain what it is called quaternary ammonium centers. Azo pigments are chemically related to azo dyes. Which its major properties are that it is insoluble in water and other solvents. Acid red 88 has also been named as a mono-azo textile dye widely used in textile and food industry.

3.1.3 *Rhodamine 6G*

Rhodamine 6G belong to a highly fluorescent rhodamine family dye. One of the most common uses of the rhodamine 6G dye is that it is used as a tracer dye within water to determine the rate and direction of flow and transport.

Rhodamine dyes fluorescence and can easily be detected cheaply with instruments called fluorometers. Rhodamine dyes can extensively find its application in biotechnology applications such as fluorescence microscopy flow cytometry, fluorescence correlation spectroscopy. It is majorly used in lipstick and can be separated through a thin-layer chromatography and identified by the process adsorption and

fluorescence spectra or be determined fluorimetrically. Its thin layer chromatography on inactivated pre-coated silicon, using the famous solvent system has been used extensively to separate biological stains, including rhodamine 6G. The dyes that have being separated from rhodamine 6G were identified by the nuclear magnetic resonance or visible spectra. The method of gel permeation chromatography on sephadex LH-zoresin in which is used mostly to separate and identify biological stains including rhodamine 6G.

Rhodamine 6G is well known as a laser dye or gain medium a dye laser. The dye has the potential of high photo-stability, high fluorescence quantum yield (0.75), low-cost and its lasting range of very close proximity to its adsorption maximum (approximately 530 nm).

3.2 Fruit Drink

Fruit drink is widely known as concentrated natural fruit pulps which are mixed to make a drink. Its original source is from natural fruit but are also usually dehydrated to reduce its moisture content to less than 3%. The main goal of dehydration is to make the fruit content last longer. Fruit juice concentration is gotten from fruit juices by removing the moisture content therefore at atmospheric pressure or under vacuum. Also, various fruit juice concentrates have been prepared by freezing and making the water as ice from the concentrated juice.

3.3 Adsorbent

The following adsorbents were taken to study the color removal using adsorption with these dyes.

Orange Peel

Banana Peel

Onion Peel

3.4 Preparation Of Adsorbent

Adsorbents like Orange peels, onion peels and banana peels were bought from a local grocery store in the Cleveland District. The peels were collected and dried at low temperature (<105 degree centigrade for 48 hours to remove moisture content. After the drying process, peels were ground to fine powder and sieved through 600 microns. The adsorbents used in the present research work prepared under nominal treatment only.

3.5 Equipment

1. Weighing balance
2. Turbidity meter
3. Shaker 115V 60CV AC
4. Mass Spectrophometer
5. TOC analyzer

3.6 Method

In this method, the batch mode analysis was used with each sample of 50ml was made by diluting the dye stock solutions and fruit nectar stock solutions and adsorbent and to ensure equal mixing and no loss of particle of the element.

When the desired concentration from the stock solution and the making of the samples were mixed vigorously for 15mins at 120rev/min followed by 90 mins of slow shaking at 50rev/min and then allowed to settle overnight.

The supernatant was then obtained from the samples and was analyzed, and readings of transmissivity and turbidity was taken

3.7 Runs Protocol

Table 1 is 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 fruit nectar wastewater type of adsorbent and dosage of adsorbent

3.7.1 Single Dye

Table 1 describes the run protocols of single dyes without fruit nectar solution

TABLE 1

Run order	Adsorbent dose(g)	Dye Concentration(ppm)	Fruit drink Concentration (ppm)
1	0	0	0
2	0	50	0
3	0	100	0
4	0	150	0
5	0	200	0
6	0.4	50	0
7	0.4	100	0
8	0.4	150	0
9	0.4	200	0
10	0.8	50	0
11	0.8	100	0
12	0.8	150	0
13	0.8	200	0
14	1.2	50	0
15	1.2	100	0
16	1.2	150	0
17	1.2	200	0
18	1.6	50	0
19	1.6	100	0
20	1.6	150	0
21	1.6	200	0
22	2	50	0
23	2	100	0
24	2	150	0
25	2	200	0

3.7.2 Low Strength Of Dyes

TABLE 2: It describes the run protocol for low strength dyes

Run order	Adsorbent dose(g)	Dye Concentration(ppm)	Fruit drink Concentration (ppm)
26	0	0	10
27	0	50	10
28	0	100	10
29	0	150	10
30	0	200	10
31	0.4	50	10
32	0.4	100	10
33	0.4	150	10
34	0.4	200	10
35	0.8	50	10
36	0.8	100	10
37	0.8	150	10
38	0.8	200	10
39	1.2	50	10
40	1.2	100	10
41	1.2	150	10
42	1.2	200	10
43	1.6	50	10
44	1.6	100	10
45	1.6	150	10
46	1.6	200	10
47	2	50	10
48	2	100	10
49	2	150	10
50	2	200	10

3.7.3 Medium Strength Of Dye

TABLE 3: it describes the run protocol for medium strength dyes

Run order	Adsorbent dose(g)	Dye Concentration(ppm)	Fruit drink Concentration
51	0	0	50
52	0	25	50
53	0	50	50
54	0	75	50
55	0	100	50
56	0.4	25	50
57	0.4	50	50
58	0.4	75	50
59	0.4	100	50
60	0.8	25	50
61	0.8	50	50
62	0.8	75	50
63	0.8	100	50
64	1.2	25	50
65	1.2	50	50
66	1.2	75	50
67	1.2	100	50
68	1.6	25	50
69	1.6	50	50
70	1.6	75	50
71	1.6	100	50
72	2	25	50
73	2	50	50
74	2	75	50
75	2	100	50

3.7.4 High Strength Dyes

TABLE 4: it describes the run protocol for high strength dyes

Run order	Adsorbent dose(g)	Dye Concentration(ppm)	Fruit drink Concentration
76	0	0	100
77	0	50	100
78	0	100	100
79	0	150	100
80	0	200	100
81	0.4	50	100
82	0.4	100	100
83	0.4	150	100
84	0.4	200	100
85	0.8	50	100
86	0.8	100	100
87	0.8	150	100
88	0.8	200	100
89	1.2	50	100
90	1.2	100	100
91	1.2	150	100
92	1.2	200	100
93	1.6	50	100
94	1.6	100	100
95	1.6	150	100
96	1.6	200	100
97	2	50	100
98	2	100	100
99	2	150	100
100	2	200	100

CHAPTER IV

RESULTS AND DISCUSSION

In this Chapter, the observation and results have been likened and represented on a graph on the behavior and performance of three adsorbent dosages (0.4, 0.8, 1.2, 1.6, 2.0g) with dye dosages (0, 50, 100, 150 and 200ppm) in the presence of (0, 10, 50, 100ppm) of fruit nectar concentration. Each unit of concentration has been likened with keeping of dye concentration and sugar constant and the results have been represented in graphs and tables after the process of adsorption and plotted differently

1. Dye 1 = Direct blue 15
2. Dye 2 = Acid red 88
3. Dye 3 = Rhodamine 6G

1. Adsorbent 1 = Orange peel
2. Adsorbent 2 = Banana peel
3. Adsorbent 3 = Onion peel

Table 5: Test trial to check the effectiveness of the dye

Type of dye		% Transmittance	Absorbance
Acid red 88	Control	5.9	1.22
	Banana	6.4	1.194
	Cornhusk	6.6	1.188
	Orange	5.8	1.24
	Onion	5.6	1.253
Direct blue 15	Control	1.2	1.939
	Banana	1.2	1.92
	Cornhusk	1.2	1.964
	Orange	1.1	1.954
	Onion	1.1	1.95
Rhodamine 6G	Control	24.8	0.606
	Banana	28.6	0.544
	Cornhusk	25.6	0.592
	Orange	26.7	0.574
	Onion	26.6	0.576

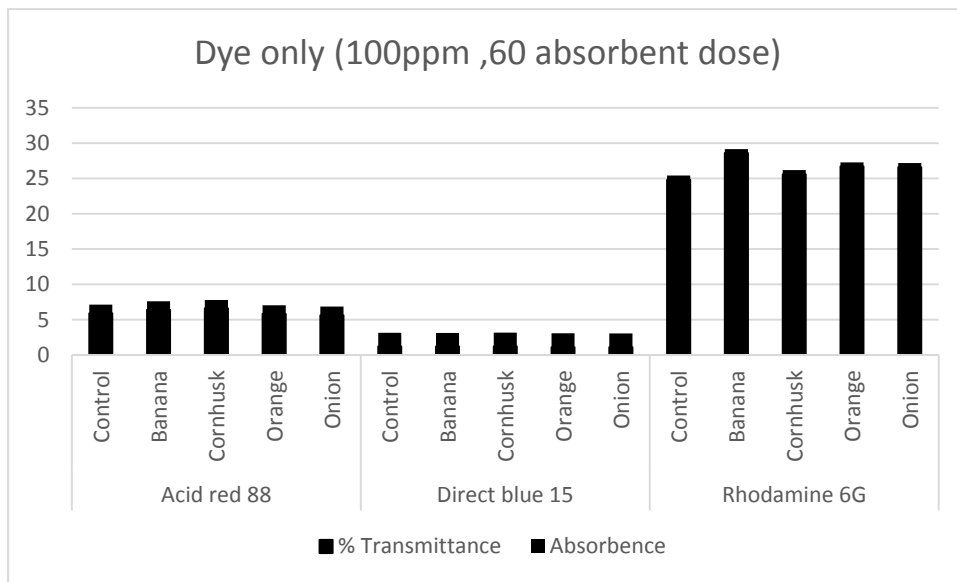


Figure 1: Test trials to check the effectiveness of each adsorbent

In the graph above, the effect of dosage is emphasized. When the dosage is low, it is seen that there is a no change in the transmittance and absorbance values.

Table 6: In this table below, the water quality of direct blue 15 after treatment in terms of transmittance at 50 mg/l is stated below

	Combined dye wastewater +Fruit nectar		
Dye Concentration(50mg/l)	Transmittance of different adsorbent		
	Orange peel	Banana peel	Onion peel
Low Concentration	73.6	63.5	60.5
Medium Concentration	62.6	59.5	55.05
High Concentration	53.5	54.6	50.3

Table 6 explains about the transmittance of combined dye and fruit nectar wastewater using different adsorbents. As shown in the table that orange peel has the highest transmittance value at 73.6% at low concentration. The maximum transmittance of banana peel at low concentration is 63.5%. The maximum transmittance of onion peel at low concentration is at 60.5%.

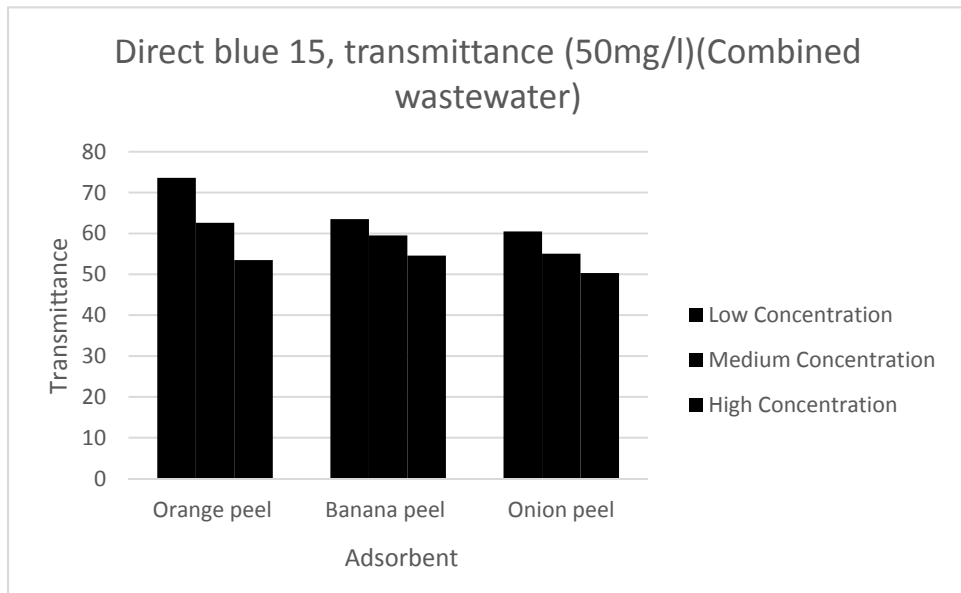


Figure 2: Direct blue 15, Comparison of transmittance at optimum adsorbent size and dosage. Direct blue (In terms of transmittance) Orange peel > banana peel > Onion peel

Table 7 shows the Water quality of acid red 88 after treatment in terms of transmittance at 50mg/l

	Combined dye wastewater + fruit nectar		
Dye Concentration (50mg/) Transmittance of different adsorbent			
	Orange peel	Banana peel	Onion peel
Low concentration	64.3	70.5	62.3
Medium concentration	65.7	50.5	55.4
High Concentration	50.7	45.8	40.3

Table 7 explains the transmittance of combined dye and fruit nectar using different adsorbents. As shown in the table that banana peel has the highest transmittance value at 70.5%. The maximum transmittance of orange peel at low concentration is 64.3% while the maximum transmittance of onion peel at low concentration of fruit drink is at 62%.

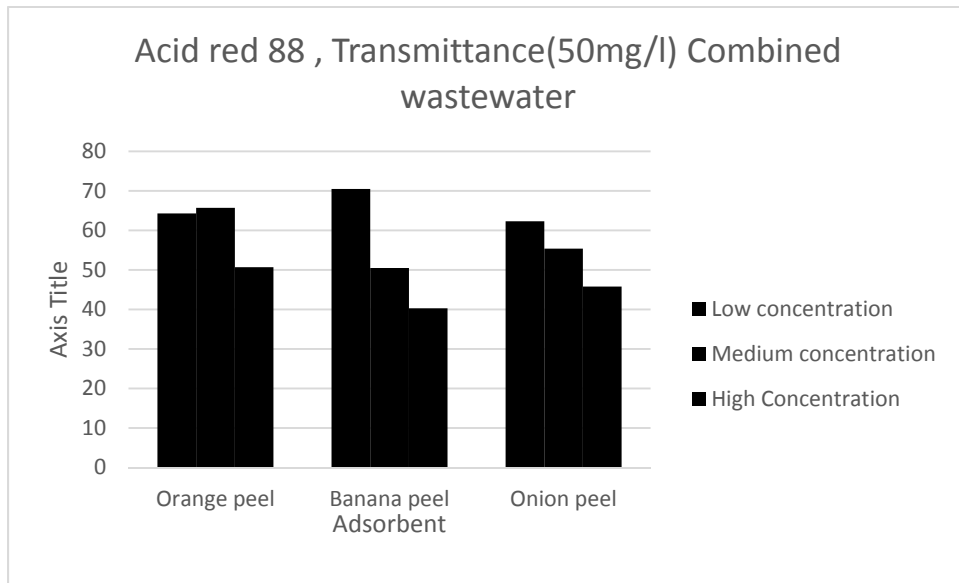


Figure 3: Acid red 88, Comparison of transmittance at optimum adsorbent size and dosage. Acid red 88 in terms of transmittance (Banana peel > Orange peel > onion peel)
 Table 8: shows the water quality of Rhodamine 6G after treatment in terms of transmittance at 50mg/l

Table 8 Water quality of Rhodamine 6G after treatment in terms of transmittance at 50mg/l

	Combined dye wastewater + fruit nectar		
Dye Concentration (50mg/l) Transmittance of different adsorbent			
	Orange peel	Banana peel	Onion peel
Low concentration	70.3	64.5	57.3
Medium concentration	52.4	52.5	55.4
High Concentration	45.3	30.3	44.8

Table 8 explains the transmittance of combined dye and fruit nectar using different adsorbents. It has the highest transmittance value at 70.3%. The maximum transmittance banana peel at low concentration is 64.5%.

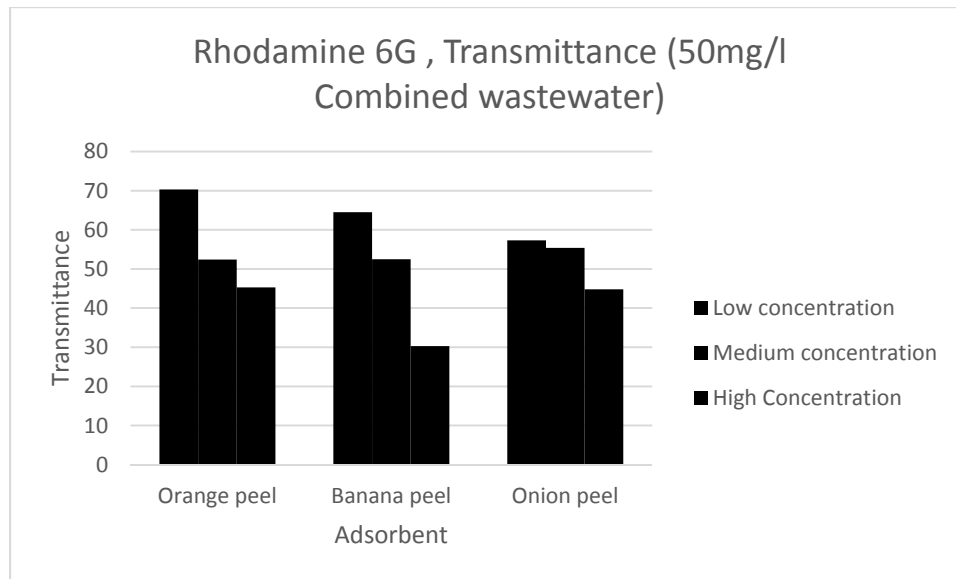


Figure 4: Rhodamine 6G, Comparison of transmittance at optimum adsorbent size and dosage. Rhodamine 6G (in terms of transmittance): Orange peel > Banana peel > Onion peel

4.1 Results on Effects Of pH

The pH observed with the three dyes i.e. Direct blue 15, Acid red 88 and rhodamine 6G is (7.4,8.2,7.5) (5.0,5.2,1.5), and (6.2,7.5,7.9) respectively. In the dye adsorption process, pH factor acts a crucial role because the impact of electrostatic attraction between dye and adsorbent change with changes with increase in pH. The rate of adsorption not only depends on available 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. The maximum transmittance of onion peel at low concentration of fruit drink is at 57.3.

4.2 Results Of Isotherms And Isotherm Coefficients

Results isotherms are presented in Appendix B, from Figure 27 to Figure 31.

Freundlich isotherm is the best fit for Direct blue 15 with the optimum dosage of low cost adsorbent being orange peel. The linear equation is $y = 1.0252x - 4.5528$ and coefficient of determination $R^2 = 0.6751$, coefficient of Freundlich isotherm, $K_f = 3.60$.

Langmuir isotherm is the best fit for Rhodamine 6Gt with the optimum dosage of low cost adsorbent being orange peel. The linear equation is $y = 1685x + 0.1566$ and coefficient of determination $R^2 = 0.8247$, coefficient of Freundlich isotherm, $K_f = 3.89$.

Langmuir isotherm is the best fit for Acid red 88 certified with the optimum dosage of low cost adsorbent being banana peel. The linear equation is $y = 1685x + 0.1566$ and coefficient of determination $R^2 = 0.8247$, coefficient of Langmuir isotherm, $K_f = 3.89$.

4.3 Effects of Parameters on Color Removal

The two-most important parameters used in color removal which are used to differentiate the quality of water is absorbance and transmittance. The highest color removal and the efficiency of the adsorption process are represented by maximum

transmittance and minimum absorbance. Since the adsorption process is performed in the laboratory constant temperature is maintained. pH factor is also considered but usually adsorption is performed at the tertiary treatment process.

CHAPTER V

CONCLUSION

1) For the combined wastewater consisting of direct blue 15 wastewater and fruit nectar the best adsorbent was orange peel with the best transmittance obtained of 73.9% and the worst adsorbent was onion peel with the transmittance of 50.3%. In the order of color removal performance is as follows

orange peel > banana peel > onion peel.

2) For the combined wastewater consisting of acid red 88 wastewater and fruit nectar the best adsorbent was banana peel with the best transmittance obtained of 70.5% and the worst adsorbent was onion peel with the transmittance of 40.3%.

In the order of color removal performance is as follows

Banana peel > Orange peel > onion peel.

3) For the combined wastewater consisting of Rhodamine 6G wastewater and fruit nectar the best adsorbent was Orange peel with the best transmittance obtained of 70.3% and the worst adsorbent was onion peel with the transmittance of 44.8%. In the order of color removal performance is as follows

Orange peel > banana peel > onion peel.

This study shows that for an improved color removal, it is best the waste-water is of the combined type, the value for the highest adsorption efficiency is 73.9%.

4) Combined waste-water treatment gives the best transmittance when compared to the others because of the dilution effect.

5.1 Engineering Significance

Textile and fruit nectar industries over the years have been known for polluting rivers with high BOD (biochemical oxygen demand) and COD (Chemical oxygen demand) in the effluent pre-treatment of the waste-water. The use of low-cost adsorbent is a cheaper way of improving the water quality. After the wastewater has passed through the primary and secondary treatment processes, the tertiary process in which adsorption is used helps to bring about better effluent quality and remove color in the waste-water to meet the E.P.A recommended standards. A two-stage treatment process is recommended in which low-cost adsorbents first and then activated carbon is used as a polishing step. This will significantly reduce the cost in the tertiary process of binary waste-water treatment.

5.2 Recommendations for Future Research

1) The use of combined agricultural waste could be used to amplify the individual adsorption qualities of both agricultural wastes. This could lead to the making of a better agricultural adsorbent.

2) Chemically modified agricultural adsorbent can also be used to treat waste-water

3) More research should be done on more agricultural waste and dye to check for the adsorption capacity of the waste.

All other water quality parameters should be considered for example Total suspended solids (T.S.S), dissolved oxygen (D.O), Biochemical oxygen demand (B.O.D) before water is considered safe to be discharged to the environment.

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APPENDIX A

Table 9: Transmittance of Direct blue 15 at low concentration (50ppm) and varying fruit nectar concentration treated with orange peel

Fruit drink concentration (ppm)	Transmittance (%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	16	16.2	12	54.6	18	69.3	18.3	70.9	19	70.2	35.2	63.7
10	46.7	51.3	29.3	60.5	24.3	70.3	25.2	73.6	47.8	72.7	36.7	65.5
50	39.4	50.2	24.4	53.6	21.2	66	15	62.6	39.8	70.3	34.6	68.8
100	30.3	49.2	20.3	51.4	20	61	15.5	53.5	35.6	64.3	32.5	60.1

Table 10: Transmittance of Direct blue 15 at medium concentration 100ppm and varying fruit nectar concentration treated with orange peel

Fruit drink concentration (ppm)	Transmittance (%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	12	35.7	15.6	64.3	21.3	54.8	23.6	50.8	23.7	54.6	24.6	56.7
10	23.4	29.8	19.5	68.4	25.5	67.2	27.8	54.8	25.9	69.9	21.5	59.8
50	21.6	23.6	17.4	67.8	23.5	59.7	22.5	53.2	20.6	59.3	21.4	71
100	19.7	25.3	18.5	58.4	20.6	50.7	23.4	49.7	25.1	50.3	27.3	63.9

Table 11: Transmittance of Direct blue at high concentration (200ppm) and varying fruit nectar concentration treated with orange peel

Fruit drink concentration (ppm)	Transmittance (%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	0.1	15	22	54	2.1	42	2.5	35	2.6	30.6	2.8	39.6
10	35	37.3	25	58	30	52	32	65	34	44.3	35	45.8
50	32	35.6	16.6	52	15.7	49	16.9	42	18.4	42.5	19	43.3
100	30.9	35.6	15.9	50	2.9	43	16	41	18	40.8	17.3	50.8

Table 12: Transmittance of Direct blue 15 at low concentration (50ppm) and varying fruit nectar concentration with banana peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying banana dosage peel											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	25	26.7	35	42.8	33	60.9	34	60.7	29.7	30.8	35.5	38.5
10	44	57.9	40.8	50.9	56	71.9	46	65.9	37.5	40.8	36.6	39.9
50	43	50	29.7	49.2	53.9	65.9	37	51.9	31.9	33.8	31.9	35.4
100	39	42	26.8	48.9	52.9	60.5	36	47.2	30.9	35.7	30.7	32.2

Table 13: Transmittance of Direct blue 15 at Medium concentration (100ppm) and varying fruit nectar concentration with banana peel

Fruit drink concentration (ppm)	Transmittance (%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	0.1	15	22	54	2.1	42	2.5	35	2.6	30.6	2.8	39.6
10	35	37.3	25	58	30	52	32	65	34	44.3	35	45.8
50	32	35.6	16.6	52	15.7	49	16.9	42	18.4	42.5	19	43.3
100	30.9	35.6	15.9	50	2.9	43	16	41	18	40.8	17.3	50.8

Table 14: Transmittance of Direct blue 15 at high concentration (200ppm) and varying fruit nectar concentration with banana peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying banana dosage peel											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	21.8	22.9	32.5	52.3	30.5	50.8	40.6	71	20.5	20.9	24	27
10	22.9	28.9	36.8	58.9	35.6	54.9	42.5	72.9	22.5	22.6	29	32
50	19.8	21.6	31	56.3	33.6	49.3	41	70.5	19.8	23.5	26	24.7
100	15	15.6	31.4	55.7	34.8	49.6	40.3	70.1	20.4	21.4	28	28

Table 15: Transmittance of Direct blue 15 at low concentration (50ppm) and varying fruit nectar concentration treated with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onion peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	23.9	25.6	26.3	50.3	24	50.6	23.5	50.3	30.5	32.3	25.2	28
10	25	30.9	29.4	57.6	25	56.3	27.9	56.3	38.9	45.3	26.3	27.5
50	22	29.6	25.3	54.6	22	52.3	24	55.3	34.3	45	27.3	27.8
100	26	26.2	22.2	52.2	21	51	21	50.3	32.4	35.9	28.3	29.5

Table 16: Transmittance of Direct blue 15 at Medium concentration (100ppm) and varying fruit nectar concentration treated with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onion peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	20.3	20.5	26.1	37.1	24.6	43	20.3	50.3	30.3	26.3	29.3	30.2
10	29.3	29.6	33.5	44.6	28.9	45	26.3	66.5	35.6	24.3	35.3	37.3
50	24.3	24.6	31.5	42.7	26	44	24.3	55.5	34	30.6	34.6	36
100	32.1	34.5	32.6	40.8	21	42	25.6	50.3	31	35.6	31.2	32

Table 17: Transmittance of Direct blue 15 at high concentration (200ppm) and varying fruit nectar concentration treated with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onion peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	30.5	32.7	35.9	43	35.5	40.6	25.2	45.8	24.9	30.2	30.2	32.5
10	33.4	34	49	52	39	50.2	36.9	54.3	30.5	34.9	35.6	36.9
50	32.5	35.6	34.5	45	38.2	42.2	34	52.6	32.9	35.2	34.5	35.2
100	29.5	31.7	39	42	35.2	37.2	32	50.3	23	30	35.9	32

Table 18: Transmittance of Acid red 88 certified with low concentration (50ppm) and varying fruit nectar concentration with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	25.2	50.9	30.5	60.3	23.2	60.5	26.3	61.5	20.9	30.5	24.5	27.7
10	35.6	69.3	35.6	65.3	24.2	61.7	26.4	64.3	29.8	32.9	25.7	29.6
50	30.9	65.3	35.3	64.3	21.2	58.8	21	65.7	26.6	29.9	21	23
100	32.9	66.5	30.3	62.3	19.8	54.4	19	50.7	25.9	27.5	19.8	23.5

Table 19: Transmittance of Acid red 88 certified at medium concentration (100ppm) and varying fruit nectar concentration treated with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	21	23	25.1	60.5	34.6	65.8	35.9	60.5	26.3	27.4	25.8	29.8
10	30.5	31.5	37.9	72.9	36.9	71.4	38.9	69.5	32.5	36.9	24.6	29.7
50	26.8	30.9	32.3	71.5	34.5	66.9	34.2	62.4	31.5	35.6	23.4	25.6
100	27.3	27	36.8	62.3	31.5	59.8	31.2	58.3	29.8	32.5	20.3	25.9

Table 20: Transmittance of Acid red 88 certified at high concentration (200ppm) and varying fruit nectar concentration treated with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	35	38.8	32.5	50.6	31.2	50.3	30.5	50.5	33.5	35.9	37.8	39.9
10	39.9	42.2	36.9	56.3	37.5	55.7	32.5	53	35.8	36.6	40.4	45.3
50	37	39	34.3	52.3	32.5	54.6	31.4	51.8	32.8	37.8	42.8	41.5
100	35	37	30.5	51.9	34.9	51.7	29.8	51.2	31.5	33.9	41.9	42.5

Table 21: Transmittance of Acid red 88 certified at low concentration (50ppm) and varying fruit nectar concentration treated with banana peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying banana peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	23.5	28.8	26.2	50.4	23.5	50.4	30.5	62.8	20.5	22.5	25.6	27.5
10	30.5	32.2	32.2	55.5	23.7	57.6	32.7	70.5	35.5	36.8	30.5	35.9
50	29.6	30.2	30.6	53.2	22.5	52.6	31.9	50.5	27.4	29.5	29.8	33.7
100	28.9	29.9	26.6	51.8	20.5	50.2	29.6	40.3	20.4	21.5	30.4	30.7

Table 22: Transmittance of Acid red 88 certified at medium concentration (100ppm) and varying fruit nectar concentration with banana peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying banana peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	22.5	26.3	21	50.6	32.5	60.5	32	64.5	29.5	30.5	35.8	36.9
10	29.8	35.6	28	57.8	34.6	70.3	34.5	70.5	35.2	35.4	38.2	40.2
50	26.3	34.9	25	56.6	33.5	69.2	31	69.5	34.8	36.7	35.3	39.2
100	24.3	33.4	24	54.3	34.8	60.4	29	64.7	33	35.8	31.5	33.3

Table 23: Transmittance of Acid red 88 certified with High concentration (200ppm) and varying fruit nectar concentration treated with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onion peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	22.6	30.5	25	53.6	23.4	56.2	24.3	50.7	24.3	28.2	30.2	32.4
10	29.4	32.6	30.7	59.2	27.4	65.4	25.7	62.6	29.3	30.6	35.2	35.8
50	26.4	36.9	25.5	54.5	21.2	61.6	24.2	49.7	25.6	29.3	33.4	32.6
100	25.4	35.4	30.4	50.2	19.2	59.2	21.4	46.2	20.1	28.6	31.5	31

Table 24: Transmittance of Acid 88 certified at low concentration (50ppm) and varying fruit nectar concentration with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onion peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	23.4	26	24.6	50.5	27.2	56	30.2	54	23.5	27.6	20.2	30.8
10	26.5	29	32.5	56.3	30.2	59	33.2	62.3	26.2	28.2	35.8	40.4
50	24.5	24.4	26.5	51	31.2	58.4	28.2	55.4	24.3	28.3	27.8	29.9
100	23.7	20.5	22.2	49.2	30.2	58.2	26.5	45.3	24.9	26.5	26.7	28.8

Table 25: Transmittance of Acid red 88 certified at medium concentration (100ppm) and varying fruit nectar concentration with onion pee

Fruit drink concentration (ppm)	Transmittance(%) result with varying onion peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	21	25	30.8	55.8	35.5	50.3	32.5	59.3	29.5	34.8	30.2	35.4
10	27	28.6	32.5	59.8	40.2	55.4	37.8	62.5	31.5	39.8	35.8	40.3
50	24.5	25.3	34.5	54.2	33.3	52.2	34.4	60.5	30.4	39.5	32.2	33.3
100	22	24.8	35.5	52.2	29.3	51	31.8	57.9	25.5	29.6	31.2	30.4

Table 26: Transmittance of Rhodamine 6G, certified at high concentration(200ppm) and varying fruit nectar treated with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onion peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	21	25	30.8	55.8	35.5	50.3	32.5	59.3	29.5	34.8	30.2	35.4
10	27	28.6	32.5	59.8	40.2	55.4	37.8	62.5	31.5	39.8	35.8	40.3
50	24.5	25.3	34.5	54.2	33.3	52.2	34.4	60.5	30.4	39.5	32.2	33.3
100	22	24.8	35.5	52.2	29.3	51	31.8	57.9	25.5	29.6	31.2	30.4

Table 27: Transmittance of Rhodamine 6G at low concentration (50ppm) and varying fruit nectar concentration treated with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	25	25.5	24.8	50.2	26.5	54.5	26.2	53.6	24	26	20.8	28.9
10	26.4	30.5	36.6	54.8	24.3	60.3	27.2	57.3	34.7	40.5	22.8	25.9
50	26	28.8	34.6	50.9	23.5	59.8	25.2	55.4	35	39	26.9	20.6
100	22	24.3	32.6	49.3	20.8	54.3	21.2	44.8	32.7	35.4	21	29.8

Table 28: Transmittance of Rhodamine 6G at medium concentration (100ppm) and varying fruit nectar concentration with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	23.6	25.6	25	50.7	24.3	52.9	28.9	53.4	23.5	26.3	25	29
10	24	26	30.5	60.8	25.8	55.8	35.9	70.3	25.9	27.9	32.5	38.2
50	25.6	27	28.9	59.8	23.6	50.3	32.5	52.4	23.3	26.5	32.1	38
100	26	30	29.5	57.9	22.8	49.3	31.7	45.3	22	26	29.8	35

Table 29: Transmittance of Rhodamine 6G at high concentration (200ppm) and varying fruit nectar concentration with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	23.6	25.6	25	50.7	24.3	52.9	28.9	53.4	23.5	26.3	25	29
10	24	26	30.5	60.8	25.8	55.8	35.9	70.3	25.9	27.9	32.5	38.2
50	25.6	27	28.9	59.8	23.6	50.3	32.5	52.4	23.3	26.5	32.1	38
100	26	30	29.5	57.9	22.8	49.3	31.7	45.3	22	26	29.8	35

Table 30: Transmittance of Rhodamine 6G at low concentration (50ppm) and varying fruit nectar concentration treated with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying orange peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	24	25.3	25.6	59.2	27.8	55.3	20.5	42.5	25	27	25	27.8
10	25	26.3	30.2	57.3	28.3	59.3	26.5	57.3	26	29	26	29
50	22.1	25.3	22.3	50.3	23.5	50.3	21.3	55.4	23	24	21.2	23
100	20.3	1.6	19.3	49.2	21.3	54.5	20.5	44.8	22	25	19.2	21

Table 31: Transmittance of Rhodamine 6G at medium concentration (100ppm) and varying fruit nectar concentration with orange peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onon peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	24	27	22	52.7	26.3	54.5	20.5	60.2	21	23	25	26.5
10	22	23	23	61.5	28.3	59.3	24.3	59.3	24	26	29	29.3
50	20.3	20.9	20.5	54.5	25.5	51.4	22.5	54.6	23	25	25.5	27
100	20.3	22.3	19.8	53.2	20.7	49.3	20.3	52.3	22	21	20.9	23.3

Table 32: Transmittance of Rhodamine 6G at high concentration (200ppm) and varying fruit nectar concentration treated with banana peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying banana peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	23.6	25.6	25	50.7	24.3	52.9	28.9	53.4	23.5	26.3	25	29
10	24	26	30.5	60.8	25.8	55.8	35.9	70.3	25.9	27.9	32.5	38.2
50	25.6	27	28.9	59.8	23.6	50.3	32.5	52.4	23.3	26.5	32.1	38
100	26	30	29.5	57.9	22.8	49.3	31.7	45.3	22	26	29.8	35

Table 33: Transmittance of Rhodamine 6G at low concentration (50ppm) and varying fruit nectar with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onon peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	24	25.3	25.6	59.2	27.8	55.3	20.5	42.5	25	27	25	27.8
10	25	26.3	30.2	57.3	28.3	59.3	26.5	57.3	26	29	26	29
50	22.1	25.3	22.3	50.3	23.5	50.3	21.3	55.4	23	24	21.2	23
100	20.3	1.6	19.3	49.2	21.3	54.5	20.5	44.8	22	25	19.2	21

Table 34: Transmittance of Rhodamine 6G at low concentration (50pm) and varying fruit nectar concentration with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onon peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	24	27	22	52.7	26.3	54.5	20.5	60.2	21	23	25	26.5
10	22	23	23	61.5	28.3	59.3	24.3	59.3	24	26	29	29.3
50	20.3	20.9	20.5	54.5	25.5	51.4	22.5	54.6	23	25	25.5	27
100	20.3	22.3	19.8	53.2	20.7	49.3	20.3	52.3	22	21	20.9	23.3

Table 35: Transmittance of Rhodamine 6G at high concentration (200pm) and varying fruit nectar concentration treated with onion peel

Fruit drink concentration (ppm)	Transmittance(%) result with varying onon peel dosage											
	0		0.4		0.8		1.2		1.6		2	
	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
0	25.6	28.8	20.3	45.9	26.3	50.9	25.6	60.9	16.2	25.2	21	22
10	27.8	30.8	25.8	50.9	27.3	52.8	27.2	65.2	24.3	27	23	25
50	26.3	25.8	22.5	48.3	24.3	49.8	24.2	42.2	29	30	19.8	26
100	28.3	24.8	20.6	42.2	23.3	47.5	23.2	40.2	30.4	31	20.3	21

APPENDIX B

LIST OF FIGURES

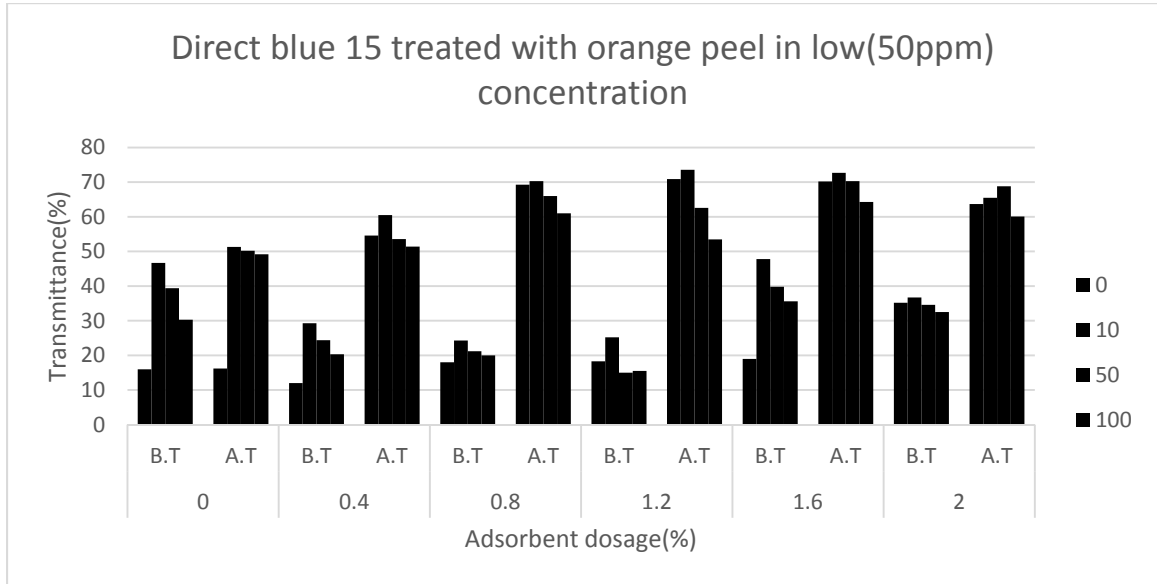


Figure 5: Comparison of transmittance before and after treatment in low concentration, direct blue 15

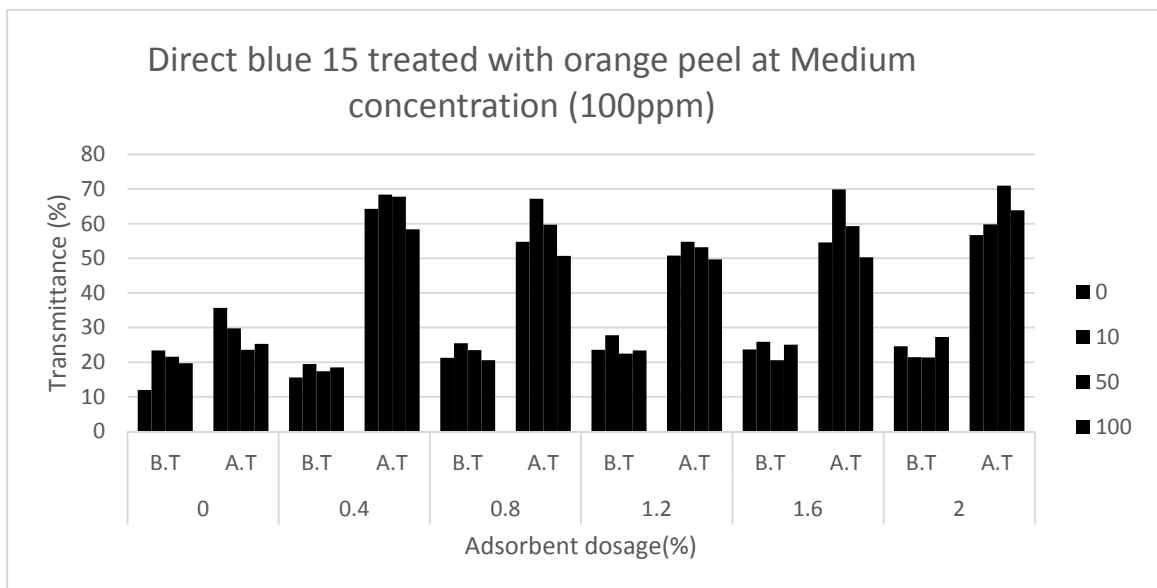


Figure 6: Comparison of transmittance before and after treatment in medium concentration, direct blue 15

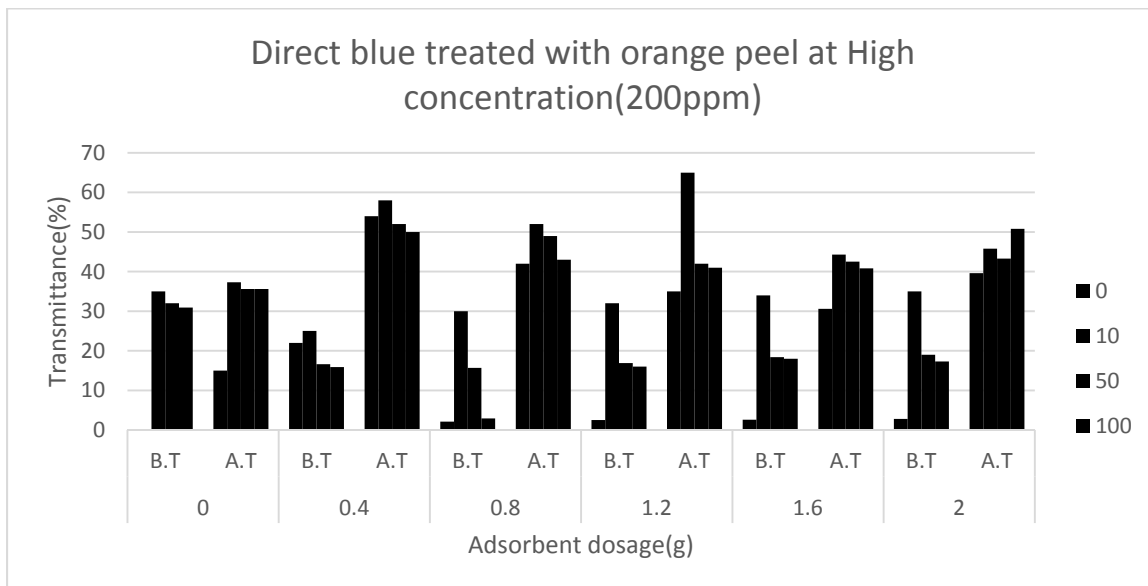


Figure 7: Comparison of transmittance values before and after treatment in high concentration, direct blue 15

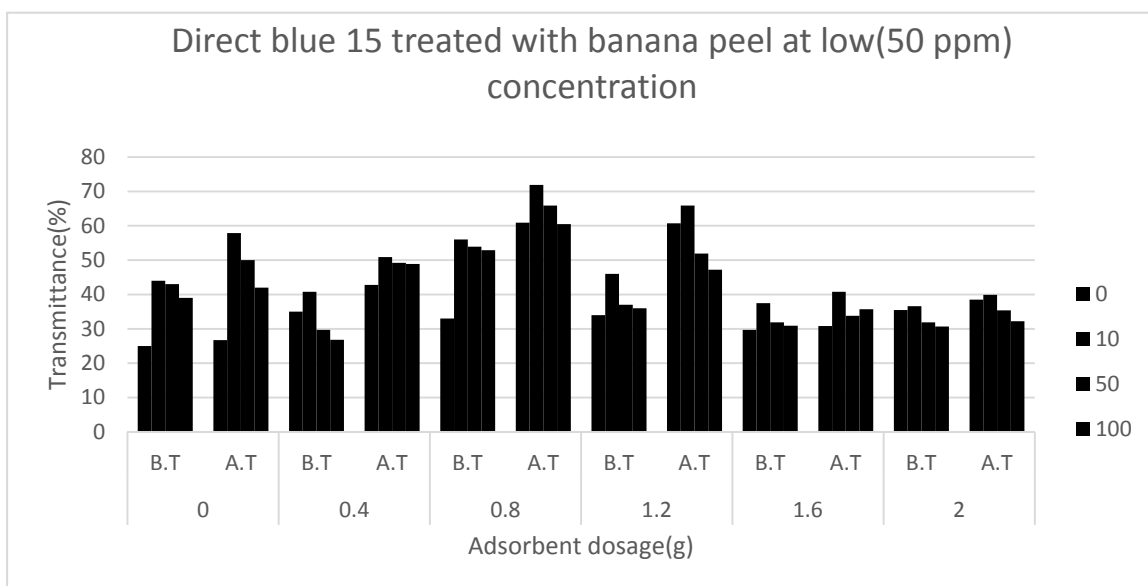


Figure 8: Comparison of transmittance before and after treatment at low concentration direct blue 15

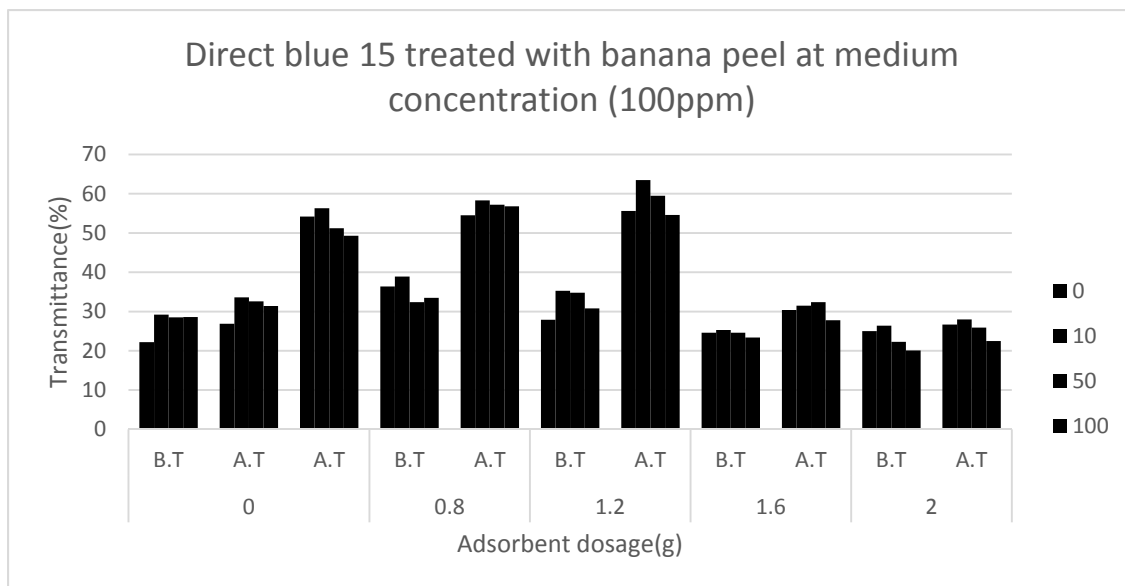


Figure 9: Comparison of transmittance before and after treatment in medium concentration, direct blue 15

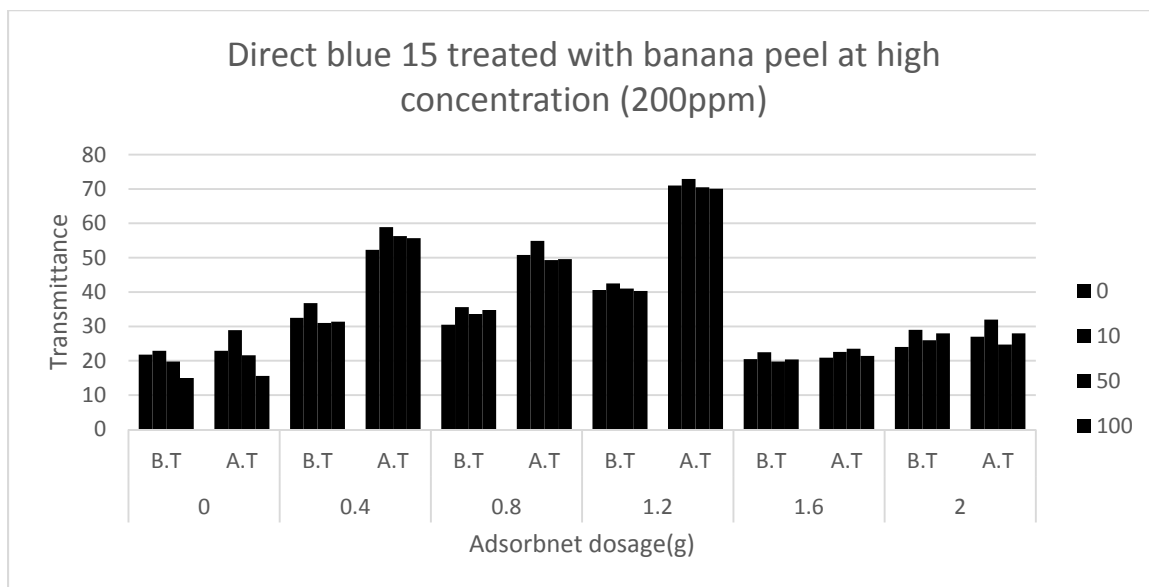


Figure 10: Comparison of transmittance before and after treatment in high concentration, direct blue 15

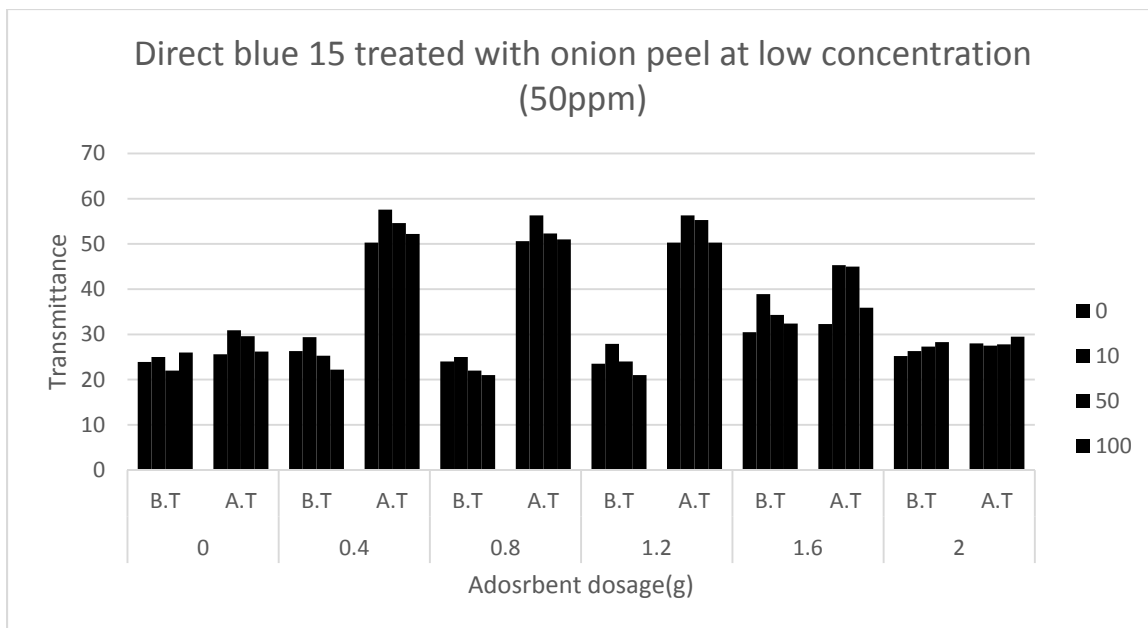


Figure 11: Comparison of transmittance before and after treatment in low concentration, direct blue 15

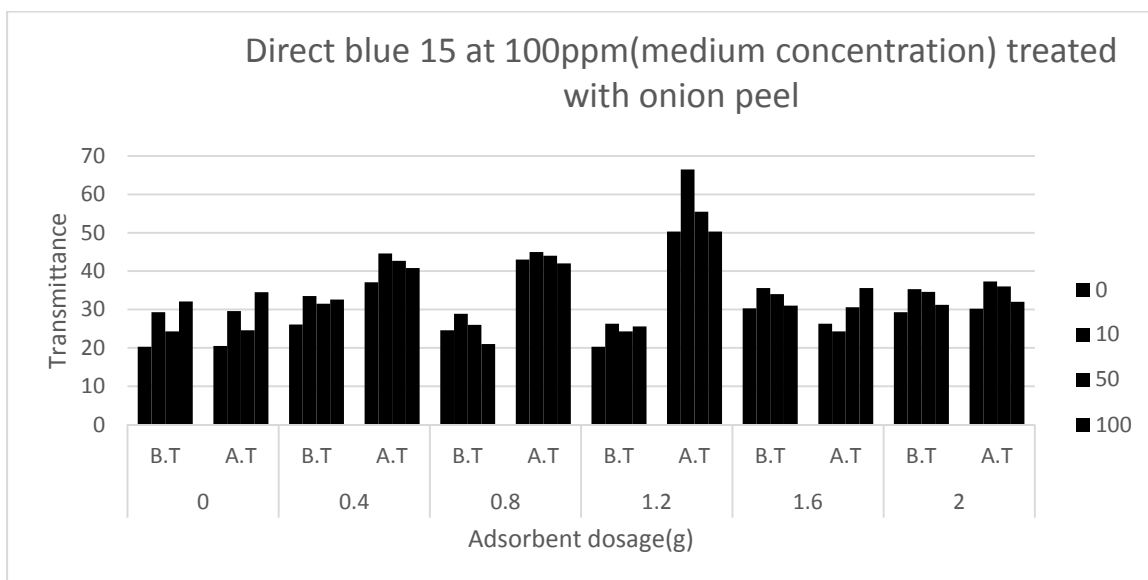


Figure 12: Comparison of transmittance before and after treatment at medium concentration, direct blue

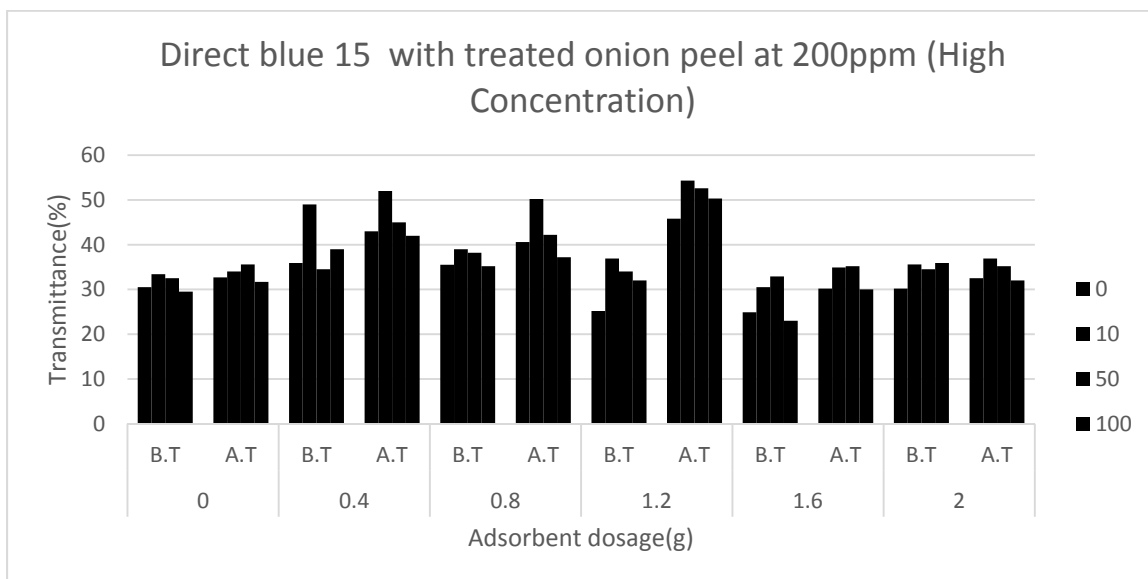


Figure 13: Comparison of transmittance before and after transmittance in high concentration, direct blue 15

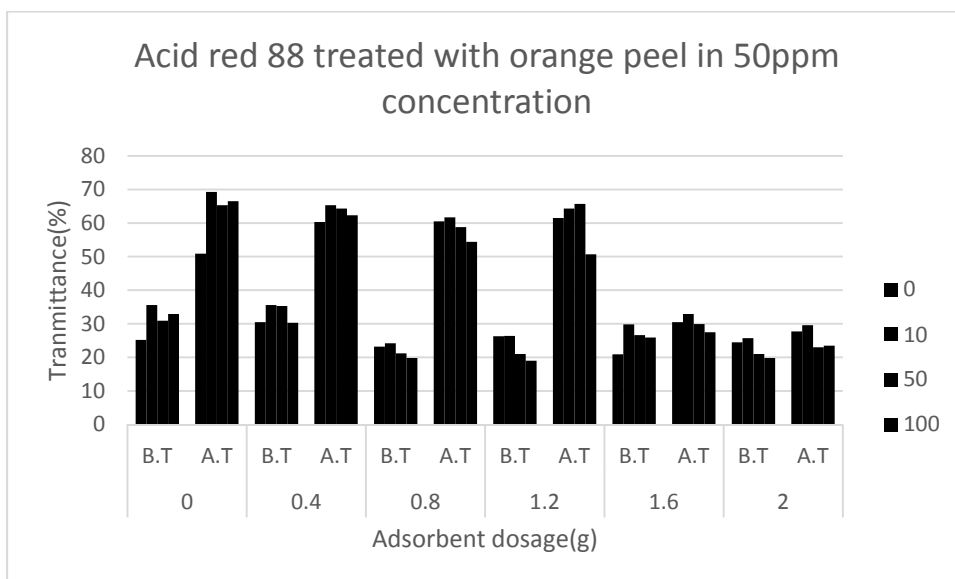


Figure 14: Comparison of transmittance before and after treatment in low concentration, Acid red 88

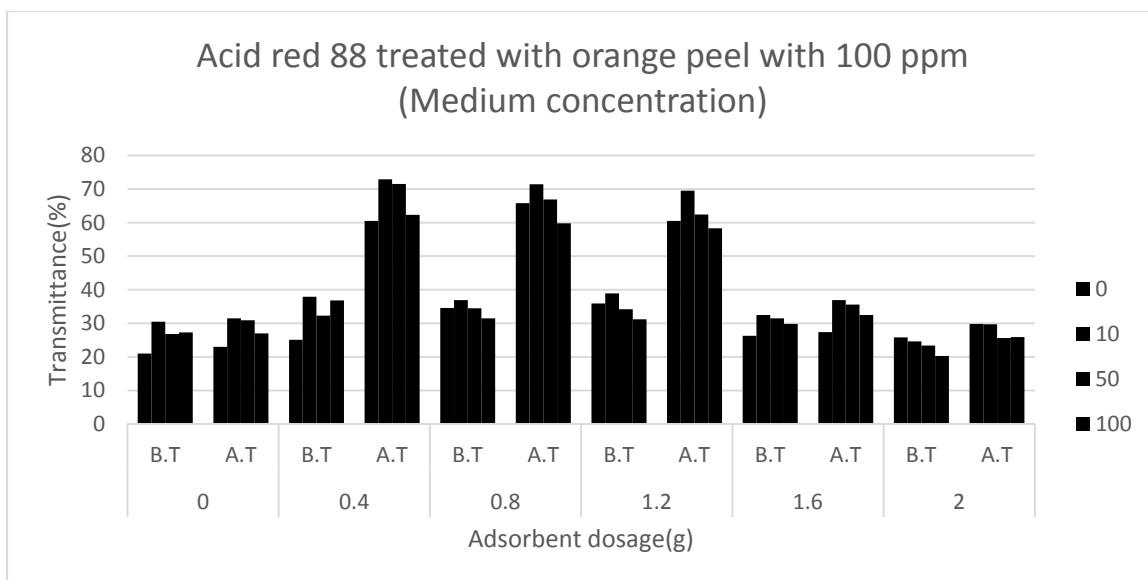


Figure 15: Comparison of transmittance before and after treatment in medium concentration, Acid red 88

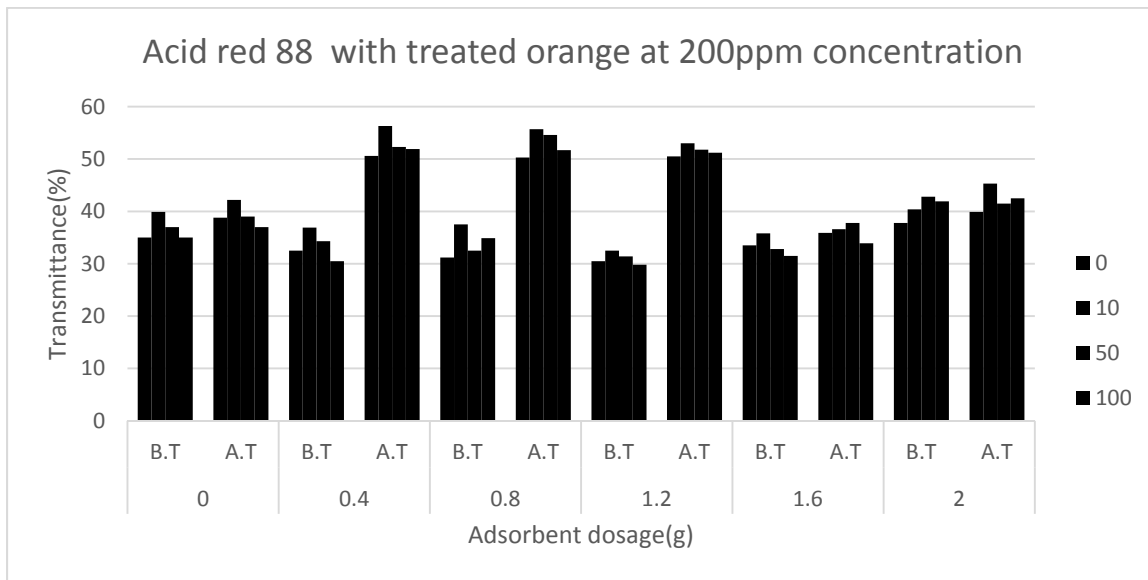


Figure 16: Comparison of transmittance before and after treatment in high concentration, Acid red 88

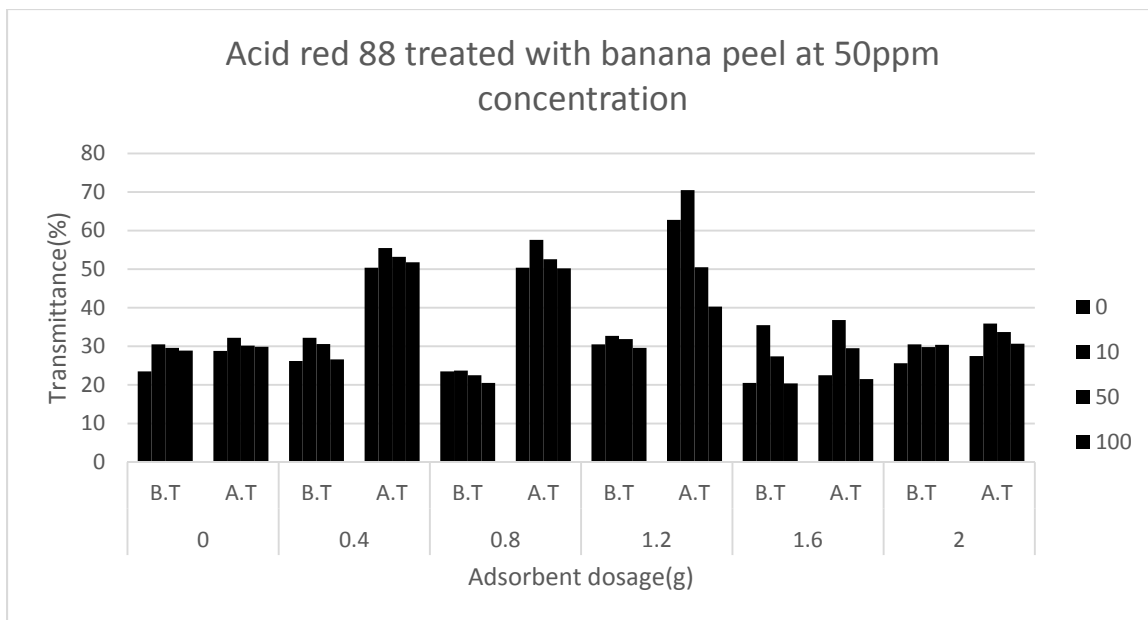


Figure 17: Comparison of transmittance before and after treatment in low concentration, Acid red 88

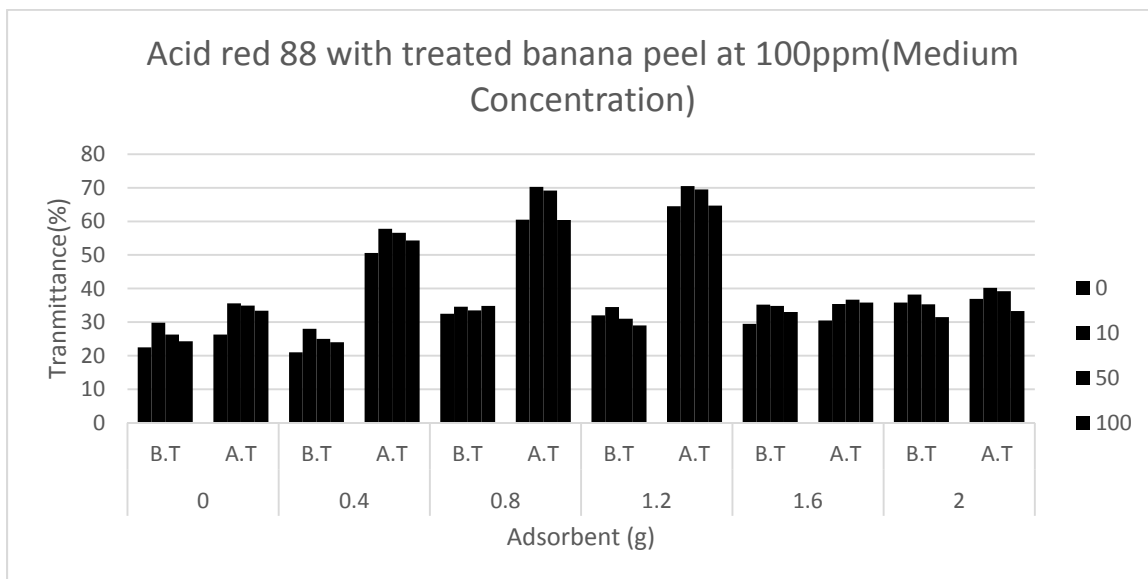


Figure 18: Comparison of transmittance before and after treatment in medium concentration, Acid red 88

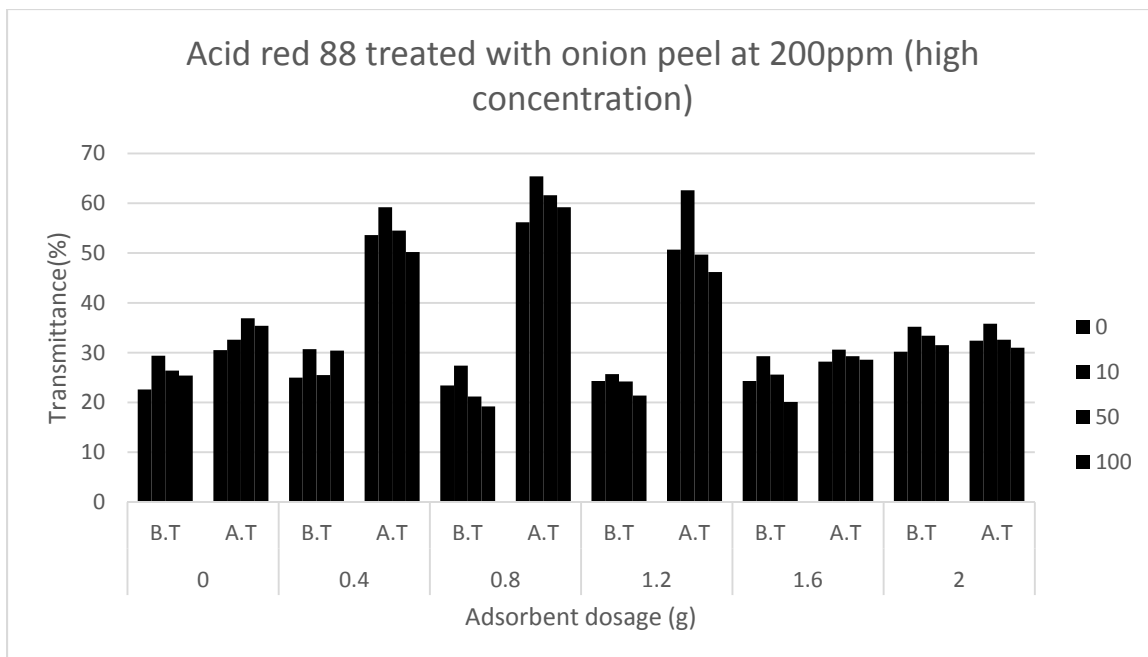


Figure 19: Comparison of transmittance before and after treatment in high concentration, Acid red 88

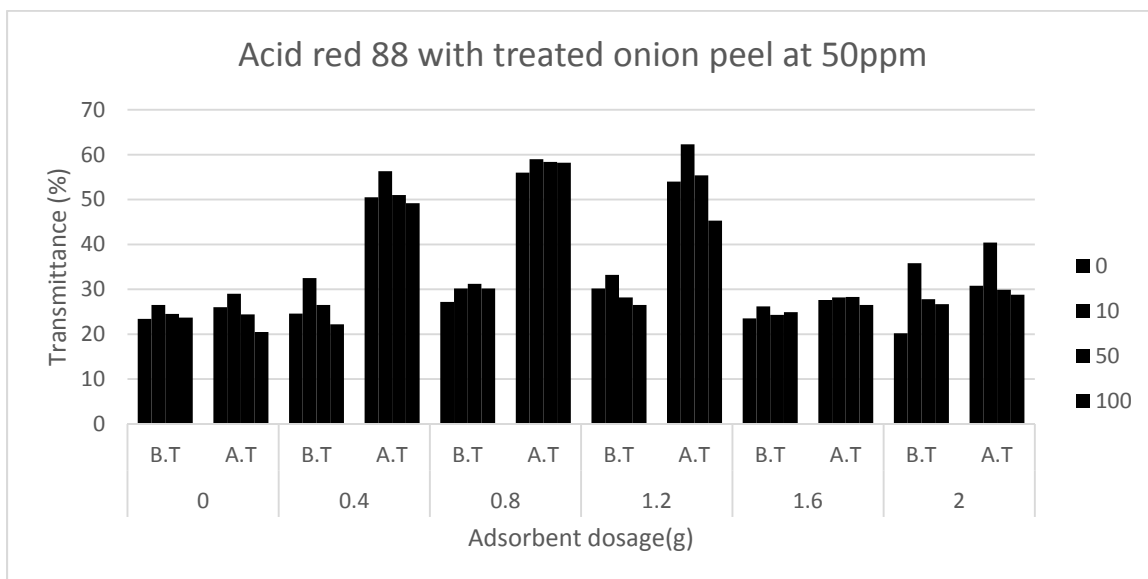


Figure 20: Comparison of transmittance before and after treatment in low concentration, Acid red 88

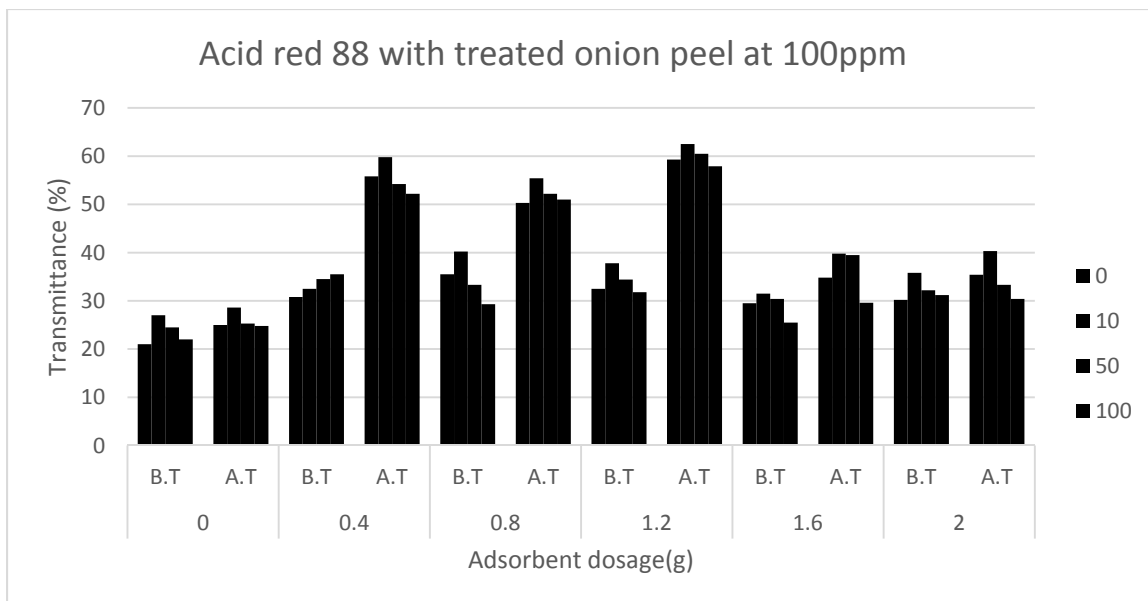


Figure 21: Comparison of transmittance before and after treatment in medium concentration, Acid red 88

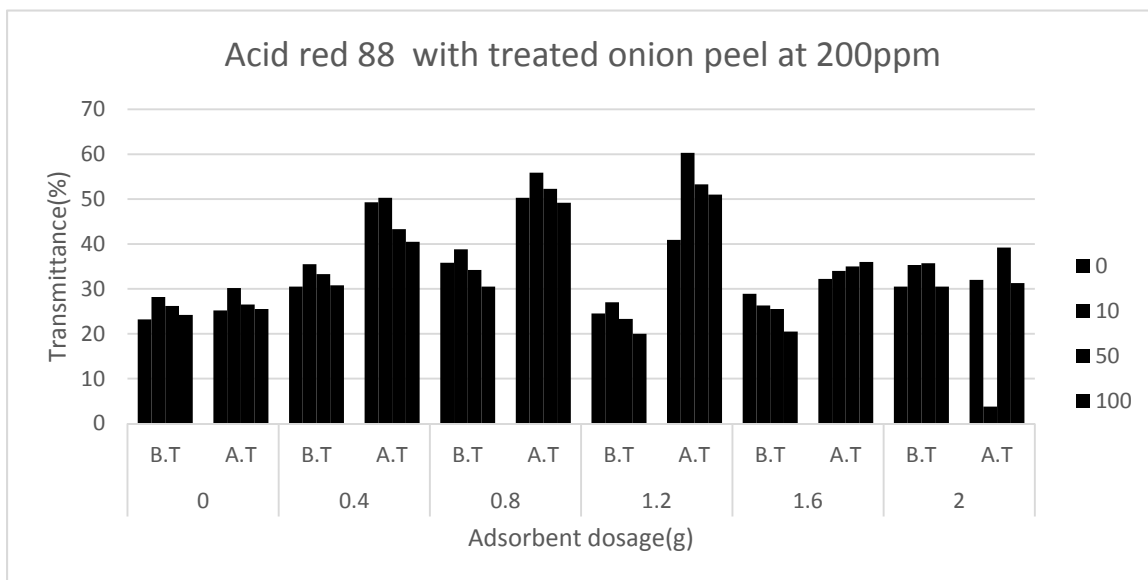


Figure 22: Comparison of transmittance before and after treatment in high concentration, Acid red 88

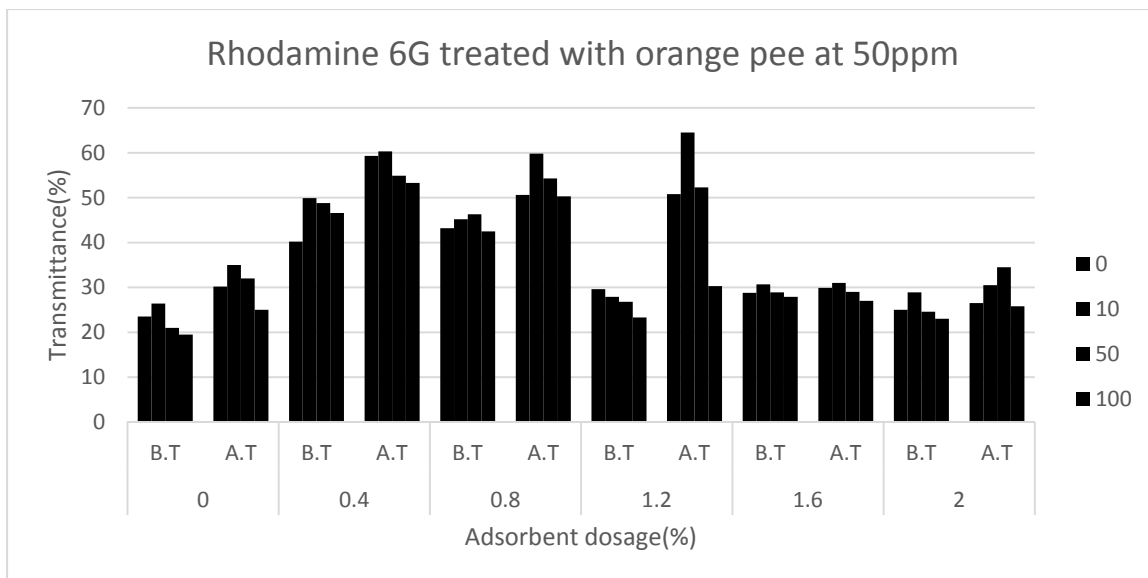


Figure 23: Comparison of transmittance before and after treatment in low concentration rhodamine 6G

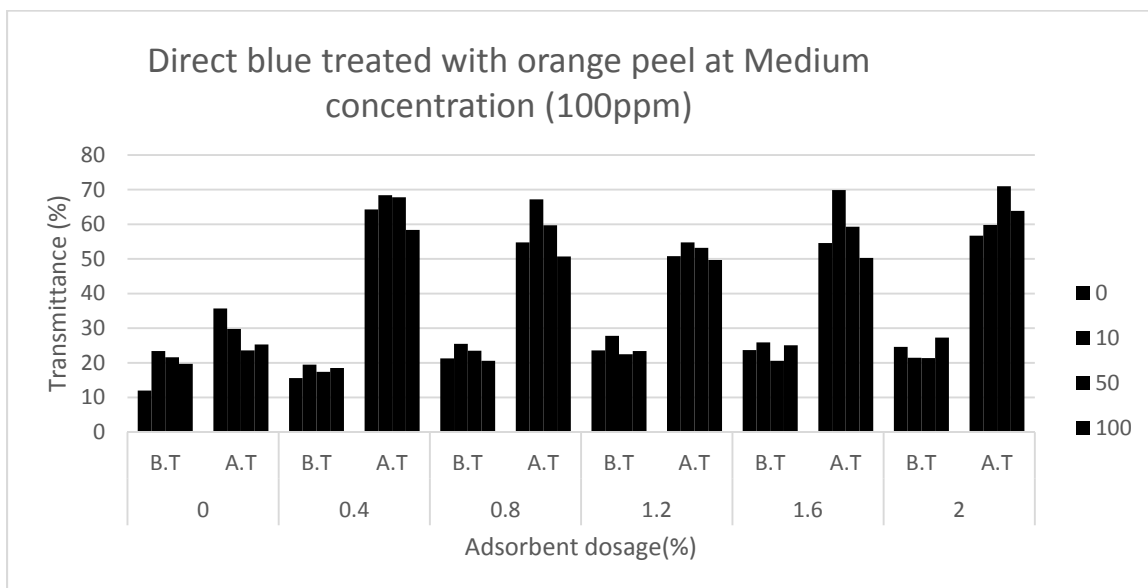


Figure 24: Comparison of transmittance before and after treatment in medium concentration rhodamine 6G

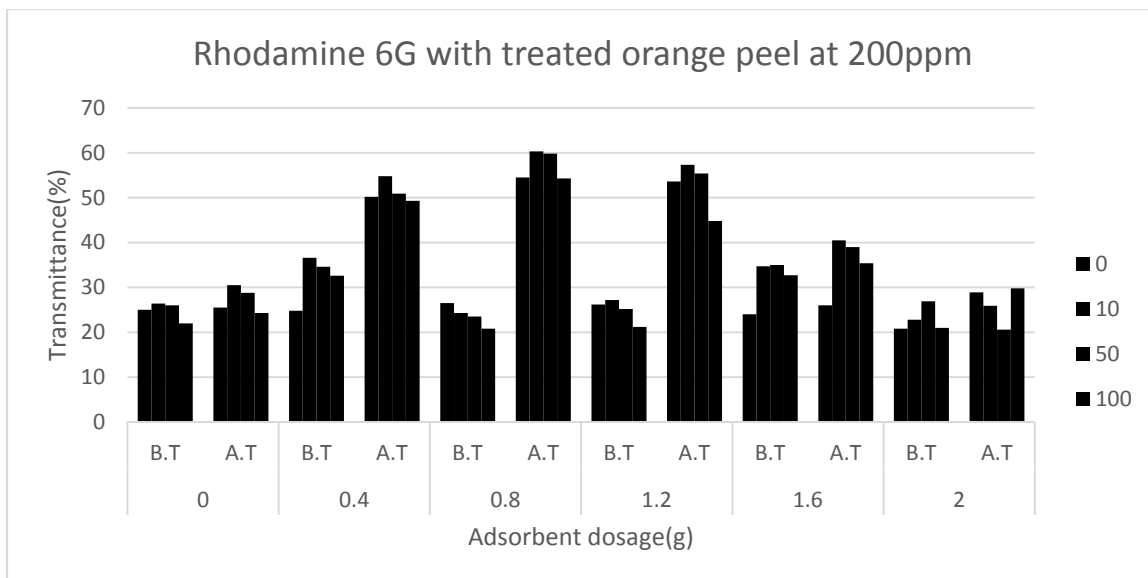


Figure 25: Comparison of transmittance before and after treatment in high concentration rhodamine 6G

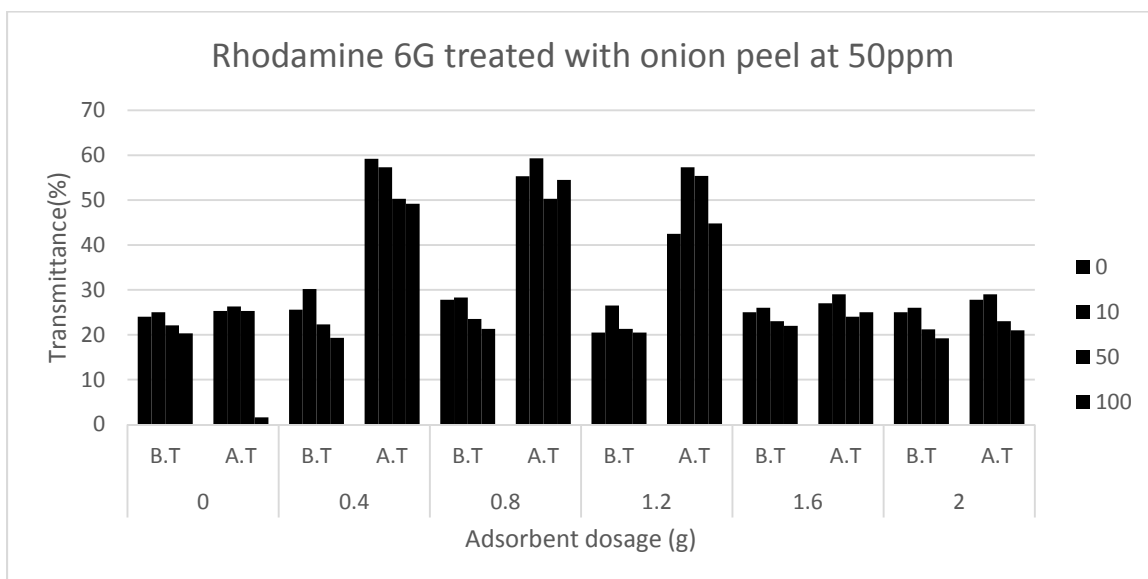


Figure 26: Comparison of transmittance before and after treatment in low concentration rhodamine 6G

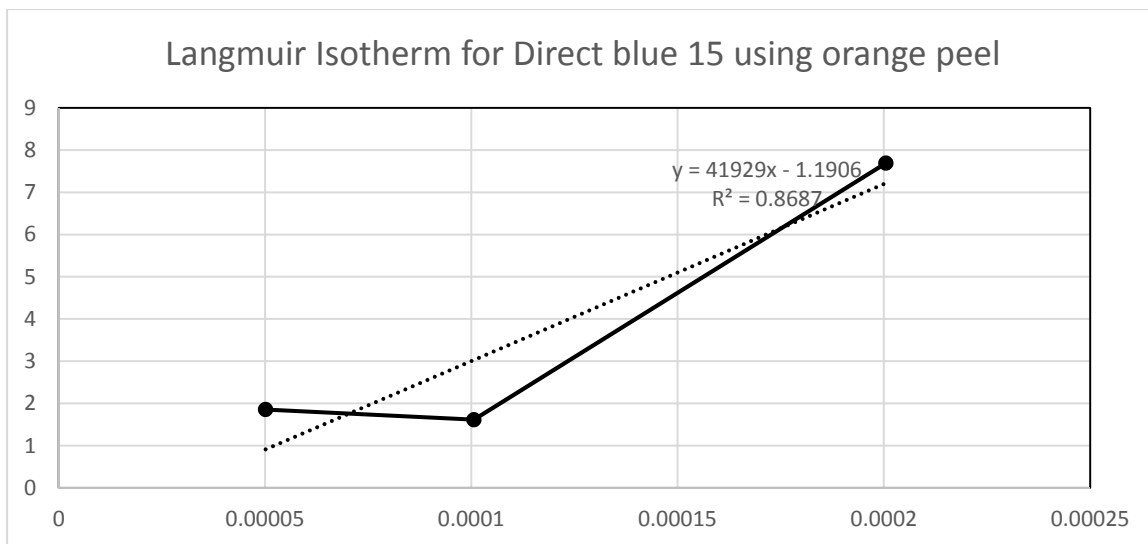


Figure 27: Langmuir isotherm model for direct blue 15 using orange peel

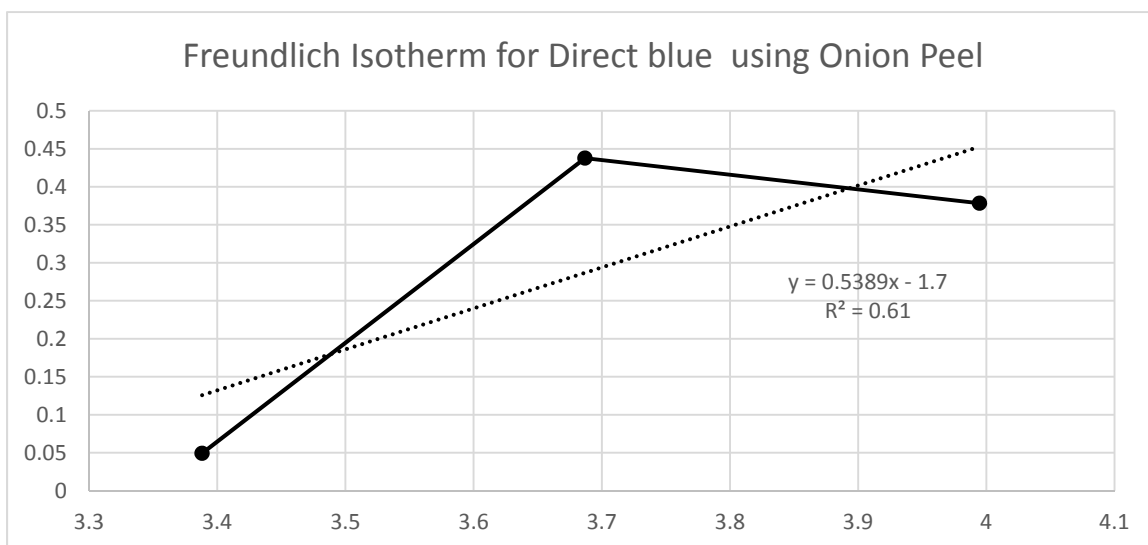


Figure 28: Freundlich isotherm models for direct blue 15 using onion peel

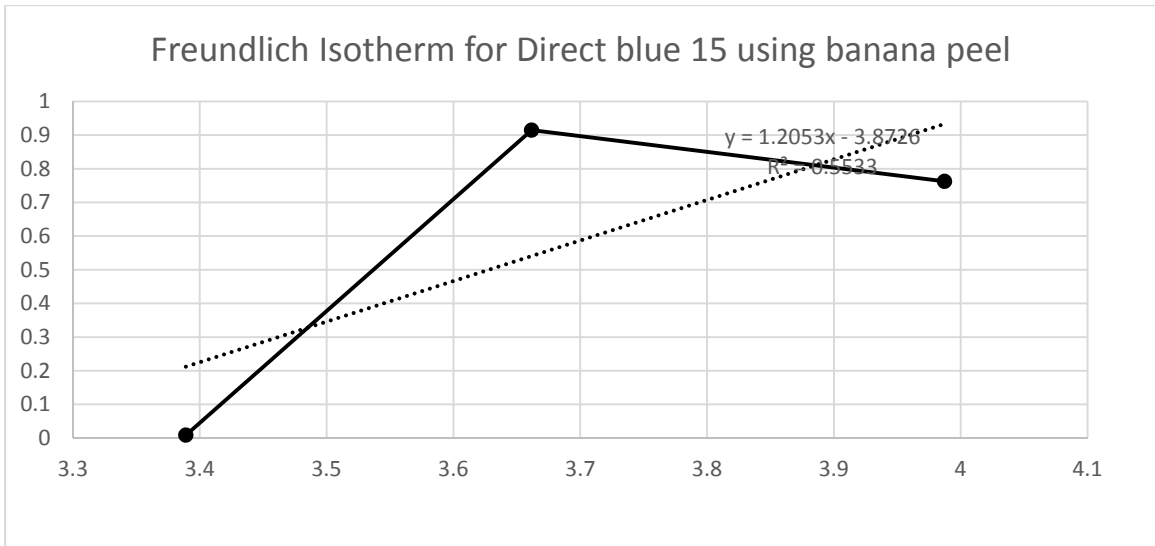


Fig 29: Freundlich isotherm model for Direct blue 15 using banana peel

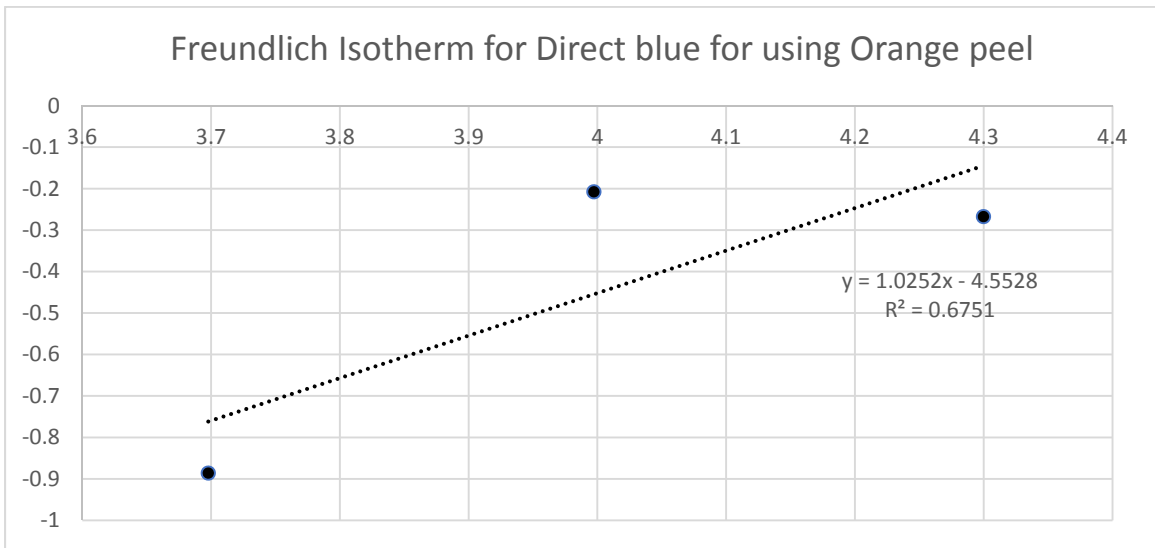


Figure 30: Freundlich isotherm model for direct blue 15 using Orange peel

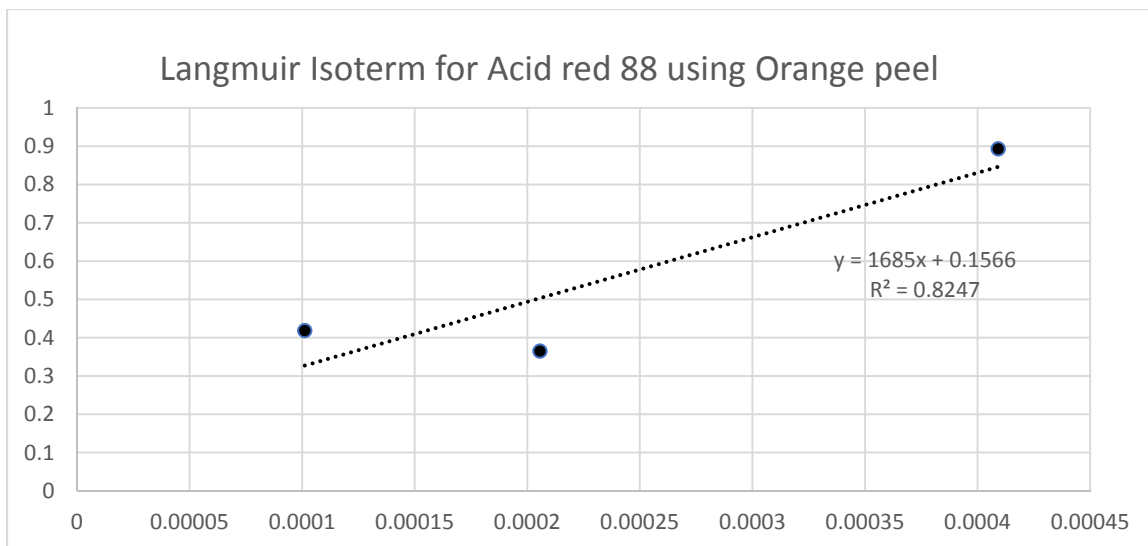


Figure 31: Langmuir isotherm for Acid red 88 using Orange peel