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ADSORPTION OF WATER-SOLUBLE DYES BY PEANUT HULLS

Miss Sukanya Phanom-ooppatham

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By	Miss Sukanya Phanom-ooptham
Field of Study	Chemical Engineering
Thesis Adivisor	Jirdsak Tscheikuna, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

Lavansiri ....Dean of Faculty of Engineering
(Professor Direk Lavansiri, Ph.D.)

THESIS COMMITTEE

Vichitra Chongvisal ....Chairman
(Assistant Professor Vichitra Chongvisal, Ph.D.)

....Thesis Advisor
(Jirdsak Tscheikuna, Ph.D.)

....Member
(Assistant Professor Varong Pavarajarn, Ph.D.)

....Member
(Assistant Professor Sutha Khaodhiar, Ph.D.)

สุกัญญา พนมอุปถัมภ์ : การดูดซับสีย้อมที่ละลายน้ำด้วยเปลือกถั่วลิสง (ADSORPTION OF WATER-SOLUBLE DYES BY PEANUT HULLS) อ.ที่ปรึกษา : ดร.เจิดศักดิ์ ไชยคุนา, 133 หน้า.

การวิจัยนี้เป็นการศึกษาการดูดซับสีย้อมที่ละลายน้ำด้วยเปลือกถั่วลิสง 2 สายพันธุ์ คือ พันธุ์พระราชทานและพันธุ์กาฬสินธุ์1 สีย้อมที่ใช้ในการทดลอง คือ สีเหลืองไดเร็กท์ สีแดงไดเร็กท์ สีฟ้ารีแอคทีฟ สีเหลืองรีแอคทีฟ การทดลองการดูดซับทำโดยใช้ถังกวนแบบกะ ที่อุณหภูมิ 30 องศาเซลเซียส ภายใต้ความดันบรรยากาศ เวลาที่ใช้ในการดูดซับคือ 25 ชั่วโมง ทำการศึกษาปัจจัยที่มีผลต่อการดูดซับ ได้แก่ ความเข้มข้นเริ่มต้นของสารละลายสีย้อมที่ 10 30 และ 50 มิลลิกรัมต่อลิตร ค่าพีเอชเริ่มต้นของสารละลายที่ 5 7 และ 9 ขนาดของอนุภาคตัวดูดซับที่ 0.150-0.180 มิลลิเมตร 0.180-0.210 มิลลิเมตร และ 0.210-0.300 มิลลิเมตร และศึกษาการดูดซับในระบบสององค์ประกอบ

จากการทดลองพบว่าเปลือกถั่วลิสงที่ใช้เป็นตัวดูดซับสามารถใช้กำจัดสีย้อมได้ โดยเปลือกถั่วลิสงสายพันธุ์พระราชทานมีความสามารถในการดูดซับสีย้อมทั้งสี่ชนิดได้ดีกว่าสายพันธุ์กาฬสินธุ์1 เปลือกถั่วลิสงทั้งสองสายพันธุ์สามารถดูดซับสีเหลืองไดเร็กท์ได้ดีที่สุด เมื่อความเข้มข้นเริ่มต้นของสารละลายสีย้อมที่ 50 มิลลิกรัมต่อลิตร ขนาดของอนุภาคเปลือกถั่วที่ 0.150-0.180 มิลลิเมตร และค่าพีเอชเริ่มต้นของสารละลายที่ 5 ซึ่งมีสภาวะเป็นกรด เมื่อความเข้มข้นของสีย้อมเพิ่มขึ้นความสามารถในการดูดซับจะลดลง สารละลายสีย้อมที่มีองค์ประกอบของสีย้อมหลายองค์ประกอบมีผลต่อการดูดซับสีย้อมของเปลือกถั่ว โดยการดูดซับสีย้อมจะเพิ่มมากขึ้นหรือลดลงขึ้นกับชนิดขององค์ประกอบสี

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สาขาวิชา..............วิศวกรรมเคมี.............ลายมือชื่ออาจารย์ที่ปรึกษา
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SUKANYA PHANOM-OOPPATHAM: ADSORPTION OF WATER-SOLUBLE DYES BY PEANUT HULLS.
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In this study, removal of water-soluble dyes from aqueous solution by peanut hull as adsorbent was investigated. Breeding of peanut hull were KAC431 and KAC1. Water-soluble dyes in this study are direct yellow, direct red, reactive blue and reactive yellow dyes. The suspendion was stirred for 25 hours at 30°C and 1 atm. Parameters such as initial concentration of dye solution of 10, 30, and 50 milligram per liter, pH of initial dye solution of 5, 7, and 9, and particle size of adsorbent of 0.150-0.180, 0.180-0.210, and 0.210-0.300 millimeter are studied.

The results show that peanut hull as adsorbent can be used to remove dye from aqueous solution. Direct yellow dye can be effectively adsorbed on both breeding of peanut hull when the initial concentration of dye solution is 50 milligram per liter, particle size of adsorbent is in the range of 0.150-0.180 millimeter, and initial pH of dye solution is 5. Adsorption ability of each type of dyes slightly decreases with increasing initial concentration of dye solutions. Adsorption ability of dye depends on components of dye in dye solution.

Department….Chemical Engineering…Student's signature…Ph. Sukanya…
Field of study...Chemical Engineering..Advisor's signature……………..
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CHAPTER I
INTRODUCTION

1.1 State of the problem

The textile industry plays an important role in Thailand. It is continuously growing both in its number of factories and production capacity. Although the textile industry makes great benefit, it consumes large quality of water and consequently produces large amounts of wastewater, which containing various pollutant. Nature of textile wastewater has already been reviewed in terms of process chemicals used and in terms classical parameters (BOD, COD, TSS, and TS) including the contents of nitrogen, phosphorus, heavy metal organic matter, and dye. The removal of dye from wastewater is one of the main problems of the textile industry because the textile industry is aware of the consumer's desire for appealing colors. The appeal of color is universal; it repeatedly serves as a common language. Consumers are usually more concerned with color than with color than with any other characteristic of a textile product.

Dyeing is fundamental operation during textile fiber processing. This operation causes the production of more or less colored wastewater. Dyes do not only add pollution problems to the water, but they are also difficult to remove because many of them are biologically non-degradable. Color removal from such effluent is a major environmental problem. Primary and secondary treatments are not enough to efficiently removal all contaminants so tertiary treatment is needed to remove color.

Dyes have been increasingly used in the textile and other industries such as plastic, rubber, paper etc. because of it is inexpensive cost of synthesis, stability and variety of color compared with natural dyes. Today there are more than 10,000 dyes available commercially. The amount of dyes discharged in the world for the textile industry is about 146,000 tones per year. Thailand does not have certain limits for quantities of color in the effluent, but have only announced that the color of effluent must not be undesirable. However, dyes impart only small fractions of the total organic load in wastewater; their high degree of color is easily recognizable and damages the aesthetic nature of the environment. Unless properly treated, the dyestuffs present in wastewater can significantly affect photosynthesis activity due to reduction of light penetration and may also be toxic to certain forms of aquatic life due to the presence of substitute metals and chlorine. Recent research indicated that some dyes are human carcinogens.

In industries, the methods employed for treating dye wastewaters include oxidation, membrane process, fitration with coagulation, ozonation, and activated carbon sorption. But these technologies do not show significant effectiveness or economic advantage. Among several removal technologies, adsorption has great importance due to the ease of operation and comparable low cost of application. The adsorption process provides an attractive alternative treatment, especially if the adsorbent is inexpensive and readily available. The recovery of dyes and easy operational procedures made adsorption technique is being widely used for wastewater treatment.

Activated carbon is the most popular and widely used dye adsorbent but there are certain problems with its use. It is expensive and the higher the quality the greater the cost. Furthermore, regeneration using solutions produces a small additional effluent, while regeneration by refractory technique results in a 10-15% loss of adsorbent and its uptake capacity. Therefore, there is a growing interest in using low cost, renewable, locally available materials for the removal of dye colors. Some agricultural byproducts have been investigated for this purpose.

There problems lead many researchers to find more effective and cheaper substitutes such as coal, peat, wood, fired clay, fly ash, silica gel, bentonite clay, pith, chitin, and chitosan, maize cob, coconut shells, rice husk, and peanut hull. Of these alternatives, peanut hull appears to be more attractive since peanut hull is an abundant and low cost agricultural waste residue and is easily available in large quantity in Thailand.

Peanut hull has many useful features such as hydrophilicity and biodegradability property. Only few researchers studied the utilization of peanut hull as biosorbent for removal of dye from wastewater. Hence, the objectives of this experiment are to study effectiveness of peanut hull in the removal of water-soluble dyes. This research studies the effects of contact time, pH of solution, initial dye concentration, particle size range of peanut hull powder and breed of peanut that affect the adsorbents in removal dyes, and also studies multicomponent those effects of several dyes in aqueous solution because as most industrial wastewater contains more than one pollutant. This is essential for accurate design of adsorption systems as the effect of multicomponent interactions in the process effluent may cause deterioration in the adsorption capacity of adsorbent for dyestuffs.

In this study, two types of water-soluble dyes are direct and reactive dyes are dissolved in demineralized water and used as the initial solution. The experiments are conducted in agitated-batch system at atmospheric pressure and at operating temperatures of 30°C. After adsorption, liquid and spent adsorbent is separated by centrifuge. These liquid samples are measured by UV/VIS spectro-photometer.

Utilization of peanut hull as biosorbent for removal of are the objective of this research, the results of study were to investigate the possibility of peanut hull as a biosorbent for removal of direct and reactive dyes from wastewater and used to develop the more efficiency of adsorption process in removal dye from aqueous solutions.

Multicomponent experiments are conducted to study the effects of component of dye solution on adsorption from the adsorbent.

CHAPTER II
LITERATURE REVIEWS

2.1 Textile Industry

The textile industry is one of the largest in the world because it involves more people and more money than any other industry. Every person comes in contact with various textile products each day. It is also one of the oldest. The textile industry includes the natural and man-made fiber producers, spinners, weavers, knitters, throwsters, yarn converters, tufters, fiberweb producers and finishers, machinery makers, and many others.

In general, the structure of textile industry can be divided into three main sub-industries, which consists of upstream industry, midstream industry, and downstream industry. Upstream industry is the first part of textile industry involving the process of manufacturing natural fiber and man-made fiber. Midstream industry consists of many complicated activities that concern with the process of spinning, weaving, knitting, dyeing and printing. Garment industry is in downstream industry. Figure 2.1 shows the structure of Thai textile industry. Basically, the textile products from any previous industry will become the raw material in the next industry.

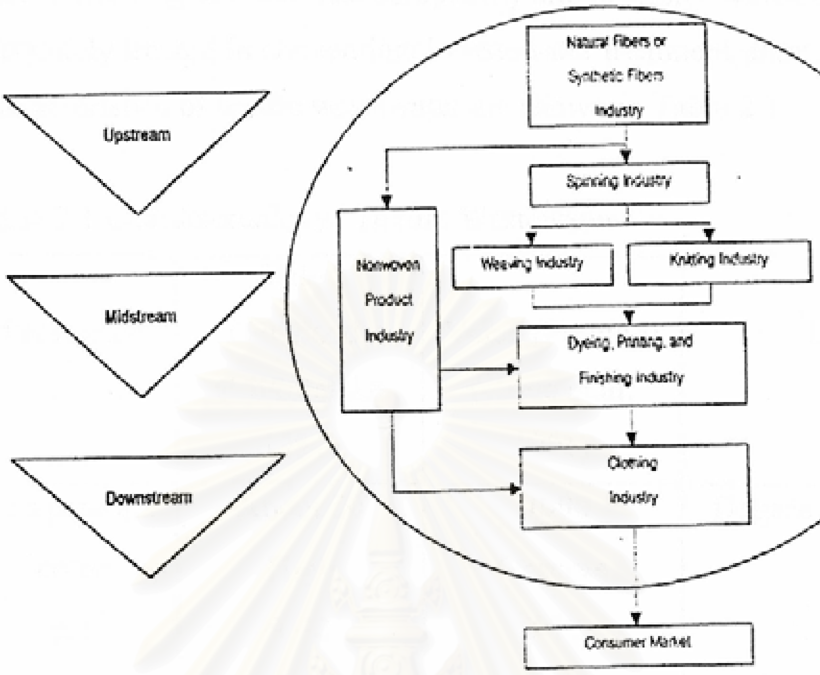

Figure 2.1 Overall Structure of Thai Textile Industry (Udomkitdecha 2000)

2.1.1 Sources and Characteristics of Textile Wastewater (langphasuk 1997)

Textile industry is involved in the manufacture of fabric from both natural and man-made fibers. There are various types of manufacturing processes depending on the raw materials and textile products. Textile mill operations consist of slashing, desizing, scouring, bleaching, mercerizing, dyeing, printing and finishing. Except of slashing and finishing step, water is a major constituent of desizing through printing step. Therefore, a large amount of wastewater is generated from these operations.

The main sources of wastewater generated the textile wet-processing industry originate from washing (scouring) and bleaching of natural fibers and from dyeing and finishing steps. Given the great variety of fibers, dyes, process aids and finishing products in use, these processes generate wastewater of great chemical complexity and diversity which are not adequately treated in conventional wastewater treatment plant. Characteristics of textile wastewater are shown in Table 2.1

Table 2.1 Characteristics of Textile Wastewater

Parameter	Value (Thailand) (Milintalake 1994)	Value (Foreign) (Gaeta et.al. 1991)	Unit
Temperature	About 50	10-90	Degree of Celsius
color	High	Observe	-
pH	9-12	2-12	-
COD	500-1200	80-400	milligram/liter
BOD	100-1000	50-2000	milligram/liter
TSS	High	20-500	milligram/liter

2.2 Colorants

Desired color of textile is generally achieved by incorporation of colored compounds referred to as dyes and pigments into fiber. The term colorant is frequently used to encompass both types of coloring materials. Dyes and pigments are both commonly supplied by the manufactures as colored powders. However, they are distinctly different in their properties and especially in the way they are used and they are distinguished on the basis of their solubility characteristics: essentially, dyes are soluble, pigments are insoluble.

Dyes are almost invariably applied to textile materials from an aqueous medium, so that they are generally required to dissolve in water. Examples of water-soluble dye are acid, basic, direct, and reactive dye.

2.2.1 Color of Dyes

Color is a visual sensation. It results from the reflectance of certain visible light rays that strike the retina of the eye and stimulate cells in the nerves of the eye. The nerves send a message to the brain, which in turn produces the sensation of a specific hue. When all the visible light rays are reflected, an object appears white; if none of the rays is reflected, it appears black. When one or more rays are reflected, the viewer senses the color produced by the specific reflected ray or combination of rays. Physiological sensation of color arises when an object does not reflect all the incident white light falling on it. Some of the light energy is absorbed and the remainder is reflected and perceived as color, the perceived color of the object is determined by the wavelength(s) of the absorbed light. The extent of absorption at a given wavelength is known as the absorbance. Light of the remaining wavelengths is transmitted, perceived by the eye and interpreted by the brain as color. The principle is illustrated in Table 2.2, which summarizes the hues produced by the selective absorption of particular wavelength.

Table 2.2 Relationship between wavelength of absorbed light and hue (Ingamells 1993)

Absorbed wavelength (nm)	Hue of absorbed light	Perceived hue
400-440	Violet	Greenish-yellow
440-480	Blue	Yellow
480-510	Blue-green	Orange
510-540	Green	Red
540-570	Yellow-green	Purple
570-580	Yellow	Blue
580-610	Orange	Greenish-blue
610-700	Red	Blue-green

Dye molecule can consider to be structured from two components, the dye chromophore and dye functional group (auxochrome).

Chromophore is an unsaturated functional group in organic compound which can cause absorption in ultraviolet-vistible range due to n →¶* and/or ¶→ ¶* transitions. Each chromophore has its adsorption maxima affected by solvent and structural detail of the molecule containing the chromophore such as the conjugation in molecule (Skoog 1992).

There are seven groups of chromophore in dye as follow:

- nitroso group: -NO or =N-OH
- nitro group: -NO_2 or =NO.OH
- azo group: -N=N-
- ethylene group: >C=C<
- carbonyl group: >C=O
- carbonyl-nitrogen group: >C=NH or >CH=NH
- sulfur group: >C=S or –C-S-S-C

In addition, other groups that have no influence on the color can be added to change the insoluble molecule to a water-soluble dye. Thus compounds may be synthesized to produce all colors of the visible spectrum by suitable choice of auxochrome such as -SO_3-Na+, -NH_2HCl, -OH and –NH_2.

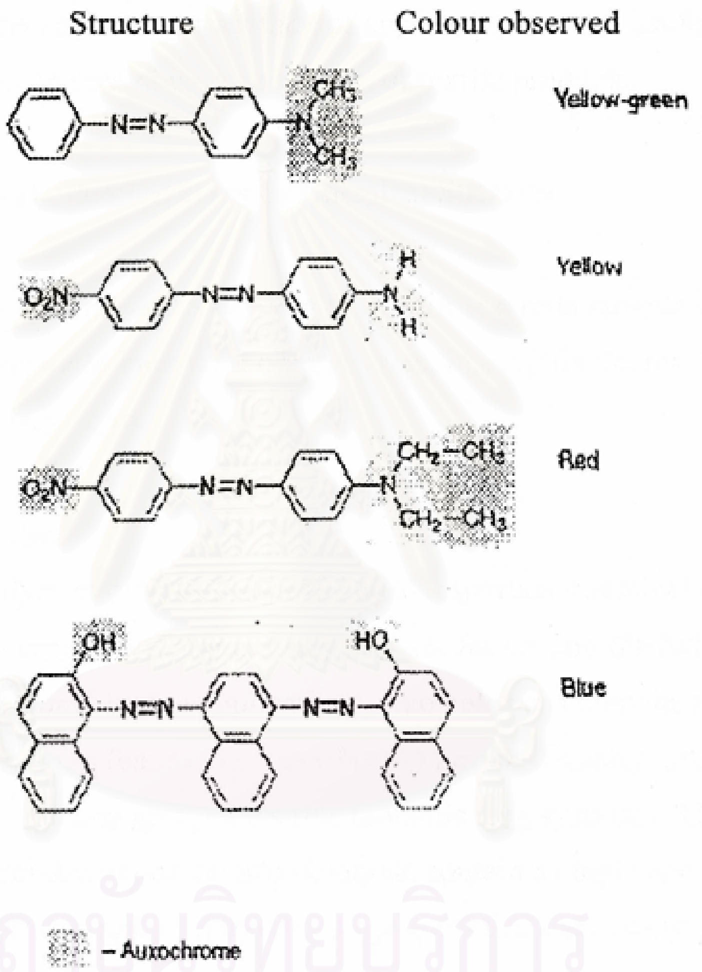

Figure 2.2 Some auxochrome groups and color observed from dye structures (Ingamells 1993)

The color of the molecule may be modified and increased in intensity of color by introducing a variety of smaller groups into molecule, example of which are shown in Figure 2.2, such group is called auxochrome.

2.2.2 Classification of Dyes

Dyes may be classified according to chemical structure or according to their method of application. Classification of dye according to chemical structure is most useful to dye chemist who may be interested dye synthesis and relationship between chemical structure and properties of dye. Classification according to method of application is most useful to technologist concerned with coloration of textile products.

2.2.2.1 Classification of Dyes by Chemical Structure

Dyes are grouped according to certain common chemical structural features. The most important organic dyes, in roughly decreasing order of importance belong to:

1) Azo dyes

Azo dyes constitute by far the most important chemical class of commercial organic colorant. They account for around 60-70% of the dyes used in traditional textile applications. Azo colorants contain as their common structure feature the azo (-N=N-) group. Usually, although not exclusively, the azo group links two aromatic ring systems. The majority of the commercially important azo colorants contain a single azo group and are therefore referred to as monoazo dyes, but there are many which contain two (diazo), three(triazo) or more such groups. See in Figure 2.3

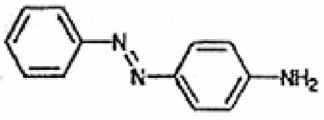

Figure 2.3 Monoazo dyes

2) Carbonyl dyes

This chemical class of colorants which is second in importance to azo dyes is characterized by the presence of a carbonyl (C=O) group, which may be regarded as the essential chromoporic unit.

The vast majority of carbonyl dyes contain two or more carbonyl groups, as illustrated in Figure 2.4, are linked to one another through a conjugated system, frequently an aromatic ring system.

Figure 2.4 Carbonyl dyes

Carbonyl dyes are capable of providing a wide range of color, essentially convering the entire visible spectrum and giving long wavelength absorption bands with relatively short conjugated system. This feature applied especially to anthraquinone and indigo derivatives, which are thus of particular are thus of particular importance in the blue shade area.

The characteristic structure features of the most important types of carbonyl colorants are review in the following:

-Anthraquinones dyes

A common arrangement of the carbonyl group in colored molecules gives rise to a group of compounds known as quinines. These may be dedined as cyclohexadienediones. The simplest quinines are o- and p-benzoquinones, Figures 2.5

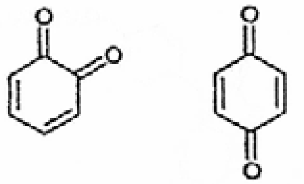

Figure 2.5 Anthraquinones dyes

-Fluorescent carbonyl dyes

One of the most important groups of fluorescent brightening agent dyes is based on the coumarin ring system, as shown in Figure 2.6

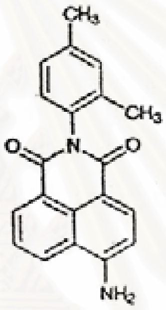

Figure 2.6 Fluorescent carbonyl dyes

-Benzodifurannones dyes

They were launched commercially in the late 1980s by ICI as disperse dyes for polyester application. Figure 2.7 shows a representative example of these dyes. They are capable of providing a range of color but the most important are red.

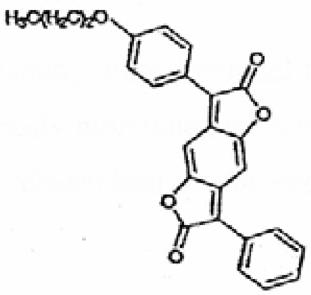

Figure 2.7 Benzodifurannones dye

-Indigoid dyes

Indigo (Figure 2.8), the parent system of this group of colorants, is one of the oldest known natural dyes.

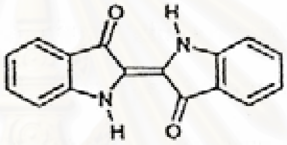

Figure 2.8 Indigoid dyes

3) Phthalocyanines dyes

Phthalocyanines are aromatic molecules. They have emerged as one of the most extensive studied classes of compounds, because if their intense, bright color, their high stability and their unique molecular structure Figure 2.9 is almost certainly the first preparation of M-phthalocyanines. When M is a metal that often be Cu.

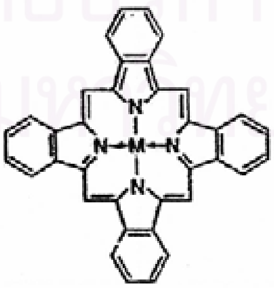

Figure 2.9 Phthalocyanines dyes

In addition, there are many other chemical types of dyes that do not full into the category previously mentioned such as polymethines, arycarbonium ion colorants, dioxazines, sulfur dyes, nitro dyes and etc.

2.2.2.2 Classification of Dyes by Methods of Application to the Fiber Types

Classification of Dyes by Methods of Application to the Fiber Types shown in Table 2.3 that lists ten of the most frequently used dye classes classified in terms of their method of application to fiber types. The table also lists the attachment mechanisms, characteristics, typical method of application and chemical used. The dye characteristics, which are important in selecting a color removal technology, are also provided.

Table 2.3 Dyes classification by methods of application to the fiber types (Buckley).

Dye class	Characteristics	Typical associated fiber	Dye-fiber attachment mechanism	Typical method of application
Acid	Anionic highly water soluble poor wet fastness	Nylon, wool	Ionic bond	Fiber placed in acidified aqueous media pH 3-5 Fiber assumes a positive charge dye Added and temperature to 50-110°C

Dye class	Characteristicss	Typical associated fiber	Dye-fiber attachment mechanism	Typical method of application
Direct	Anionic highly water soluble poor wet fastness	Cotton, Viscose	Ionic bond	Fiber placed in dyebath slightly alkaline Add dye electrolyte (NaCl, Na2SO4) to displace dye to fiber temperature to 98 °C
Basic or cationic	Cationic highly water soluble	Acrylics	Ionic bond	Fiber placed in acidified aqueous dyebath at pH 4 to 6 dye added temperature increase from 100 to 105 °C dye diffuses into fiber
Dispersed	colloidal dispersion very low water solubility good wet fastness	Polyester, nylon, acrylic, cellulose acetate	Colloidal impregnation, adsorption	Fiber placed in acidified dyebath pH 4.5 Dye added temperature to 130 °C cause dye migration into fiber
Vat	As per sulphur dye	Cotton, Viscose	Dye precipitated in-situ in fiber	As with sulphur dye

Dye class	Characteristics	Typical associated fiber	Dye-fiber attachment mechanism	Typical method of application
Reactive	Anionic highly water soluble good wet fastness	Cotton, Viscose, wool	Covalent bonds	Fiber placed in aqueous dye solution add salt to displace dye to fiber add alkali to cause reaction between dye and fiber
Sulphur	Colloidal after reaction in fiber in soluble wet fast	Cotton, Viscose	Dye precipitated in-situ in fiber	Fiber placed in dyebath dye dissolves in alkaline sodium sulphur Dye displaced to fiber with electrolyte dye precipitated in-situ with air or peroxide
Azoic	As per sulphur dye	Cotton, Viscose	Dye precipitated in-situ in fiber	Fiber placed in dyebath coupler applied to fiber dye chrome added boiled to precipitate
Mordant or chrom	Anionic water soluble good wet fastness	wool	Fiber-Chrom-dye complex	Fiber placed in acidified dyebath add sodium dichromate Add dye temperature

Dye class	Characteristics	Typical associated fiber	Dye-fiber attachment mechanism	Typical method of application
Metal complex acid dye	Anionic low water solubility good wet fastness	Nylon, Wool	Ionic bond	As with acid dyes pH 5-7

Dye can be classified in several ways: according to hue produced, according to chemical class, and according to the method of application and types of fibers to which they are successfully applied. Direct and reactive dyes were selected in this study.

1. Substantive or Direct dyes

Substantive or Direct dyes comprise the largest and most commercially significant group of dyestuffs. Direct dyes are water soluble; they are applied primarily to cellulose fibers and occasionally to protein fibers and polyamides. Most direct belong to one of two main groups;

1) Azo dyes: these may be monoazo, diazo, triazo, or polyazo as chromophores.
2) Direct dyes derived from benzidine, triphenyl methane, or phthalocyanine. It should be noted that dyes based on benzidine have been removed from the American market, as there is some evidence that they may be carcinogens. However, they may still be available from foreign dye

manufacturers. Auxochromes found in the various types of direct dyes include $–NaO_3S$, $-NH_2$, -OH, and $–OCH_3$.

Direct dyestuffs exhibit relatively good colorfastness to sunlight, and some are considered to have excellent lightfastness. However, the colorfastness to washing may be poor. Direct dyes are another class of dyes, one of the two types of dyes that are mixed in 'all purpose' dyes such as Rit. (The other type in the mixture is an acid dye, which will not stay in any cellulose fiber for long). The colors of direct dyes are duller than those provided by fiber reactive dyes and the washfastness are poor - expect anything dyed with them to 'bleed' forever. The one advantage is that direct dyes may be more lightfast, that is, resistant to fading in the light, than fiber reactive dyes. The "direct dye" classification in the Colour Index system refers to various planar, highly conjugated molecular structures that also contain one or more anionic sulfonate group. It is because of these sulfonate groups that the molecules are soluble in water. Though most direct dyes still can be obtained in powder form, it is increasingly popular to receive them as liquid concentrates. The advantage of concentrates is that they are easy to handle and meter.

The direct dyes are almost always azo dyes, with some similarities to acid dyes. They also have sulphonate functionality, but in this case, it is only to improve solubility, as the negative charges on dye and fibre will repel each other. Their flat shape and their length enable them to lie alongside cellulose fires and maximize the Van-der-Waal, dipole and hydrogen bonds. Below is a diagram of a typical direct dye. Note that the sulphonate groups are spread evenly along the molecule on the opposite side to the hydrogen bonding –OH groups, to minimize any repulsive effects.

2. Reactive Dyes

Reactive dyes typically have a relatively low fixation degree on the textile substrate. They are used for cotton dyeing, which makes up about half of fiber consumption in the world.

Reactive dyes are combined with the fiber molecule through a complex system utilizing a reactive molecule on both the dye and the fiber. The connection may be diagramed as follows:

Fiber molecule ---- reactive coupling agent ---- dye

The three major types of coupling agents include mono-, di-, or trichlorotriazinyl compounds, pyrimidine derivatves, and vinyl sulfone. The major chromophore systems include the azo group, the anthraquinone structure, and the phthalocyanine or tetrabenzopor-phyrazine nucleus.

One of major factors determining the release of a dye to the environment is its degree of fixation on the substrate. Table 2.4 represents the summary of the data available.

The problem of color effluent has become identified particularly with the dyeing of cellulose fibers (notably cotton, which accounts for almost 50% of the total fiber consumed by the textile industry worldwide), and in particular with the use of reactive dyes. It can be seen from Table 2.4 that as much as 50% of reactive dye used must be lost to the effluent.

Table 2.4 Estimate degree of fixation for different dye/fiber combinations (Cooper 1995)

Dye class	Fiber	Degree of fixation (%)	Loss to effluent (%)
Acid	Polyamide	80-95	5-20
Basic	Acrylic	95-100	0-5
Direct	Cellulose	70-95	5-30
Disperse	Polyester	90-100	0-10
Metal-complex	Wool	90-98	2-10
Reactive	Cellulose	50-90	10-50
Sulphur	Cellulose	60-90	10-40
Vat	Cellulose	80-95	5-20

2.3 Wastewater Treatment (Black 1977)

Most conventional sewage treatment plants are designed to merely remove or reduce the organic materials and thus decrease the BOD of the wastewater. There are three basic types of treatment that may be used in treating sewage: primary, secondary, and tertiary. These terms refer to the quality of effluent released rather than the actual treatment process employed. The processes employed in the various types of tertiary treatment may vary widely, depending on the type of tertiary plant constructed.

Primary treatment includes process such as screening, neutralization, equalization and gravity sedimentation. Purpose of primary treatment is to remove suspended matter, including oil and grease and to achieve uniform flows and concentrations, as the suspended matter is removed, BOD and COD is also reduced.

Secondary treatment involves the use of biological methods (trickling filters and/or activated sludge) in addition to the usual methods employed in primary treatment. These biological methods approximate the natural purification processes that wastewater would be subjected to in a natural waterway in a shorter time period and reduced amount of physical space.

In tertiary treatment the sewage is subjected to one or more additional processes, either prior to or after receiving conventional primary and secondary treatment. This additional specific for a given area, such as the removal of certain industrial chemicals, dissolved metals, phosphates or nitrates. Tertiary treatment very depending upon the actual wastewater generated or anticipated to be generated in particular area. The treatment of wastewater containing industrial waste, trace metal and so on, will be considered under industrial wastewater treatment.

Wastewater from the textile industry is a serious pollution problem because it is high in both color and organic content. A combination of several processes is generally necessary to achieve adequate removal of all contaminants.

Common methods employed in the tertiary treatment are chemical coagulation and filtration, carbon adsorption, chemical oxidation, ammonia stripping and advanced biological treatment.
Table 2.5 describes treatment processes and shows the range of removal efficiencies of contaminants.

Table 2.5 Textile wastewater treatment.

Treatment Process Unit	Range of Removal Efficiency				
	BOD	COD	TSS	Grease	Color
Primary Treatment					
- Screening	0-5	-	5-20	-	-
- Equalization	0-20	-	-	-	-
- Neutralization	-	-	-	-	-
- Chemical Coagulation (remove varies with chemicals and dosage used)	40-70	40-70	30-90	90-97	0-70
- Flotation	30-50	20-40	50-60	90-96	-
Secondary Treatment					
- Chemical Activated Sludge and Clarification	70-95+	50-70	85-95	0-15	20%dye remova for biological treatment unite
- Extended Aeration and Clarification	70-94+	50-70	85-95	0-15	
- Aerobic lagoon and Clarification	60-90	45-60	85-95	0-10	-
- Aerobic Lagoon	50-80	35-60	50-80	0-10	-
- Packed Tower	40-70	20-40	-	-	-
- Roughing Filter	40-60	20-30	-	-	-
Tertiary Treatment					
- Chemical Coagulation	40-70	40-70	30-90	90-97	0-70
- Mixed Medoa Filtration	25-40	25-40	60	-	-
- Carbon Adsorption	25-40	25-40	25-40	-	80-90
- Chlorination	0-5	0-5	-	0-5	0-5
- Ozonation	-	30-40	50-70	-	70-80

Treatment Process Unit	Range of Removal Efficiency				
	BOD_5	COD	TSS	Grease	Color
Advanced Treatment					
- Spray Irrigation	90-95	80-90	95-98	-	-
- Evaporation	96-99	95-98	99	-	-
- Reverse Osmosis	95-99	90-95	95-98	-	-

Source: UNEP (1994)

2.3.1 Color Removal

Conventional water processes such as oxidation, coagulation and filtration are effective in removing color. Adsorption and ion exchange can also be employed. In practice, color is usually removed to acceptable levels by normal water treatment operations. Each of these color removal processes is briefly discussed as follows. (Qasim 2000)

-Oxidation

Such oxidizing chemicals as potassium permanganate, chlorine, chlorine compounds and ozone can remove color. Color removal is most effective when followed by coagulation and other conventional treatment processes. Potassium permanganate can oxidize color causing compounds but is normally used for disinfection or for taste and odor control.

- Ozone

Ozone is a more powerful that chlorine, and removes color better than chlorine. It has the added benefit that it does not depress the pH level as much-nor does it produce trihalomethanes (THMs). The cost of ozone is usually not justified merely for color removal, but ozone is frequently employed for taste and odor removal.

-Coagulation

Conventional coagulation, as part of the overall water treatment process, effectively removes some color in addition to turbidity; however. The mechanism of color removal appears to be different from that for turbidity removal. With enhanced coagulation, and may adsorb color causing compounds on the growing floc. The quality of raw water, charge difference, and degree of ionization of the suspended and dissolved solids appear to account for the distinct responses during coagulation. Because of the varied nature and origins of color, jar tests and pilot testing can help to identify the best color removal strategy.

- Filtration

Filters remove suspended solids that cause turbidity and color. In a conventional treatment process of coagulation and flocculation followed by sedimentation, the solids removed in the filter consist of the lightest portion of floc that did not settle in the sedimentation basin. Thus, the filters remove most of the apparent color due to turbidity and some of the true color captured during the prior treatment processes. Filtered water is low in turbidity; most color remaining in the water is attributed to the dissolved solids and is measured as true color.

- Ion Exchange

Ion Exchange processes remove ionic species by employing resins and electrical charge methods. The expense of ion exchange, however, inhibits its widespread application to remove color or even taste and odor.

- Adsorption

Activated carbon is the most widely used as adsorbent for dye removal. Since it is high cost that lead many researchers to search for more effective and cheaper materials. Many adsorbents have been investigated for removal of water-soluble dye in synthesis wastewater and from textile effluent. Examples of these adsorbents are described as follow.

1) Activated carbon

Activated carbon is the original adsorbent used to adsorb dye molecules and removal color. The activated carbon can be granulated (GAC) or powdered (PAC). GAC is normally used in columns, through which effluent is passed. PAC is usually dosed as slurry into effluent stream for subsequent removal and disposal. Surface area of it is about 600-1,000 m^2/g.

Rajeshwarisivaraj et.al. (2001) investigated the activated carbon from Cassava peel as an adsorbent in the removal of dyes and metal ions from aqueous solution. Actevated carbons prepared from waste cassava peel employing physical and chemical method that the material impregnated with H_3PO_4. The treatment was carried out using a batch process. 500 mg of the adsorbent was agitated at room temperature (30°C) with 50 ml of the adsorbate for the predetermined time at 160 rpm and range of biosorbent was 0.150-0.250 mm. The supernatant was separated by centrifugation at 10,000 rpm. This experiment was found that the activated carbon that prepare by chemical method removed direct brown more efficient than that prepare by physical activation at 700 °C.

Fawzi et. al. (2003) studied the activated date pits as potential adsorbents for dye containing waters. Batch adsorption experiments were undertaken by contacting a known amount of the adsorbent with 10 ml of methylene blue solution. The initial dye concentration was in the range of 20-400 mg/l. The samples were allowed to reach equilibrium within 4 hr. They found that dye removal increased with an increase in solution pH. The factors affecting the rate of dye removal with four important classes of dyestuffs, from aqueous solutions. The factor affecting the rate of dye removal with four important dyes carbon was an excellent adsorbent and tends observed for the different variables were similar. The maximum capacity of adsorption is 80.29 mg/g. The rate of adsorption increased with initial dye concentration, and mass of adsorbent agitation but decreased when particle size of adsorbent increase.

P.K. Malik (2004) studies dye removal from waste water using activated carbon developed from Mahogany sawdust. atch studies were carried out at the temperature of 30°C. Isothermal studies were conducted with different doses of adsorbent 0.01-0.3 g and 100 ml sample and the pH of this studied to different values 2.0-9.0. The experiment data were analysed by the Langmuir and Freundlich models of adsorption. Equilibrium data fitted well with the Langmuir model. This adsorbent was employed for the removal of direct dyes from spent textile dyeing wastewater. The experiment data were found that the most ideal pH for adsorption of direct dye onto sawdust carbon was found to be 3 and below. The maximum capacity found to be more than 300 mg dye per gram of the adsorbent.

2) Clays

Dyes can be adsorbed on to several low-cost natural material and special materials based on inorganic particulate synthetic clay have been developed for the adsorption of dye waste. Surface area of these materials is about 50-200 m^2/g.

Osathanugrah (1994) investigated the adsorption property of clay-minerals, bentonite and kaolinite clays, and the mixture of clay-minerals and chemical coagulants, on removal of dyestuffs; disperse, direct, and reactive dye, from 6 dyes prepared solution and 5 samples of the textile effluent. It was found that bentonite clay is the best adsorbent and alum is more effective coagualant than the others when they reach the optimum pH. But pH has no effect to bentonite adsorption.

3) Biosorbent

Biosorbents are naturally occurring polymers, which are biodegradable. Adsorb species within their structure act as ion-exchanges. Surface area of them are about 30-200 m^2/g. Most of them obtain from plans and waste of agriculture products such as maize cob, sawdust, fly ash and etc.

Yuh-Shan Ho et. al. (2005) studied the removal of basic dye from aqueous solution using tree fern as a biosorbent. A batch sorption system variables studied includes sorbent particle size and initial concentration of dye solution. In all sets of experiments, 0.25 g of tree fern was thoroughly mixed into 250 ml of dye solution with initial pH value of 5. Batch sorption experiments were conducted at a constant temperature on a rotary shaker at 100 rpm. After shaking the flasks for 24 hr and separated by filtration through a membrane filter 0.25 µm, the results revealed that the maximum sorption capacity was 0.90 mmol/g. Maximum saturated monolayer sorption capacity of tree fern for Basic Red13 was 408 mg/g. Various thermodynamic parameters such as $\Delta G°$, $\Delta H°$, and $\Delta S°$ were calculated indicating that this system was a spontaneous and endothermic process.

Gulbahar Akkaya et. al. (2007) studied kinetics of the adsorption of reactive dyes by chitin. It was studied at the initial concentration of 300 ppm (pH = 6.94 for reactive yellow2 and pH = 7.12 for reactive blue5) and

600 ppm (pH = 6.98 for reactive yellow2 and pH = 7.18 for reactive blue5) of the dyestuffs. Samples of 0.2 g of chitin with the samples of 50 ml of each dyestuff. In this experiment investigated the effect of initial concentration, shaking rate, temperature and pH on the adsorption of reactive yellow2 and reactive black5 by chitin. They found chitin adsorbed less both dyes than chitosan. The adsorption of reactive yellow2 by chitin from aqueous solution must be studied at low pH but the adsorption of reactive blue5 from aqueous solution must be studied at high pH.

Phumkacha (1996) studied of color removal if textile wastewaters by using three different kinds of process as follow: 1) coagulation by alum 2) batch adsorption by adsorbents. Granular activated carbon, fly ash and 3) color removal by using both alum and adsorbent. The experiment consisted of 2 parts. First, the experiment was done four synthetic wastewater; acid dyes, direct dyes, reactive dyes, and basic dyes. Acid dyes, direct dyes, and reactive dyes have negative charge except basic dyes which have positive charge. The efficiency of color removal by alum coagulation was more than 80% for all types of dyes except basic dyes. Color removal by granular activate carbon was efficiency for positive dyes. Fly ash efficiency removes in all types of dyes. The efficiency of alum granular activated carbon and alum-fly ash combination were more then that the alum only. The second experiment for real textile wastewater; the color removal efficiency by alum were in the range of 67.7-72.8%, the COD reduction in he range of 56.0-65.1%, the cost of alum coagulation in the range of 5.0-7.5 bahts/m^3.

Semrat (2000) investigated the color removal efficiency for textile mill wastewater by activated carbon and agricultural waste as sorbent, coconut shell carbon and bagasse carbon. In order to increase adsorption efficiency of agricultural waste carbon, solution was used. The results reveal that coconut shell carbon is unable to use as adsorbent by considering from adsorption isotherm test. Activated carbon and bagasse carbon are feasible because of its longer breakthrough time. Breakthrough time of activated carbon, activated carbon mixed bagasse carbon, and bagasse carbon are 2-12, 2-9, and 2-6 respectively. COD reduction ranging from 84-99% and 54-58%, 50-98% and 44-75%, and 51-59% and 15-73%, respectively.

2.4 Adsorption (Kenneth 1992, Alley 2000)

Adsorption is mass transfer process that can generally be defined as the accumulation of materials at the interface between two phases. These phases can be any of the following combination: liquid - liquid, liquid-solid, gas-liquid and gas-solid. In the adsorption process, molecules, as shown in Figure 2.10, or atom or ions in a gas or liquid diffuse to the surface of a solid, where they bond with the solid surface or are held there by weak intermolecular forces. The adsorbed solutes are referred to adsorbate, whereas the solid material is the adsorbent.

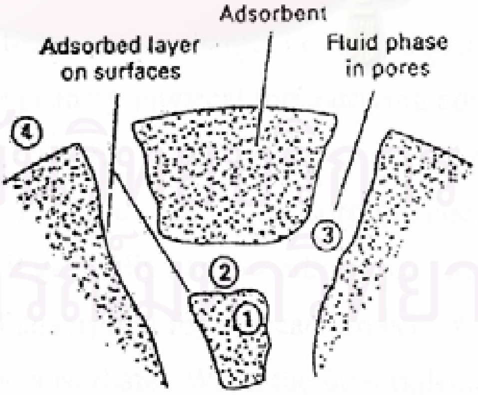

Figure 2.10 Adsorption operations with solid-particle adsorbent

2.4.1 Adsorption Theory

Thermodynamic system of the adsorption in which the various compounds are striving for equilibrium. The primary force driving the interaction between the adsorbate and the adsorbent is the electrostatic attraction and repulsion and repulsion between molecules of the adsorbate and the adsorbent. These driving forces can be either physical or chemical.

2.4.1.1 Physical Adsorption

Physical adsorption is a result of intermolecular forces that interact between the adsorbate and the adsorbent. These physical electrostatic forces include the van der waals force, consisting of weak attraction and repulsion through dipole-dipole interactions and dispersing interactions, and hydrogen bonding. Dipole-dipole interactions are the result of polar compounds orienting themselves so that their charges result in a lower combined free energy. Dispersing interactions are the result of attractive forces between electrons and nuclei of molecular systems. If the molecules come too close to each other, repulsive forces can push the molecules apart. Hydrogen bonding is a special case of dipole-dipole interaction in which the hydrogen atom in molecule has a partial positive charge, attracting another atom or molecules with a partial negative charge. For liquid phase systems, the van der waals force is the primary physical force driving adsorption. Physical adsorption is a readily reversible reaction and includes both mono- and multilayer coverage. Because physical adsorption does not involve the sharing of electrons, it generally has low adsorption energy, and is not site specific. The heat of adsorption for the reaction is on the order of 40 Btu/lb.per mole of the adsorbate. When the intermolecular forces between a chemical molecule in a liquid stream and a solid (the adsorbent) are greater than the forces between the molecules of the liquid stream the chemical is adsorbed onto the adsorbent surface.

2.4.1.2 Chemical Adsorption

Chemical adsorption (Chemisorption), like physical adsorption, is also based upon electrostatic forces. The mechanisms of chemical adsorption are similar to those of physical adsorption, yet are often stronger (approaching the adsorption energies of chemical bonds). The transfer of electrons and the formation of chemical bonds between the adsorbate and the adsorbent produce chemical adsorption. It may be an irreversible reaction and have high adsorption energies. The heat of adsorption is significantly greater than for physical adsorption, ranging from 80 to 400 Btu/lb.mole. It is not unusual for the adsorbate to have chemically changed due to the reaction. Chemical adsorption involves only monolayer coverage, and is a site specific reaction, occurring at specific functional group locations. Functional groups are distinctive arrangements of atoms in organic compounds that give that compound its specific chemical and physical and physical properties.

In discussing the fundamentals of adsorption, it is useful to distinguish between physical adsorption, involved only relatively weak intermolecular forces, and chemical adsorption, which involve essentially the formation of a chemical bond between the adsorbate molecule and the surface of the adsorbent. Table 2.6 was shown some difference between physical adsorption and chemical adsorption.

Table 2.6 Distinction between physical adsorption and chemical adsorption

Physical adsorption	Chemical adsorption
- Low heat of adsorption (<2 or 3 times latent heat of evaporation)	- High heat of adsorption (>2 or 3 times latent heat of evaporation)
- Non specific	- Highly specific
- Monolayer or multilayer	- Monolayer only
- No dissociation of adsorbed species	- May involve dissociation
- Only significant at relatively low Temperatures	- Possible over a wide range of Temperatures
- Rapid, non-activated, reversible	- Activated, may be slow and irreversible
- No electron transfer although Polarization of adsorbate may occur	- Electron transfer leading to bond formation between adsorbate and surface

Adsorption onto solid adsorbent has great environmental significance, since it can effectively remove pollutants from both aqueous streams. Due to the high degree of purification that can be achieved, this process is often used at the end of a treatment sequence.

2.4.2 Mechanism of Adsorption onto the Porous Adsorbent (McKay et. al. 1980)

For the adsorption of a solute onto the porous surface of an adsorbent, these are essentially four stages in the adsorption process, the following steps are required:

(1) transport of dye from the bulk of solution to the exterior surface of the adsorbent;

(2) movement of dye across the interface and adsorption onto external surface sites;

(3) migration of dye molecules with in the pores of the adsorbent, and

(4) interaction of dye molecules with the available sites on the interior surfaces, bounding the pore and capillary spaces of the adsorbent.

2.5 Peanut hull

The peanut or groundnut (Arachis hypogaea) is a species in the legume family Fabaceae native to South America as shown in Table 2.7. It is an annual herbaceous plant growing to 30 to 50 cm tall. The leaves are opposite, pinnate with four leaflets (two opposite pairs; no terminal leaflet), each leaflet 1 to 7 cm long and 1 to 3 cm broad. The flowers are a typical pea flower in shape, 2 to 4 cm across, yellow with reddish veining. After pollination, the fruit develops into a legume 3 to 7 cm long containing 1 to 4 seeds as shown in the Figure 2.11.

Peanuts are also known as earthnuts, goobers, goober peas, pindas, jack nuts, pinders, manila nuts and monkey nuts.

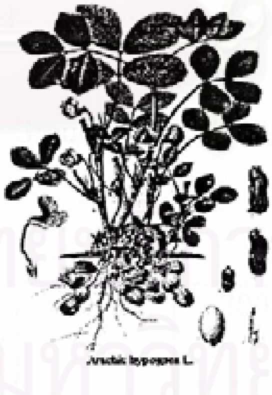

Figure 2.11 Peanut (*Arachis hypogea*)

Table 2.7 Scientific classification of peanut

Scientific classification	Scientific name
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Fabales
Family	Fabaceae
Subfamily	Faboideae
Tribe	Aeschynomeneae
Genus	Arachis
Species	A. hypogaea
Binomial name	Arachis hypogaea

In Thailand, Peanut is easily available in large quantity so peanut hull is an abundant and low cost agricultural waste residue and is easily available in large quantity in Thailand too. Table 2.8 was shown Area, production and yield of peanut in Thailand since 2001 to 2003 and Figure 2.12 also shown the plant area in Thailand.

Table 2.8 Quantity of Peanut or Groundnut in Thailand. (From Wikipedia, the free encyclopedia)

Year	2001	2002	2003
Harvested area (Rai)	423.664	439.57	446.19
Production (Tons)	116.342	121.234	122.392
Yield per rai (kg)	275	276	274

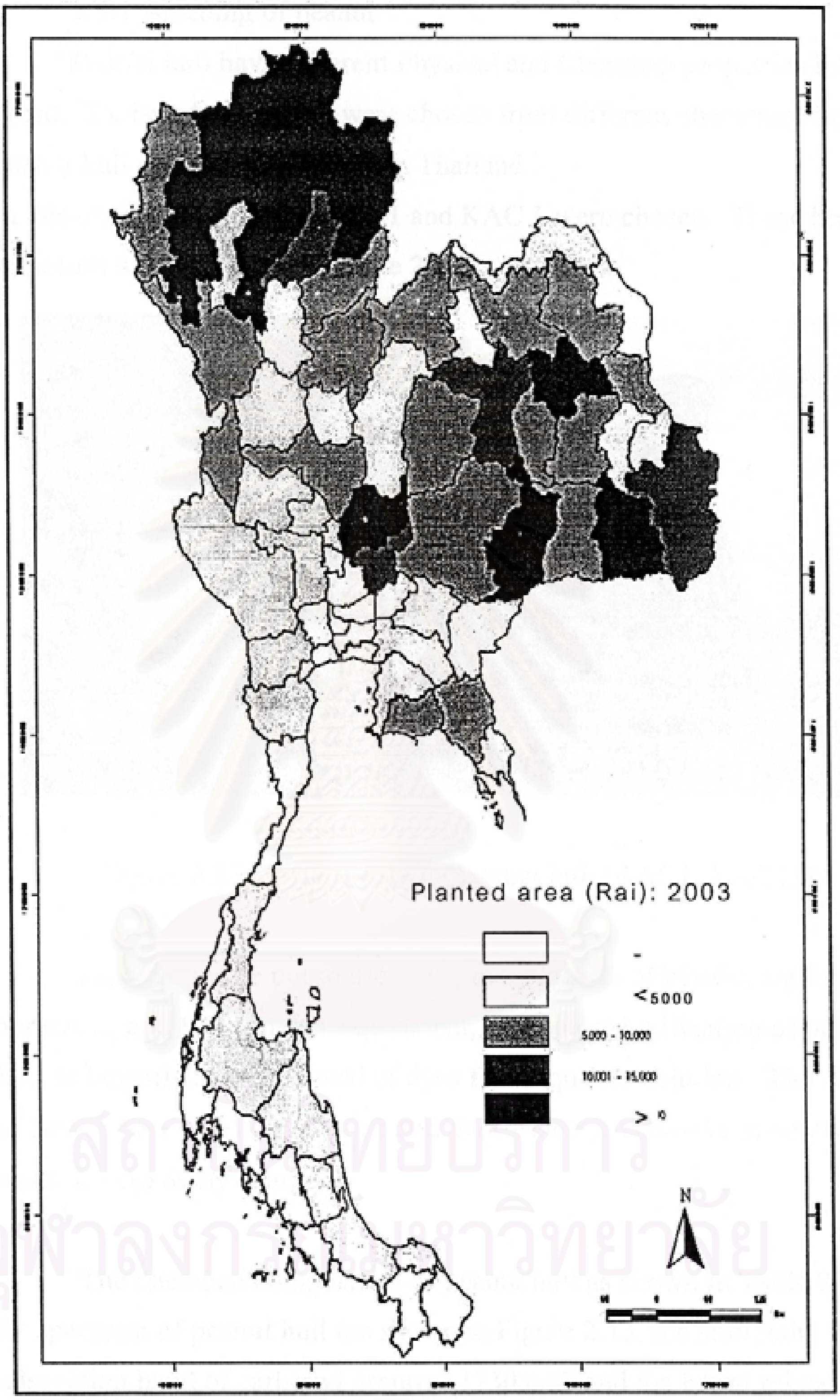

Figure 2.12 the plant area in each province of Thailand (2003).

2.5.1 Breeding of peanut

Peanut hull have different Physical and Chemical properties by their breed. So, breeds of peanut were chosen from different characteristic of peanut hull and easily available in Thailand.

In this experiment, The KAC 431 and KAC 1 were chosen. These breeding of peanut hull as shown in Figure 2.13.

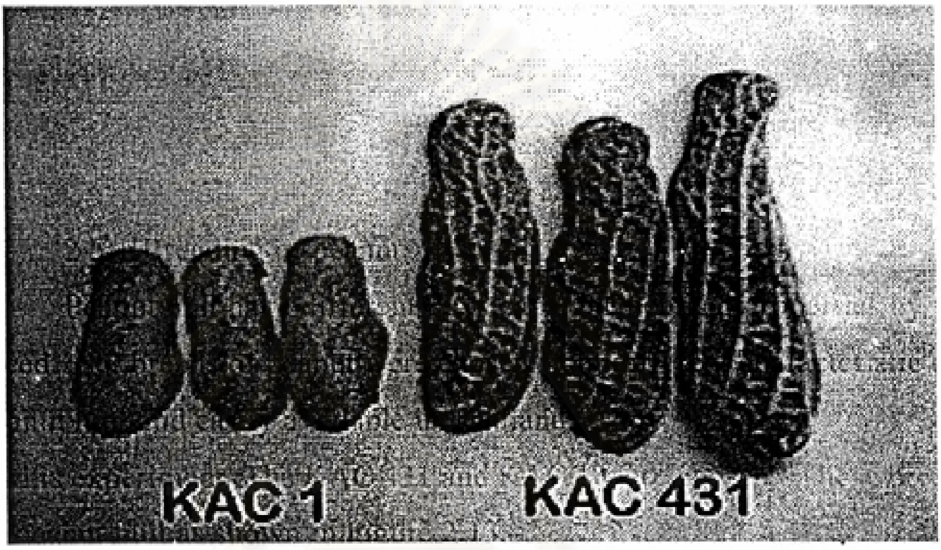

Figure 2.13 Characteristic of peanut hull (KAC1, KAC431)

Peanut hull are put to use in the manufacture of plastic, wallboard, abrasives, and fuel. In this experiment, also studied utilization of peanut hull as biosorbent for removal of dyes from aqueous solution. The structure of peanut hull is cellulose based and the surface of cellulose in contact with water is negatively charged.

The chemical composition of peanut hull as shown in Table 2.8. The IR spectrum of peanut hull are shown in Figure 2.13, the stretching vibration adsorption band of carboxyl group at 1730 cm^{-1} and the broad mixed stretching vibration adsorption band of amino and hydroxyl groups at 3392 cm^{-1}.

Table 2.9 Chemical composition of peanut hull. On dry matter basis (g/100 g dry matter) except for dry matter. (Snedecor and Cochran, 1968)

Dry matter	92.5
Organic matter	94.3
Crude protein	6.4
Ether extract	3.4
Crude fibre	64.3
Nitrogen-free extract	20.2
Ash	5.7
Acid insoluble ash	2.5
Neutral detergent fibre	81.4
Acid detergent fibre	71.2
Acid detergent lignin	28.9
Cellulose	42.3
Hemicellulose	10.2

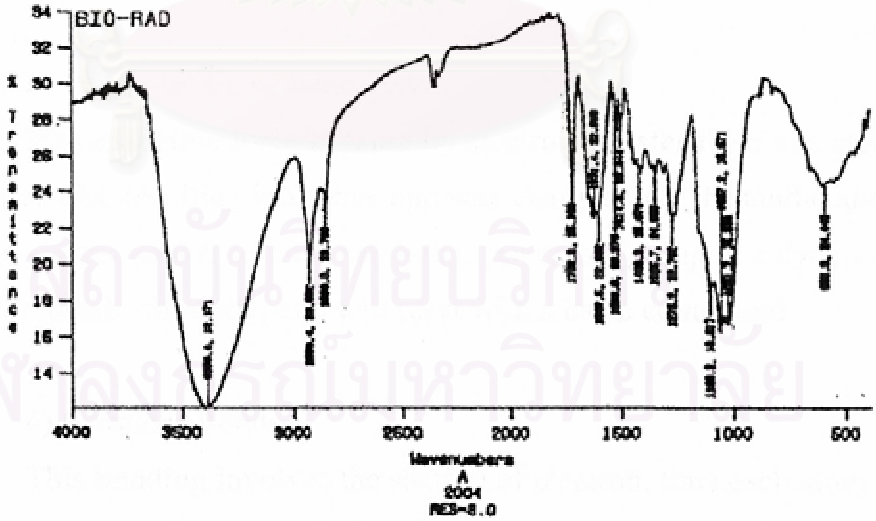

Figure 2.14 The IR spectrum of peanut hull.

2.5.2 The chemical groups in dye molecule.

1) Van der Waals Forces

These forces are weak interaction between the nuclei of constituent atoms of one molecule with the electrons of another. The van der Waals forces increase with increasing of the molecular size. They operate only when dyes and adsorbent molecules are in close proximity to ah other, when hey can become dominant force of attraction.

2) Hydrogen Bonds

The hydrogen atom is the smallest of all the atoms: in organic compounds it normally forms a single covalent bond only. Often, however, a neighboring atom may have a higher affinity for electrons than does the hydrogen atom, causing a drift of the electrons shared by the hydrogen towards the larger atom. This leaves a slight positive charge on the hydrogen atom, which in turn encourages bond formation between it and nearby atom such as nitrogen or oxygen. Such bonds are readily broken and reformed and they are one of the factors involves when substances are dissolved by water.

3) Electorstatic or Ionic Forces

This attractive force is cause by electron transfer from one atom to another. The resulting ions have opposite charges, like the acidic and basic groups react together to form salt links. An acidic group in a dye molecule will dissociate similarly, and will react with a basic compound.

4) Covalent Bonds

This bonding involves the sharing of electron, thus each atom has two electrons in its valence shell. Covalent bonding is stronger than salt link, hydrogen bond and van der Waals force, respectively. The relative strengths of different bonds are given in Table 2.9.

Table 2.10 Comparison of bond strength.

Bond type	Relative strength
Ven der Waals	1.0
Hydrogen	3.0
Salt link	7.0
Covalent	30.0

2.6 Related Literatures

Peanut hull is an excellent natural adsorbent as such was considered to be attributable to the following factors:

1. high hydrophilicity of peanut hull owing to large number of hydroxyl groups.
2. flexible structure of polymer chain which enables to take suitable configuration of the complexation with dye molecules.

Renmin Gong et. al. (2005) reported that dye adsorption capacity of peanut hull depend on three major functional groups (amino, carboxyl, and hydroxyl groups). These functional groups in peanut hull were chemically modified individually to determine their contribution to the adsorption of ionic dyes. The dyes used were methylene blue, brilliant cresyl blue, neutral red, amaranth, sunset yellow and fast green FCF. It was found that carboxyl group inhibited the adsorption of anionic dyes but it was major functional group in the adsorption of all six dyes and the adsorption of cation of cation dyes, hydroxyl group was methylation of amino group was important functional group in the adsorption of all six dyes and the effect of amino group was not significant on the adsorption of six dyes.

CHAPTER III

EXPERIMENTAL PROCEDURE AND ANALYSIS METHODS

This chapter consists of description in experimental procedure and analytic method. It is divided into four sections. First section concerns with materials such as adsorbent, dyes and chemicals. Second section reviews all equipment that used in the experiments. Third section describes the experiment apparatus and adsorption procedure. The last section refers to analysis techniques and errors of the experiments.

3.1 Materials

3.1.1 Adsorbent

Adsorbent was powder peanut hull. The peanut hull used in this study was obtained from a local market.

3.2 Chemical

3.2.1 Water-soluble dyes

Four types of water-soluble dyes in this study were obtained from Tung Ti Hua Heng. Figture 3.1 to 3.4 show chemical structure of dye.

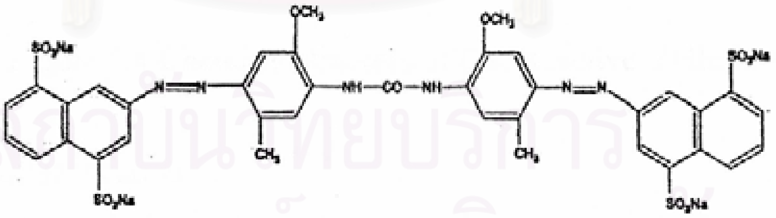

Figure 3.1 Chemical structure of C.I. Direct Yellow12

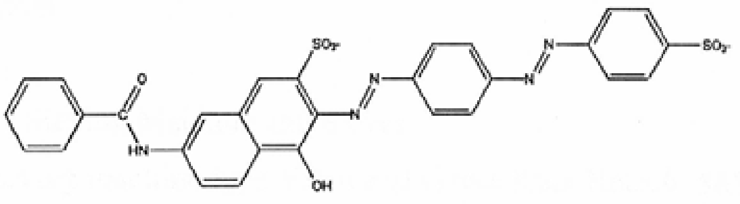

Figure 3.2 Chemical structure of C.I. Direct Red81

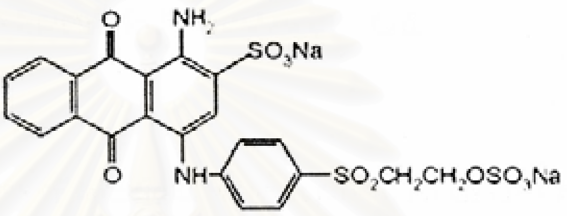

Figure 3.3 Chemical structure of C.I. Reactive Blue19

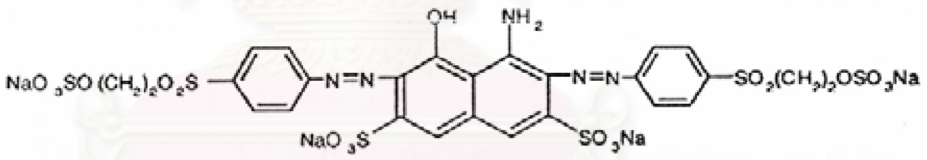

Figure 3.4 Chemical structure of C.I. Reactive Yellow145

3.2.2 Buffer solution

Buffer solution pH 4+/-0.05 contain potassium hydrogen phthaiate stabilized with 0.01% sodium azide was obtained from Asia Pracific Specialty Chamicals Limited and Buffer solution pH 10.0+/-0.05 contain sodium tetraborate-sodium hydroxide stabilized with 0.01% sodium azide was supplied by AJAX. Those buffers were used to adjust the pH of the dye solution to pH 5, pH 7 and pH 9.

3.3 Equipment

3.3.1 Sieving Machine and Sieves

A sieving machine type Vibro and sieves from Retsch, 5657 HAAN, Germany were used for classification of particle sizes of adsorbents.

3.3.2 Analytical Balance

Adsorbent was weighted by using BP210s, Sartorious. In this study were obtained from Scientific Promotion Co., Ltd.

3.3.3 pH Meter

The pH values of solutions were obtained on an HI 8424, microcomputer pH meter, Hanna.

3.3.4 Ultraviolet-visible Spectrophotometer (UV/VIS)

The 6405 UV/VIS spectrophotometer, Jenway, was used for qualitative and quantitative analysis of dye adsorption at wavelengths.

3.3.5 Surface Area Analyzer

The specific BET (Brunauer-Emmett-Teller) surface area was determined by using a surface area analyzer, ASAP 2000.

3.4 Experimental Procedures

3.4.1 Adsorbent Preparation

Peanut hull was extensively washed with demineralizes water to remove soil and dust, dried in an oven at 105 °C to a constant weight and them preserved in a desiccator. Dry peanut hull was crushed into powder, sieved to different particle sizes and then preserved in a desiccator for use.

3.4.2 Feed Preparation

For all type of dye, aqueous dye solution were prepared at pH 5, pH 7 and pH 9, which adjusted by using buffer pH 4 (contain potassium hydrogen phthaiate stabilized with 0.01% sodium azide) and buffer pH 10 (contain Sodium tetraborate-sodium hydroxide stabilized with 0.01% sodium azide).

The λmax values of the dye solution were determined by wavelength scanning using UV/VIS. The λmax values of each dye solutions are shown in Table 3.1.

Table 3.1 λmax of each dye solutions

Dye Types	λmax
Direct Yellow 12	405
Direct Red 81	497
Reactive Blue19	595
Reactive Yellow145	419

3.4.2.1 Preparation of Calibration Curve of Dye Solution at Various pHs

Several concentrations of the aqueous dye solutions were prepared at pH 5, pH 7 and pH 9. The calibration curve was plotted between dye concentration and absorbance. Calibration curve of each dye at pH 5, pH 7 and pH 9 are shown in Appendix B.

Table 3.2 shows the slope values obtained from the calibration curves plotted between the absorbance of dye solutions and their concentration.

Table 3.2 Slope values of the dye solutions at specified wavelength

Type of dye	Wavelength (nm)	Slope
Direct Yellow 12	405	3.2073
Direct Red 81	497	10.607
Reactive Blue19	595	6.5655
Reactive Yellow145	419	4.2855

3.4.2.2 Effect of Various pHs on Dye Stability

The aqueous dye solutions (50 mg/l) were prepared at pH 5, pH 7 and pH 9. The amount of 150 ml of each dye solution was stirred at 30°C for 25 hours. The absorbance of each dye remained in the supernatant after 0 hr and 25 hr stirred was calculated from Equation (3.1) and plotted against the pH.

$$Qs = \frac{As}{S} \qquad (3.1)$$

When Qs = amount of dye in supernatant after 0 hr or 25 hr (mg/l)
As = Absorbance of dye in supernatant after 0 hr or 25 hr
S = Slope value from calibration curve of dye concentration and absorbance

3.4.3 Adsorption Procedure

Figure 3.5 shows the apparatus of adsorption experiment. Five grams of peanut hull were added into a 250 ml flask. Approximately 150 ml of aqueous dye solution with initial concentration of 50 mg/l, which adjusted to pH 5, pH 7 and pH 9 was poured into the flask. The pHs of the system were adjusted by using buffer. The suspension was stirred for 25 hours at 30 °C. After that, the suspension was separated by centifugue. The adsorbances of residual dye in solution were determined by UV/VIS spectrophotometer at λmax of each dye. Blanked used in the experiment were demineralizes water with the same peanut hull and pH corresponding to the dye solution.

For multicomponent, kept conditions that give maximum capacities of dyes like a single component system. In studied experiment, the adsorption of two binary system dyes (direct yellow and direct red), (reactive blue and reactive yellow) onto peanut hull has been studied as four single component.

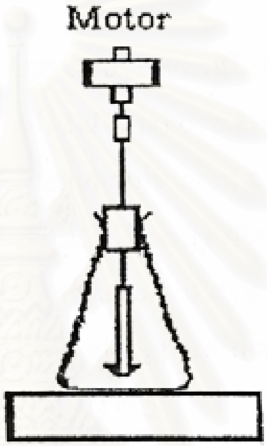

Figure 3.5 Schematic diagram of the experimental apparatus

3.4.4 Desorption Procedure

Desorption of each dye on adsorbent approximately 50 mg was carried out in 150 ml of demineralizes water at pH 5. Demineralizes water was adjusted pH by using Buffer. The suspensions were stirred for 25 hours. The supernatant was separated by centifugue. The absorbances of desorbed dye in the supernatant were determined by using UV/VIS spectrophotometer at λmax of each dye.

3.5 Analysis Technique and Errors of Experiments

The section is described analytic techniques and errors of experiments. UV/VIS spectrophotometer used for determined the residual dye in solution. The adsorbents were analyzes characteristic such as surface area and pore volume of adsorbents. Analytic procedure are described below but analytical result were shown in Chapter IV

3.5.1 Dye Concentration

Dye exhaustion or amount of dye adsorbed is usually defined in terms of difference between the initial and final dye concentrations. UV/VIS spectrophotometer is the most commonly used technique for quantitative determination of dye concentration. Usually the Beer-Lambert law is employed to determine the concentration of dye in solution from a measurement of absorbance at wavelength of maximum absorption dye.

$$\text{Absorbance} = \log (I_c/I) = acl \qquad (3.2)$$

Where I_c = Intensity of light incidient optical cell holding the dye solution
I = Intensity of light transmitted through the cell
a = Absorptivity of extinction coefficient (l/g.cm) of dye
c = Concentration of dye solution in the cell (g/l)
l = Path length through the cell (cm)

3.5.2 Surface Area and Pore diameter

A micromeritics model ASAP 2000 was used to determine surface are and average pore diameter of adsorbent. The instrument detects the volume of adsorbed nitrogen gas on surface at various relative pressure. There are two operating steps, degassing step and analysis step.

The adsorbent was prepared by heat and keep it in desiccator to remove moisture. Then, the adsorbent was degassed by heat and placed under vacuum to remove moisture and other contaminants. Temperature of degassing was carried out at 150 °C and vacuum until pressure dropped to 10 mmHg. After that, the sample was weight and the degassed sample was transfer from the degas port to the analysis port.

At the analysis step, the sample was analyzed at vacuum pressure of 15 mmHg and liquid nitrogen was used as a coolant. The nitrogen was used as analysis gas. The volume of adsorbed nitrogen on sample will relate with relative pressure (P/P_0). The volumes of adsorbed nitrogen gas and relative pressure were plotted the graph. The Y-intercept and slope of the graph was calculated BET surface area of sample.

3.5.3 Calculation of amount of adsorbed dye on the adsorbent

The amounts of adsorbed dyes were calculated from Equation (3.3), which was derived from Beer's law as follow:

$$Qa = \frac{[C - (Aa - Abl)/S\,] \times V}{W \times 100} \tag{3.3}$$

Where Qa = Amount of adsorbed dye (mg of adsorbed dye per g of adsorbent)
C = Initial concentration of dye (mg/l)
Aa = Absorbance of unadsorbed dye after adsorption
Abl = Absorbance of blank
S = Slope value from calibration curve of dye concentration and absorbance
V = Volume of dye solution (ml)
W = Weight of adsorbent (g)

3.5.4 Experimental and Analysis Error

3.4.4.1 Experimental Error

In this section, experiments are conducted to verify repeatability of the experiments, an average and a standard deviation value of the experiment. Equation (3.4) define an average value. The results are calculated for their average values, percentage of maximum and percentage of minimum errors. Equations (3.4) to (3.6) are used for calculation of average value, percentage of maximum and percentage of minimum errors of the experiment. Four experiments are conducted peanut hull (KAC431) weight 5 g, particle size of peanut hull are 0.150-0.180 mm, pH5 and operated at a temperature 30°C.

$$\text{Average value} \qquad X = \frac{\sum X}{N} \tag{3.4}$$

$$\%\text{Maximum error} = \frac{\text{maximum conc.} - \text{average conc.} \times 100}{\text{average conc.}} \tag{3.5}$$

$$\%\text{Minimum error} = \frac{\text{average conc.} - \text{minimum conc.} \times 100}{\text{average conc.}} \tag{3.6}$$

Average concentration of dye and percent error are calculated and shown in Table 3.3.

Table 3.3 Average maximum capacity and error of experiment various initial concentration of Direct Yellow12.

initial conc. (mg/l)	Adsorbed dye (mg/g)					% Maximum error	% Minimum error
	EXP1	EXP2	EXP3	EXP4	average		
10	14.816	14.792	14.208	14.644	14.615	1.38	2.78
30	14.741	14.647	14.158	14.39	14.484	1.77	2.25
50	14.638	14.311	14.091	13.776	14.204	3.06	3.01

3.5.4.2 Blank Test

A set of experiments is conducted to verify any possibility of dyes to be adsorbed on the glassware as well as their decomposition. Each dye is prepared at an initial concentration of 50 mg/l and the time is 25 hours.

The results of this study in Table 3.4 were plotted in Figure 3.6. It indicated that the concentration of direct dyes and reactive dyes remain constant at the end of 25 hours. So it can be concluded that the concentration of dye is adsorbed on the glassware of decomposed is very low for all dye in operating blank test. Thus, it can neglect the error occurring.

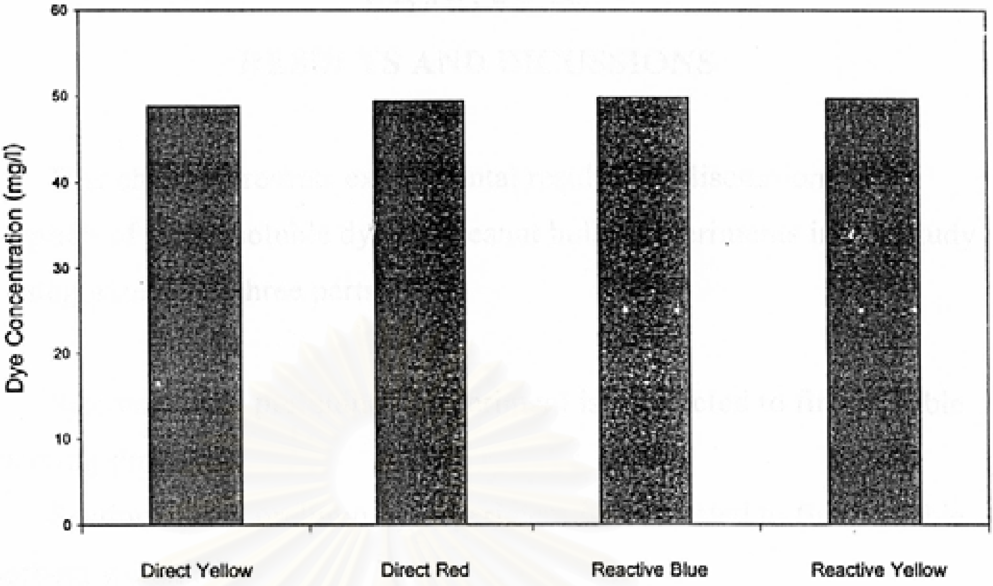

Figure 3.6 Dye concentration for blank test.

Table 3.4 Dye concentration for blank test.

Type of dye	Dye concentration				Average	max	min	SD
direct yellow	49.024	48.758	49.185	48.359	48.832	49.185	48.359	0.361
direct red	49.627	49.284	49.057	49.482	49.363	49.627	49.057	0.247
reactive blue	49.821	49.712	49.983	49.864	49.845	49.983	49.712	0.112
reactive yellow	49.821	49.482	49.817	49.664	49.696	49.821	49.482	0.160

CHAPTER IV
RESULTS AND DICUSSIONS

This chapter presents experimental results and discussions on adsorption of water-soluble dyes by peanut hull. Experiments in this study are categorized into three parts:

Section 4.1: A preliminary experiment is conducted to find suitable contacting time

Section 4.2: A preliminary experiment is conducted to find suitable absorbent weight.

Section 4.3: Adsorption experiments are conducted to study effects of aqueous solutions such as initial dye concentration, pH of aqueous solution, particle size rang, and dye desorption.

Section 4.4: Multicomponent experiments are conducted to study effects of several dyes in aqueous solution.

Preliminary experimental result

Adsorption study was derived from batch experiment. All operating conditions of preliminary experiments adsorption of each dye as shown in Table 4.1. After each experiment the liquid products are analyzed by UV/VIS spectrophotometer to find the dye concentration. Experimental results are shown in Appendix A. The amounts of adsorbed dye is calculated using Equation 4.1 and is used for further discussion. From Equation 4.1 was derived from Beer's law as follow:

$$Qa = \frac{[C-(Aa-Abl)/S]\times V}{W\times 100} \qquad (4.1)$$

Where Qa = Amount of adsorbed dye (mg of adsorbed dye per g of adsorbent)

C = Initial concentration of dye (mg/L)

Aa = Absorbance of unadsorbed dye after adsorption

Abl = Absorbance of blank

S = Slope value from calibration curve of dye concentration and absorbance

V = Volume of dye solution (mL)

W = Weight of adsorbent (g)

Table 4.1 Operating conditions of preliminary dye adsorption experiments.

Feed concentration (mg/l)	50
Feed solution (ml)	150
Pressure (atm)	1
Temperature (°C)	30
Breeding of peanut hull	KAC431
	KAC1
Dye types	Direct Yellow12
	Direct Red81
	Reactive Blue19
	Reactive Yellow145
Initial pH of feed	5
Particle size (mm)	0.150-0.180

4.1 Effect of Contact Time on Adsorption of Dyes

Preliminary experiments were conducts in order to find effect of contacting time. The objectives of this section are to find suitable time required for each subsequent experiment. In each adsorption studied, dye solution was added to 5 g of each breed of peanut hull. The experiments were done by varying contact time.

In this studied adsorption, contact time between adsorbent and liquid are varied from 1 to 27 hours. Samples were consecutively collected every 1 hour. Adsorption isotherms are usually determined under equilibrium conditions.

The results were plotted in Figures 4.1 to 4.2, indicate that the ability of concentration dye removal depends on the contact time. The concentration curves in Figure 4.1 to 4.2 were the normalized concentration in the solution is plotted versus contact time. The concentration curve of dye in the bulk can be adsorbed rapidly on the adsorbent during the initial stage of the adsorption processes. After a very rapid adsorption, the concentration of dye in bulk is lower than the initial stages. Until final stage, the concentration of dye is very slow and concentration curve is nearly constant. Adsorption of dye solution reach equilibrium ranged 1 to 20 hr for using KAC431 and range 1 to 18 hr for using KAC1. The equilibrium time of 25 hr was required. However, the experimental data were measured at 27 hr to make sure that full equilibrium was attained. Amount of dyes adsorbed onto peanut hull increased with time and after 25 hour, it reached a constant value beyond which no more dyes were further removed from the solution.

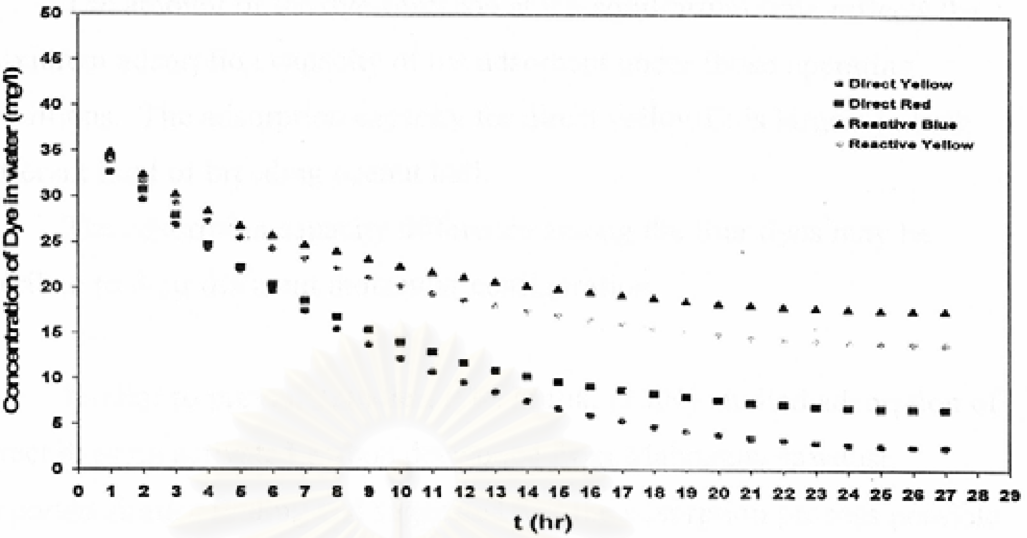

Figure 4.1 Amount of adsorbed dye various of contact time by peanut hull (KAC431).

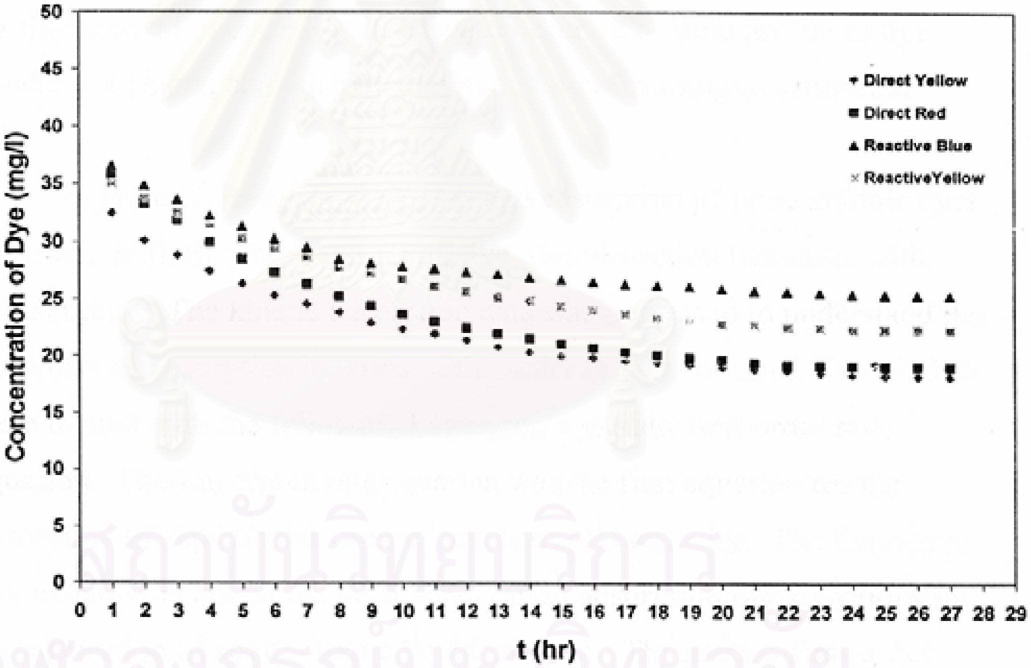

Figure 4.2 Amount of adsorbed dye various of contact time by peanut hull (KAC1).

The amount of the dye adsorbed at the equilibrium time reflects the maximum adsorption capacity of the adsorbent under those operating conditions. The adsorption capacity for direct yellow12 is largest in both different kind of breeding peanut hull.

The adsorption capacity difference among the four dyes may be ascribed to their different molecular configuration.

Similar to previous studies. P.K. Malik. (2004) studied adsorption of direct dyes on activated carbon developed from Mahogany sawdust. Reported similar finding and suggested that the adsorption process possible monolayer coverage of dyes on the surface of the adsorbent.

K.K. Singh et al. (2006) studies kinetic and equilibrium of wheat bran for the removal of cadmium from wastewater. The time profile of dye uptake is a single, smooth and continuous curve leading to saturation.

Renmin Gong et al. (2005) studied adsorption of three anionic dyes on peanut hull. Similar trend for all dye, the adsorption increases with contact time. The kinetic adsorption data was processed to understand the dynamics of adsorption in terms of the order of rate constant. Kinetic data were treated with the following Lagergren's pseudo-first-order rate equation. The Lagergren rate equation was the first equation for the adsorption of liquid/solid system based on solid capacity. The Lagergren rate equation is one of the most widely used adsorption rate equations for the adsorption of solute from a liquid solution. The pseudo-first-order kinetic model of Lagergren may be represented by:

$$\frac{dq}{dt} = kad(qe-qt)$$

Integration this equation for the boundary condition t=0 to t=t and q=0 to q=q, gives:

$$\ln (qe-qt) = \ln qe - kadt$$

or

$$\log (qe-qt) = \log qe - kadt/2.303 \qquad (4.2)$$

Where qe = Amount of adsorbed dye (mg of adsorbed dye per g of adsorbent) at equilibrium.

qt = Amount of adsorbed dye (mg of adsorbed dye per g of adsorbent) at time.

kad = Rate constant

t = time (hr)

This section describes adsorption behavior by the rate of the reaction. The progress of the reaction then could be followed by observing the decrease of concentration with time.

Figures 4.3 to 4.4, plotted the adsorption isotherm and the results indicate how the adsorption molecules distribute between the liquid phase and the solid phase when the adsorption process reaches an equilibrium state. The process was found to be very rapid initially, and a large fraction of the total amount of dye was removed within a few hours. In this study, the experiment data were linear at 1 to 7 hour, so these were considered.

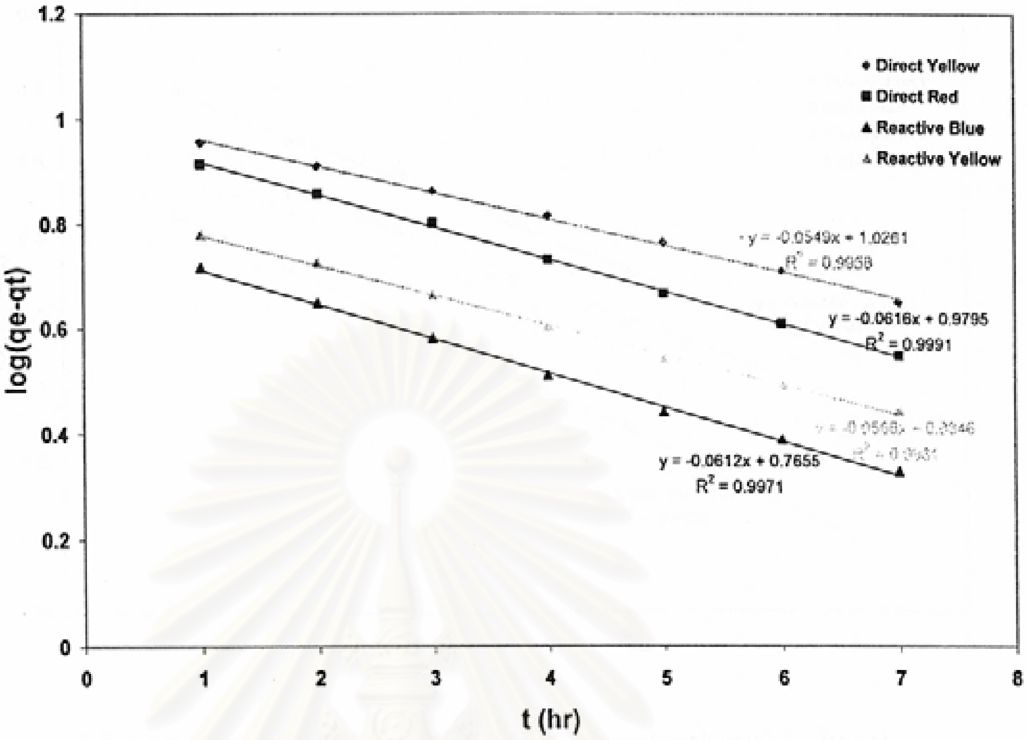

Figure 4.3 Lagergren plots for adsorption of direct yellow12, direct red81, reactive blue19, and reactive yellow145 by peanut hull (KAC431).

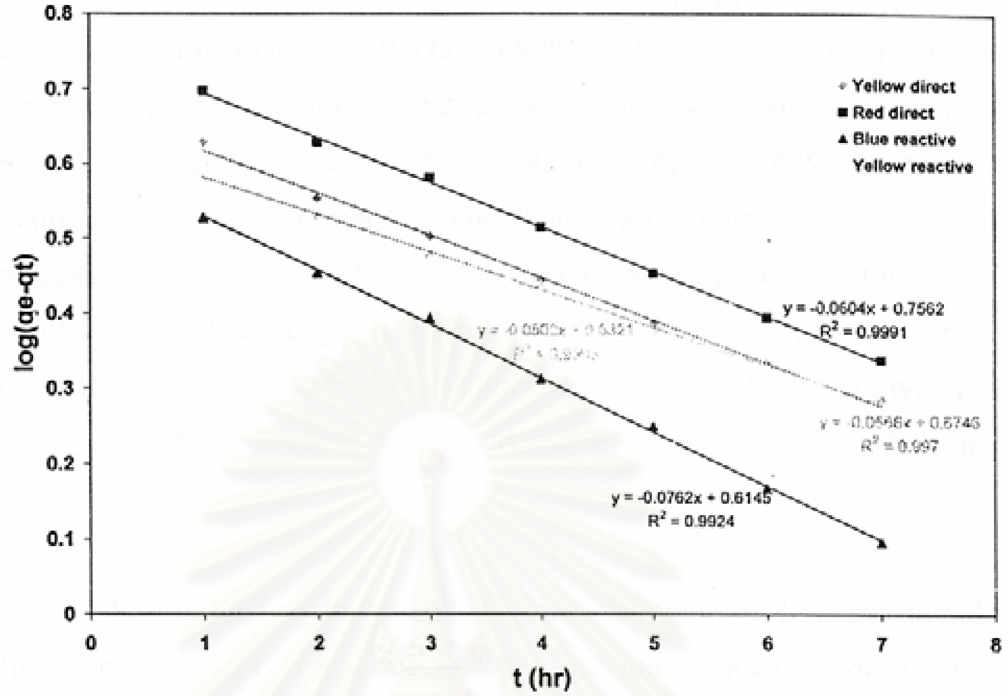

Figure 4.4 Lagergren plots for adsorption of direct yellow12, direct red81, reactive blue19, and reactive yellow145 by peanut hull (KAC1).

The result of this study, the specific rate constants, k_{ad}, for the adsorption of dye on peanut hull were determined from the pseudo-first-order rate equation given by Lagergren. The straight-line plot of log(qe-qt) versus t. The values of k_{ad}, calculated from the slopes of the plots, were 0.0549, 0.0616, 0.0568, and 0.0612 for direct yellow12, direct red81, reactive blue19, and reactive yellow145, respectively for KAC431. For KAC1, The values of k_{ad}, calculated from the slopes of the plots, were 0.0568, 0.0604, 0.0762, and 0.0502 for direct yellow12, direct red81, reactive blue19, and reactive yellow145, respectively. These values showed fast adsorption of each dye on peanut hull. The higher value showed that adsorption was faster.

The values of correlation coefficients for the pseudo-first-order kinetic model were 0.9958, 0.9991, 0.9981, and 0.9971 for direct yellow12, direct red81, reactive blue19, and reactive yellow145, respectively for KAC431. For KAC1, were 0.997, 0.9991, 0.9924, and 0.9993 for direct yellow12, direct red81, reactive blue19, and reactive yellow145, respectively. The high values of correlation approach to 1 and this confirmed that the Langmuir isotherm model was favorable for adsorption of all dyes on to peanut hull under the conditions used in this study, and this again showed that the data conformed well to the pseudo-first-order rate kinetic model.

The result of contact time experiment summarizes that the suitable time should be 25 hours because at this time, rate of dye deposition on adsorbent is very slow and reached equilibrium values at about 25 hr for all dyes. After that, dye uptake became much less significant. The removal of dye is so high and constant enough for studying in this thesis.

4.2 Effect of Adsorbent Weight on Adsorption of Dyes

A set of experiments is conducted to find the effect of adsorbent weight on adsorption of dyes. The adsorbent weights in this study are 1, 3, 5 and 7 gram while the contact time is kept at 25 hours. Efficiency of dye removal is considered from the concentration dye of solution. If concentration dye is high, efficiency is low. On the other hand, high efficiency is obtained when amount of concentration dye in liquid product is low.

The results of experiment as in Table 4.2 to 4.3, shown in Figure 4.5 to 4.6, indicate that the ability of dye depends on adsorbent weight. For KAC431, adsorption increased from 8.261 to 14.896, 7.633 to 13.153, 4.956 to 10.082, and 6.577 to 11.251 mg/g for direct yellow12, direct red81, reactive blue19, and reactive yellow145, respectively as the dose was increased from 1 to 7 g/l in the solution and KAC1, adsorption also increased from 3.533 to 9.893, 3.149 to 9.756, 2.243 to 8.681, and 2.692 to 8.819 mg/g for direct yellow12, direct red81, reactive blue19, and reactive yellow145, respectively.

The results indicate that content of direct and reactive dyes increase with amount of adsorbent. Increase in adsorption with the dose can be attributed to increased surface area and the availability of more adsorption sites.

Table 4.2 Amount of adsorbed dye at various of peanut hull(KAC431) weight.

Type of dye	Adsorbent weight (g)	Adsorbed dye (mg/g)			
		average	max	min	SD
direct yellow	1	8.261	9.862	7.255	1.140287
direct yellow	3	11.847	12.799	10.988	0.765613
direct yellow	5	14.204	14.638	13.776	0.363207
direct yellow	7	14.896	14.942	14.825	0.04998
direct red	1	7.633	8.349	6.348	0.884689
direct red	3	10.054	11.641	8.459	1.360233
direct red	5	12.973	13.801	12.502	0.582427
direct red	7	13.153	13.961	12.661	0.575479
reactive blue	1	4.952	5.976	3.217	1.311878
reactive blue	3	7.768	8.963	7.082	0.823258
reactive blue	5	9.699	9.932	9.428	0.255232
reactive blue	7	10.082	10.284	9.932	0.161353
reactive yellow	1	6.577	7.508	4.827	1.243716
reactive yellow	3	8.318	9.054	7.521	0.627622
reactive yellow	5	10.824	14.523	8.313	2.969837
reactive yellow	7	11.251	14.625	9.167	2.622807

Table 4.3 Amount of adsorbed dye at various of peanut hull(KAC1) weight.

Type of dye	Adsorbent weight (g)	Adsorbed dye (mg/g)			
		average	max	min	SD
direct yellow	1	3.533	3.949	2.972	0.417773
direct yellow	3	7.054	8.438	5.154	1.373652
direct yellow	5	9.513	10.066	8.909	0.587574
direct yellow	7	9.893	10.612	9.291	0.555654
direct red	1	3.149	4.106	2.418	0.731156
direct red	3	6.914	7.671	6.124	0.65438
direct red	5	9.27	11.538	7.746	1.747805
direct red	7	9.756	11.788	8.249	1.521775
reactive blue	1	2.243	2.862	1.954	0.425844
reactive blue	3	5.318	7.5	4.531	1.455506
reactive blue	5	7.374	8.091	6.817	0.644398
reactive blue	7	8.681	8.944	8.439	0.211611
reactive yellow	1	2.692	3.584	1.985	0.819018
reactive yellow	3	6.041	7.862	5.103	1.275794
reactive yellow	5	8.283	9.632	7.016	1.283518
reactive yellow	7	8.819	10.169	7.483	1.396984

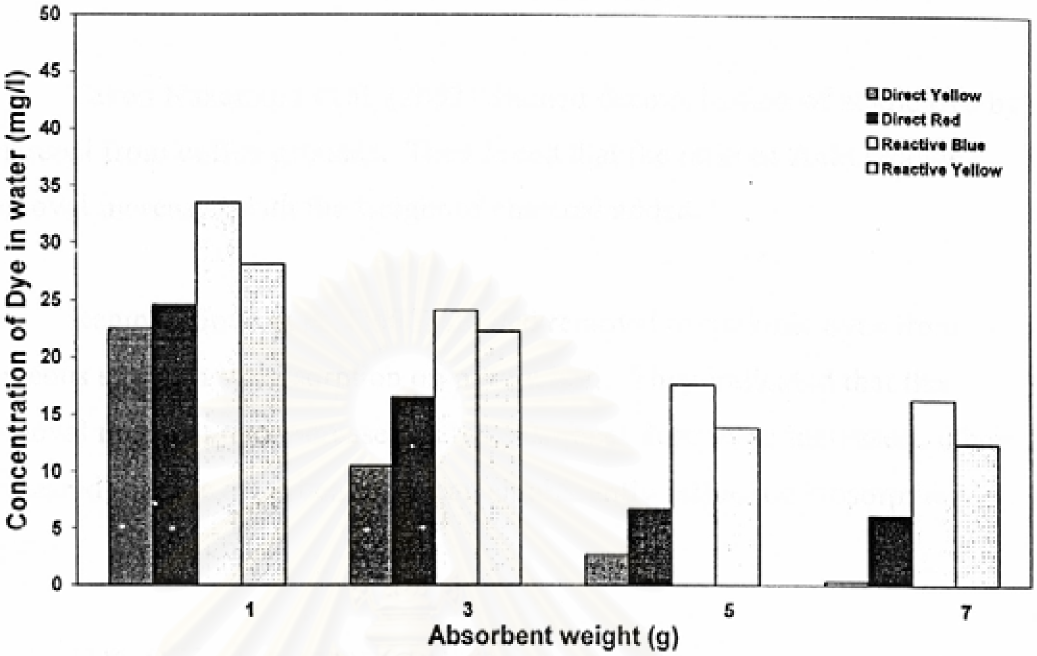

Figure 4.5 Amount of adsorbed dye at various of peanut hull(KAC431) weight.

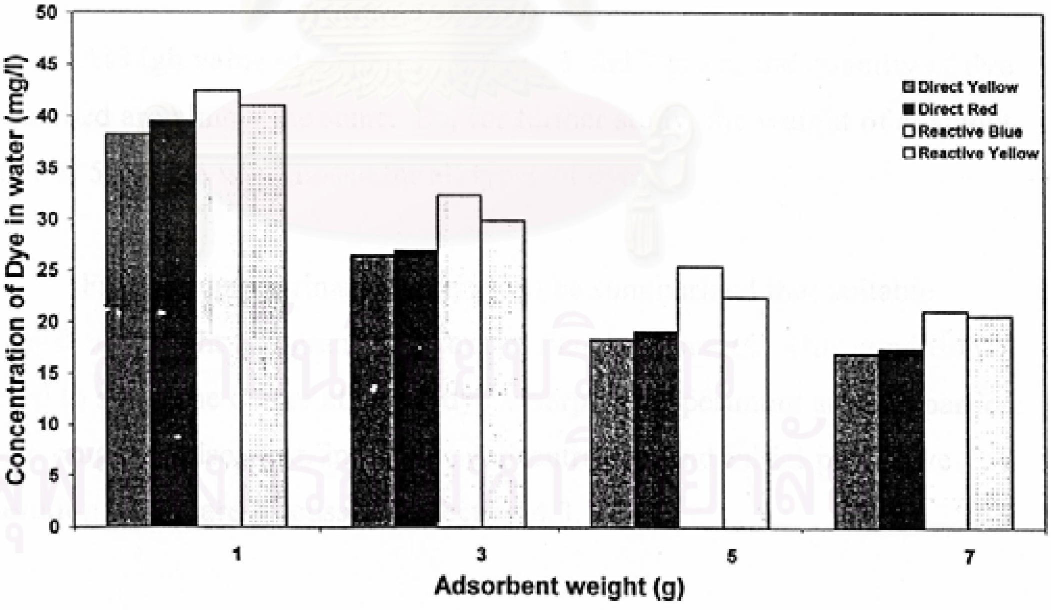

Figure 4.6 Amount of adsorbed dye at various of peanut hull(KAC1) weight.

The results from previous section also indicate that the unit adsorption was increased as the adsorbent increased in the solution.

Takeo Nakamura et al. (2003) Studied decolorization of acidic dye by charcoal from coffee grounds. They found that the ratio of Acid Orange7 removal increased with the weight of charcoal added.

Renmin Gong et al. (2005) studied removal of cationic dyes from aqueous solution by adsorption on peanut hull. They indicated that the removal ratios of dye increased as the adsorbent dose were increased. They indicated that the adsorbent dose can significantly influence biosorption of dyes.

V.K. Garg et al. (2003) studied dye removal from aqueous solution by adsorption on treated sawdust. They reported that dye removal ability increased with increasing adsorbent dose

At high value of adsorbent weight, 5 and 7 gram, the quantity of dye adsorbed are almost the same. So, for further study, the weight of a peanut hull of 5.0 gram was chosen for all types of dyes.

From the preliminary study, it can be summarized that suitable adsorbent weight is 5 gram, and contact time is 25 hours. This condition is used to study the others effect of dye adsorption experiment such as particle size range of adsorbent, initial dye concentration, and initial pH of dye solution which are discussed in Section 4.3.

4.3 Adsorption experiment

This section describes results of effects of particle size range of adsorbent, initial dye concentration, and initial pH of dye solution. Table 4.4 shows all operating conditions of adsorption of each dye.

Table 4.4 Operating conditions of dye adsorption experiments

Adsorbent weight (g)	5
Feed solution (ml)	150
Feed concentration (mg/l)	50
Time (hour)	25
Pressure (atm)	1
Temperature (°C)	30
Breeding of peanut hull	KAC431
	KAC1
Dye types	Direct Yellow12
	Direct Red81
	Reactive Blue19
	Reactive Yellow145
Initial pH of feed	5, 7,9
Initial dye concentration (mg/l)	10, 30, 50
Particle size (mm)	0.150-0.180
	0.180-0.210
	0.210-0.300

4.3.1 Effect of Particle Size of Adsorbent on Dye Adsorption

A set of experiments is conducted to study effect of particle size of adsorbent on adsorption of each dye. Peanut hull are sieved into three particle size ranges. Particle sizes of peanut hull are 0.150-0.180 mm, 0.180-0.210 mm, and 0.210-0.300 mm was studied in this experiment.

Peanut hull are sieved into three particle size ranges. Surface area of adsorbent(activated carbon, peanut hull(KAC431), and peanut hull(KAC1) determined by BET surface area analyzer. Table 4.5 shows surface area and pore diameter of each particle size range of adsorbent.

Table 4.5 Surface area and pore diameter of adsorbent

Types of adsorbent	Surface area (m2/g)	Average pore diameter (A)
activated carbon	789.3719	18.2146
peanut hull(KAC431)	54.632	113.0281
peanut hull(KAC1)	3.2089	62.4344

The results of particle size experiment are shown in Table 4.6 to 4.7 and are plotted in Figure 4.7 to 4.8, show the effect of particle size of adsorbent on dye adsorption. They are observed that four dyes are similar trends. The adsorption ability of direct and reactive dyes decreases with increasing particle size of all types of peanut hull.

Renmin Gong et al. (2005) conducted experiment to investigate the possibility of peanut hull for removal anionic dyes. They concluded that the removal ratios of dye increased as the adsorbent particle size decreased. They reported that the ratio of dyes sorbed had approached the maximum values in all dyes when the sorbent particle size in 80-100 mesh. They indicated that the adsorbent particle size can significantly influence biosorption of dyes.

Table 4.6 Particle Size of peanut hull(KAC431) on Dye Adsorption.

Type of dye	Particle size (mm)	Adsorbed dye (mg/g)			
		average	max	min	SD
direct yellow	0.05-0.06	11.145	12.452	8.853	1.587094
direct yellow	0.06-0.08	12.834	13.456	12.097	0.558911
direct yellow	0.08-0.09	14.204	14.638	13.776	0.363207
direct red	0.05-0.06	9.252	10.452	6.636	1.761772
direct red	0.06-0.08	11.847	12.457	10.976	0.625916
direct red	0.08-0.09	12.973	13.801	12.502	0.582427
reactive blue	0.05-0.06	6.899	7.32	6.475	0.364592
reactive blue	0.06-0.08	8.315	8.964	6.848	0.992212
reactive blue	0.08-0.09	9.699	9.932	9.428	0.255232
reactive yellow	0.05-0.06	8.174	8.841	7.412	0.637484
reactive yellow	0.06-0.08	9.548	12.155	7.862	1.982828
reactive yellow	0.08-0.09	10.824	14.523	8.313	2.969837

Table 4.7 Particle Size of peanut hull(KAC1) on Dye Adsorption.

Type of dye	Particle size (mm)	Adsorbed dye (mg/g)			
		average	max	min	SD
direct yellow	0.05-0.06	7.482	7.998	6.797	0.550568
direct yellow	0.06-0.08	8.648	9.123	8.207	0.409844
direct yellow	0.08-0.09	9.513	10.066	8.909	0.587574
direct red	0.05-0.06	6.821	9.393	5.054	1.88707
direct red	0.06-0.08	8.451	11.226	6.743	2.086095
direct red	0.08-0.09	9.27	11.538	7.746	1.747805
reactive blue	0.05-0.06	5.014	5.896	4.277	0.666355
reactive blue	0.06-0.08	6.822	7.816	5.975	0.946304
reactive blue	0.08-0.09	7.374	8.091	6.817	0.644398
reactive yellow	0.05-0.06	6.153	6.786	5.623	0.501901
reactive yellow	0.06-0.08	7.795	9.281	6.948	1.088125
reactive yellow	0.08-0.09	8.283	9.632	7.016	1.283518

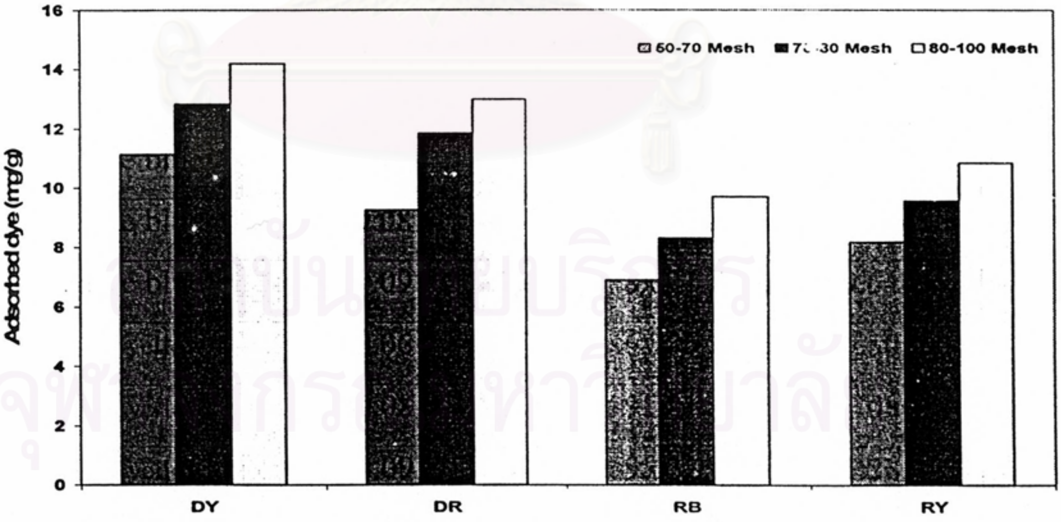

Figure 4.7 Effect of particle sizes of peanut hull (KAC431) on adsorption of Direct Yellow, Direct Red, Reactive Blue and Reactive Yellow.

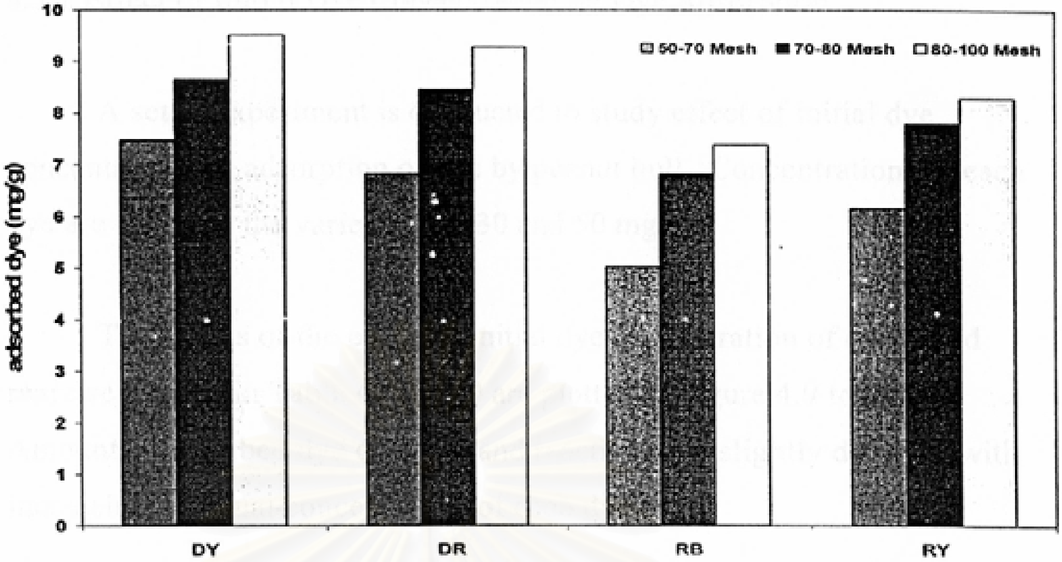

Figure 4.8 Effect of particle sizes of peanut hull (KAC1) on adsorption of Direct Yellow, Direct Red, Reactive Blue and Reactive Yellow.

The result of effect of particle size experiment summarizes that the maximum adsorption values in all four dyes when the particle size of peanut hull in 0.150-0.180 mm. So, this particle size was chosen in further experiment.

4.3.2 Effect of Initial Dye Concentration on Dye Adsorption

A set of experiment is conducted to study effect of initial dye concentration on adsorption of dye by peanut hull. Concentrations of each dye are varied at the varied of 10, 30 and 50 mg/l.

The results of the effect of initial dye concentration of direct and reactive dyes as in Table 4.8 to 4.9 are plotted in Figure 4.9 to 4.10. Amount of adsorbed dye of direct and reactive dyes slightly decrease with increasing of initial concentration of each dye.

K. Santhy et al. (2006) studied removal of reactive dyes from wastewater by adsorption on coir pith activated carbon. It was evident that the removal of dye increased with decreasing dye concentration and similar results were obtained in the removal of Reactive Red2 and Reactive Blue4 also.

Table 4.8 Effect of initial dye concentration on dye adsorption by peanut hull (KAC431).

Type of dye	Int. Conc. (mg/l)	Adsorbed dye (mg/g)			
		average	max	min	SD
direct yellow	10	14.615	14.816	14.208	0.2818
direct yellow	30	14.484	14.741	14.158	0.2631
direct yellow	50	14.204	14.638	13.776	0.3632
direct red	10	13.224	14.053	12.593	0.6332
direct red	30	13.146	13.982	12.52	0.6254
direct red	50	12.973	13.801	12.502	0.5824
reactive blue	10	9.895	10.152	9.702	0.2191
reactive blue	30	9.816	10.026	9.658	0.1845
reactive blue	50	9.699	9.932	9.428	0.2552
reactive yellow	10	11.967	14.733	10.246	2.1332
reactive yellow	30	11.254	14.623	9.028	2.6397
reactive yellow	50	10.824	14.523	8.313	2.9698

Table 4.9 Effect of initial dye concentration on dye adsorption by peanut hull (KAC1).

Type of Dye	Int. Conc. (mg/l)	average	max	min	SD
direct yellow	10	9.962	10.194	9.411	0.368931
direct yellow	30	9.793	10.138	9.261	0.397902
direct yellow	50	9.513	10.066	8.909	0.587574
direct red	10	9.914	12.436	8.412	1.81551
direct red	30	9.588	11.897	8.106	1.723794
direct red	50	9.27	11.538	7.746	1.747805
reactive blue	10	9.246	10.023	8.478	0.879412
reactive blue	30	8.853	9.876	8.037	0.944039
reactive blue	50	7.374	8.091	6.817	0.644398
reactive yellow	10	9.428	11.026	7.663	1.719553
reactive yellow	30	8.988	10.763	7.426	1.60979
reactive yellow	50	8.283	9.632	7.016	1.283518

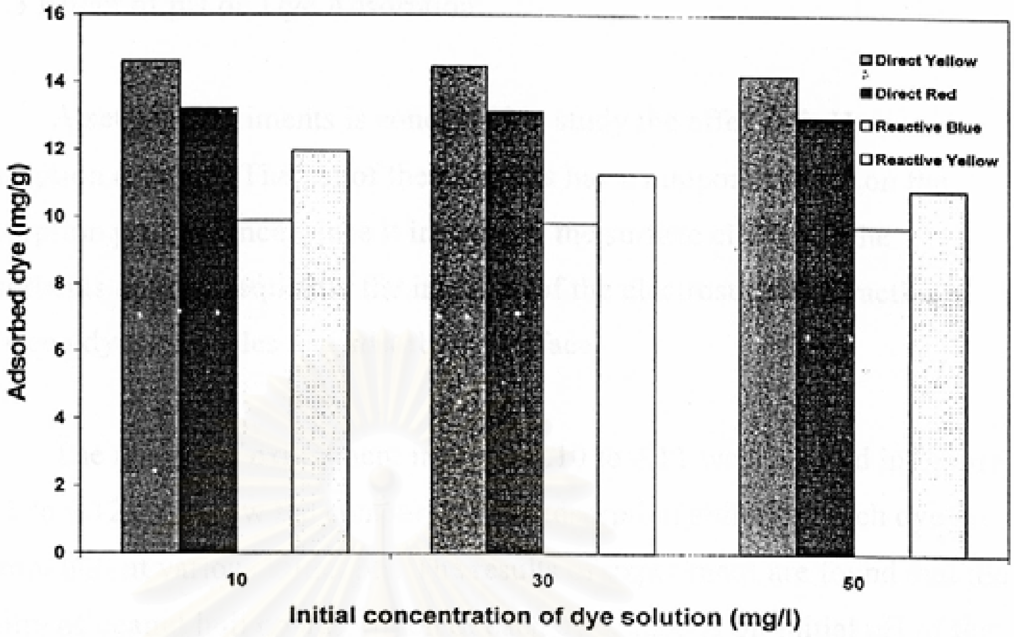

Figure 4.9 Effect of initial dye concentration on dye adsorption by peanut hull (KAC431).

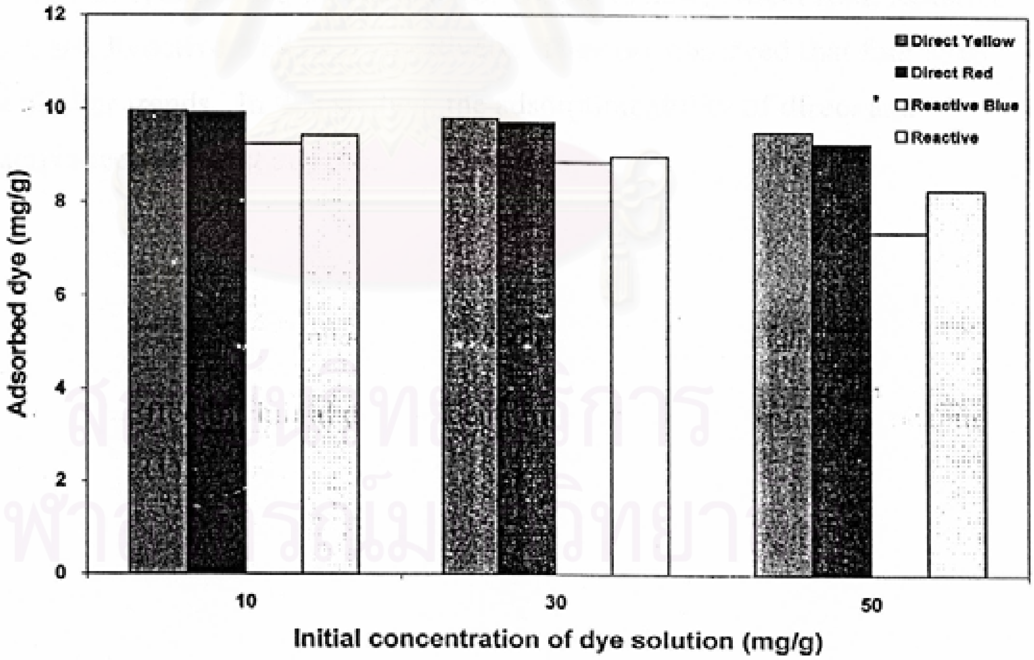

Figure 4.10 Effect of initial dye concentration on dye adsorption by peanut hull (KAC1).

4.3.3 Effect of pH on Dye Adsorption

A set of experiments is conducted to study the effect of pH on adsorption of dyes. The pH of the solutions has an important role on the adsorption performance, since it influences the surface charge of the adsorbents and consequently the intensity of the electrostatic interactions between dye molecules and adsorbents surface.

The results of experiment in Table 4.10 to 4.11 were plotted in Figure 4.11 to 4.12 that show the comparisons of adsorption ability of each dye on peanut hull at various initial pH. The results of experiment are found that the ability of peanut hull on adsorption of each dyes depend on initial pH of the solution at all operating. The result when used KAC431 as adsorbent, 14.204, 12.973, 9.699, 10.824 mg/g peanut hull for Direct Yellow, Direct Red, Reactive blue, and Reactive Yellow, respectively. For KAC1, 9.513, 9.270, 7.374, and 8.283 peanut hull for Direct Yellow, Direct Red, Reactive blue, and Reactive Yellow, respectively. They are observed that four dyes are similar trends. In this studied, the adsorption ability of direct and reactive were highest at pH 5.

Table 4.10 Effect of pH on adsorption of dye by peanut hull (KAC431).

Type of dye	pH	Adsorbed dye (mg/g)			
		average	max	min	ŜD
direct yellow	5	14.204	14.638	13.776	0.363207
direct yellow	7	11.867	12.559	10.643	0.875778
direct yellow	9	9.153	10.645	7.453	1.431635
direct red	5	12.973	13.801	12.502	0.582427
direct red	7	10.371	11.532	9.023	1.032388
direct red	9	7.428	8.466	6.454	0.935307
reactive blue	5	9.699	9.932	9.428	0.255232
reactive blue	7	7.814	8.889	6.341	1.127144
reactive blue	9	5.217	6.235	4.394	0.84289
reactive yellow	5	10.824	14.523	8.313	2.969837
reactive yellow	7	8.762	9.602	7.428	0.972689
reactive yellow	9	6.483	7.224	5.562	0.692272

Table 4.11 Effect of pH on adsorption of dye by peanut hull (KAC1).

Type of dye	pH	Adsorbed dye (mg/g)			
		average	max	min	SD
direct yellow	5	9.513	10.066	8.909	0.587574
direct yellow	7	7.265	8.179	5.785	1.032598
direct yellow	9	4.483	5.152	3.361	0.7796
direct red	5	9.27	11.538	7.746	1.747805
direct red	7	7.106	8.477	5.718	1.147692
direct red	9	4.256	5.859	3.201	1.184553
reactive blue	5	7.374	8.091	6.817	0.644398
reactive blue	7	5.252	6.381	4.786	0.759431
reactive blue	9	4.006	4.984	3.247	0.775382
reactive yellow	5	8.283	9.632	7.016	1.283518
reactive yellow	7	5.982	7.442	4.73	1.363736
reactive yellow	9	4.017	4.941	3.186	0.846634

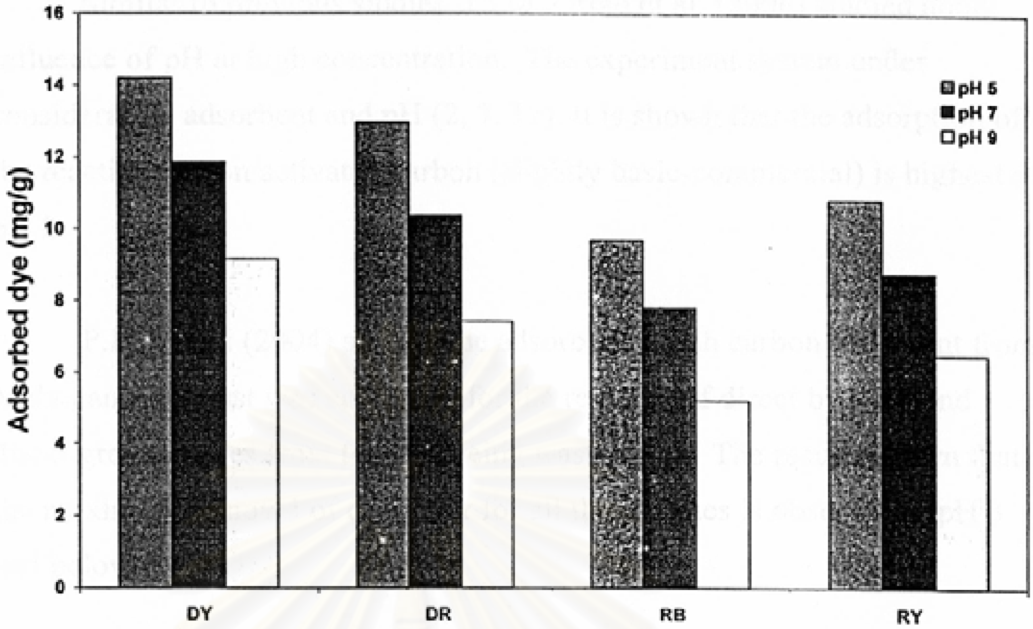

Figure 4.11 Effect of pH on adsorption of Direct Yellow, Direct Red, Reactive Blue and Reactive Yellow by peanut hull (KAC431).

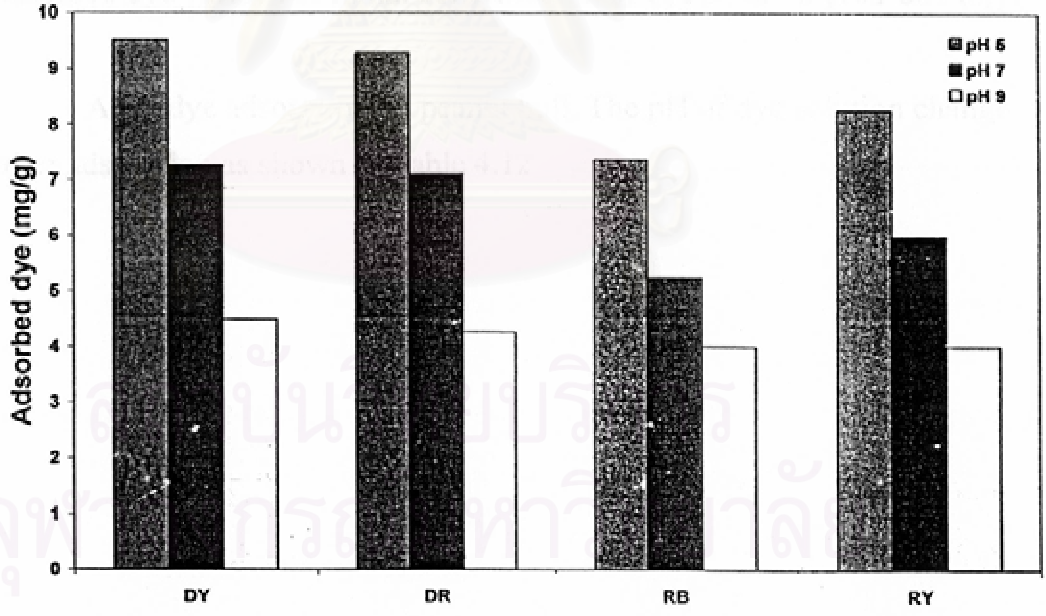

Figure 4.12 Effect of pH on adsorption of Direct Yellow, Direct Red, Reactive Blue and Reactive Yellow by peanut hull (KAC1).

Similar to previous studies. J.J.M. Orfao et al. (2006) studied about influence of pH at high concentration. The experiment system under consideration adsorbent and pH (2, 7, 12). It is shown that the adsorption of the reactive dye on activated carbon (slightly basic-commercial) is highest at pH 2.

P.K. Malik (2004) studied the adsorbent which carbon adsorbent from Mahogany sawdust was employed for the removal of direct blue 2B and direct green B dyes from textile dyeing wastewater. The results shown that the maximum removal of dye color for all the samples is observed at pH 3 and below.

Zumriye Aksu *et. al.* (2006) observe that use of agriculture waste sugar beet pulp for the removal of reactive dye. The biosorption of Gemazol turquoise blue-G was maximum at pH 2.0 (qe = 83.7mg/g). Amount of adsorbed dye various of initial concentration of dye solution (100-800 mg/l)

After dye adsorption by peanut hull, The pH of dye solution change after adsorption as shown in Table 4.12

Table 4.12 The pH of dye after adsorption by peanut hull.

Type of dye	Initial pH of dye	pH of dye after adsorption	
		KAC 431	KAC 1
Direct Yellow	5	4.37	4.41
Direct Red	5	4.29	4.36
Reactive Blue	5	4.84	4.92
Reactive Yellow	5	4.81	4.87
Direct Yellow	7	5.97	6.04
Direct Red	7	5.49	6.29
Reactive Blue	7	6.32	6.94
Reactive Yellow	7	5.64	6.81
Direct Yellow	9	6.25	6.58
Direct Red	9	6.17	6.18
Reactive Blue	9	6.83	6.79
Reactive Yellow	9	6.78	6.58

The results are summarized that all direct and reactive dyes in this study can be adsorbed on peanut hull better in acidic solution (low pH value).

4.3.4 Effect of dye desorption

This set of experiments is conduct to study effect of dye desorption of each dye on adsorbent. Results of desorption dye are presented in Table 4.13 to 4.14.

The results of experiment were plotted in Figure 4.13. In this experiment, concentration of dye desorption from adsorbent is very low for all types of dye. Thus, it can neglect the dye desorption occurring.

Table 4.13 Dye desorption by peanut hull(KAC431).

Type of Dye	Absorbance of desorbed dye				dye concentration (mg/l)	SD
direct yellow	0.006	0.007	0.010	0.011	2.700	0.002
direct red	0.004	0.007	0.010	0.013	2.700	0.004
reactive blue	0.004	0.004	0.080	0.007	1.720	0.038
reactive yellow	0.006	0.008	0.011	0.012	2.607	0.003

Table 4.14 Dye desorption by peanut hull(KAC1).

Type of Dye	Absorbance of desorbed dye				dye concentration (mg/l)	SD
direct yellow	0.005	0.007	0.009	0.010	2.537	0.002
direct red	0.008	0.007	0.009	0.011	2.653	0.002
Reactive blue	0.001	0.001	0.001	0.002	1.193	0.001
reactive yellow	0.002	0.003	0.007	0.004	1.307	0.002

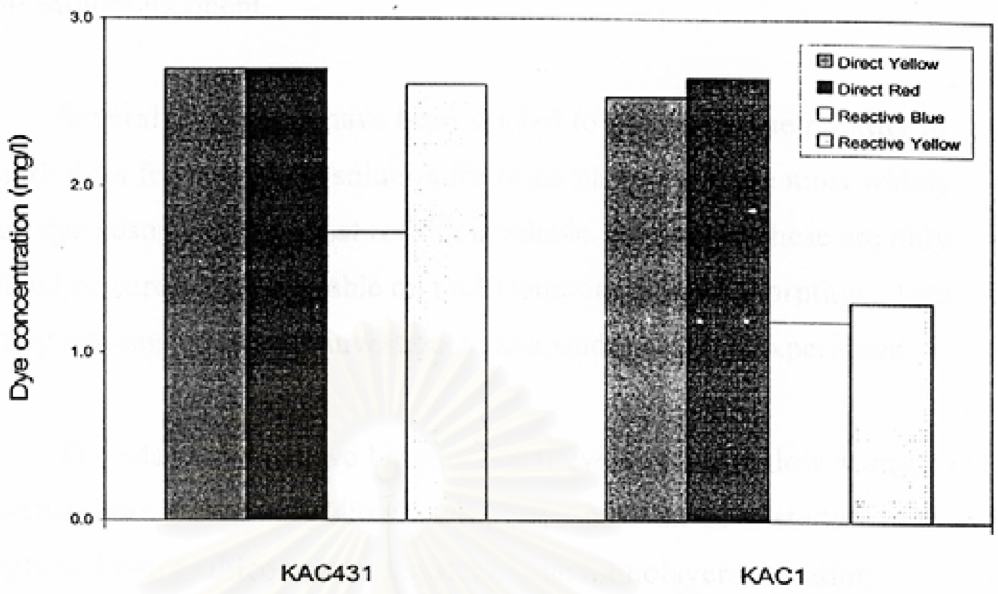

Figure 4.13 Dye desorption by peanut hull.

4.4 Multicomponent

Several adsorbents have been studied to determine their ability to adsorb dyes from aqueous solution for research purpose the most widely used dye adsorbent and most readily available. However, these are only limited research data available on multicomponent dye adsorption. Two binary systems have been investigated and studied in this experiment.

The adsorption of two binary system dyes (direct yellow + direct red), (reactive blue + reactive yellow) onto peanut hull has been studied as four single and two multicomponent system. The monolayer saturation capacities are 14.204, 12.973, 9.699, and 10.824 mg/g peanut hull for Direct Yellow, Direct Red, Reactive Blue, and Reactive Yellow, respectively. The result showed a maximum saturation capacity or each multicomponent dye system as Table 4.15.

From Table 4.15, experimental data indicated that competitive adsorption for active sites on the peanut hull surface results in a reduction in the overall uptake capacity of the each dye. The interactions of these compounds may mutually enhance or mutually inhibit adsorption capacity. A reduction in individual dye adsorption capacity in multicomponent is common in dye adsorption on peanut hull system.

Table 4.15 Result of single and multicomponent system adsorption experiment.

Single component system	Direct Yellow12	Direct Red81	Reactive Blue19	Reactive Yellow145
qi,max (mg/g)	14.204	12.973	9.699	10.824
Multicomponent system	Direct Yellow12 + Direct Red81		Reactive Blue19 + Reactive Yellow145	
qi,max (mg/g)	7.149	6.513	4.485	5.421

Y. Al-Degs et. al. (2006) studied competitive adsorption of reactive dyes from solution: equilibrium isotherm studies in single and multisolute systems. They described that factors may be the electrical repulsion of dye from the carbon surface by other adsorbed dyes of similar charge, and the attraction of dyes to each other on the surface. They reported that the adsorption capacity of an individual dye decreased in the presence of a second or a third dye. In addition, they indicated that reduced capacities could be attributed to a combination of a number of factors. These include:

(1) interaction between dyes in solution.
(2) change of the adsorbent surface charge due to adsorption.
(3) Competitive adsorption between dyes for active sites on the carbon surface where displacement effects replace the other dyes from the adsorption sites.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The following conclusions are drawn from the study.

1. All two types of peanut can be used to remove direct and reactive dye.
2. Removal of water-soluble dyes using peanut hull depends on type of dye.
3. Adsorption ability of each type of dye depends on initial pH solution. Direct and reactive dyes can be adsorbed on peanut hull better in acidic solution (low pH value).
4. Adsorption ability of each type of dye depends on adsorbent weight and initial concentration of dye solution. Adsorption ability of direct and reactive dyes increase with increasing adsorbent weight and initial concentration of each dye.
5. Adsorption ability of each type of dye depends on particle size. Adsorption ability of direct and reactive dyes decreases with increasing of particle size of peanut hull.
6. Adsorption ability of each type of dye depends on breeding of peanut. The result found that adsorption ability of direct and reactive dyes on KAC431 better KAC1.
7. Equilibrium adsorption capacities decreased in multicomponent systems as compared to single component system.

5.2 Recommendation

Recommendations for future studies and research are as follows:

1. The available data were not sufficient for reliable design of multicomponent system. Some of these variables on components such as ternary system.

2. The future study should attempt to correlate the single component equilibrium data with the multicomponent equilibrium data.

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Appendix

Appendix A

Table A1 Conditions and results of adsorption experiment.

1. Contact time on adsorption experiment by peanut hull (KAC431).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	1	0.099	0.102	0.105	0.112	5.216
direct yellow	0.150-0.180	5	50	5	2	0.094	0.098	0.097	0.091	6.118
direct yellow	0.150-0.180	5	50	5	3	0.083	0.088	0.088	0.086	6.947
direct yellow	0.150-0.180	5	50	5	4	0.074	0.075	0.079	0.083	7.714
direct yellow	0.150-0.180	5	50	5	5	0.068	0.067	0.070	0.076	8.426
direct yellow	0.150-0.180	5	50	5	6	0.062	0.060	0.059	0.070	9.122
direct yellow	0.150-0.180	5	50	5	7	0.051	0.059	0.059	0.054	9.771
direct yellow	0.150-0.180	5	50	5	8	0.048	0.049	0.051	0.051	10.377
direct yellow	0.150-0.180	5	50	5	9	0.037	0.044	0.045	0.050	10.884
direct yellow	0.150-0.180	5	50	5	10	0.032	0.037	0.042	0.048	11.348
direct yellow	0.150-0.180	5	50	5	11	0.027	0.037	0.032	0.041	11.786
direct yellow	0.150-0.180	5	50	5	12	0.020	0.034	0.032	0.038	12.123

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	13	0.018	0.030	0.026	0.035	12.448
direct yellow	0.150-0.180	5	50	5	14	0.017	0.023	0.025	0.032	12.734
direct yellow	0.150-0.180	5	50	5	15	0.016	0.021	0.021	0.028	12.989
direct yellow	0.150-0.180	5	50	5	16	0.016	0.018	0.019	0.024	13.214
direct yellow	0.150-0.180	5	50	5	17	0.013	0.016	0.017	0.023	13.396
direct yellow	0.150-0.180	5	50	5	18	0.012	0.012	0.016	0.020	13.586
direct yellow	0.150-0.180	5	50	5	19	0.010	0.013	0.016	0.015	13.729
direct yellow	0.150-0.180	5	50	5	20	0.009	0.011	0.015	0.015	13.842
direct yellow	0.150-0.180	5	50	5	21	0.008	0.010	0.013	0.013	13.951
direct yellow	0.150-0.180	5	50	5	22	0.007	0.010	0.013	0.013	14.024
direct yellow	0.150-0.180	5	50	5	23	0.006	0.008	0.011	0.013	14.108
direct yellow	0.150-0.180	5	50	5	24	0.005	0.008	0.011	0.013	14.167
direct yellow	0.150-0.180	5	50	5	25	0.004	0.007	0.010	0.013	14.204
direct yellow	0.150-0.180	5	50	5	26	0.004	0.007	0.009	0.013	14.236
direct yellow	0.150-0.180	5	50	5	27	0.004	0.006	0.009	0.012	14.239

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct red	0.150-0.180	5	50	5	1	0.361	0.358	0.390	0.338	4.769
direct red	0.150-0.180	5	50	5	2	0.319	0.323	0.367	0.295	5.782
direct red	0.150-0.180	5	50	5	3	0.289	0.301	0.337	0.254	6.644
direct red	0.150-0.180	5	50	5	4	0.250	0.283	0.297	0.217	7.593
direct red	0.150-0.180	5	50	5	5	0.240	0.246	0.260	0.196	8.341
direct red	0.150-0.180	5	50	5	6	0.197	0.214	0.258	0.192	8.909
direct red	0.150-0.180	5	50	5	7	0.171	0.213	0.220	0.183	9.436
direct red	0.150-0.180	5	50	5	8	0.152	0.188	0.210	0.162	9.965
direct red	0.150-0.180	5	50	5	9	0.143	0.166	0.187	0.155	10.397
direct red	0.150-0.180	5	50	5	10	0.136	0.147	0.175	0.136	10.798
direct red	0.150-0.180	5	50	5	11	0.130	0.139	0.149	0.130	11.123
direct red	0.150-0.180	5	50	5	12	0.123	0.121	0.139	0.114	11.487
direct red	0.150-0.180	5	50	5	13	0.113	0.108	0.130	0.109	11.746
direct red	0.150-0.180	5	50	5	14	0.102	0.106	0.125	0.102	11.924
direct red	0.150-0.180	5	50	5	15	0.091	0.106	0.111	0.102	12.108

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct red	0.150-0.180	5	50	5	16	0.079	0.102	0.105	0.101	12.258
direct red	0.150-0.180	5	50	5	17	0.070	0.101	0.102	0.096	12.387
direct red	0.150-0.180	5	50	5	18	0.065	0.095	0.099	0.095	12.502
direct red	0.150-0.180	5	50	5	19	0.063	0.091	0.094	0.092	12.596
direct red	0.150-0.180	5	50	5	20	0.056	0.087	0.092	0.091	12.694
direct red	0.150-0.180	5	50	5	21	0.052	0.081	0.092	0.090	12.779
direct red	0.150-0.180	5	50	5	22	0.047	0.077	0.091	0.089	12.846
direct red	0.150-0.180	5	50	5	23	0.044	0.075	0.087	0.089	12.912
direct red	0.150-0.180	5	50	5	24	0.043	0.073	0.084	0.088	12.955
direct red	0.150-0.180	5	50	5	25	0.042	0.073	0.083	0.088	12.973
direct red	0.150-0.180	5	50	5	26	0.042	0.073	0.083	0.088	12.975
direct red	0.150-0.180	5	50	5	27	0.042	0.072	0.083	0.088	12.984
reactive blue	0.150-0.180	5	50	5	1	0.220	0.250	0.222	0.225	4.524
reactive blue	0.150-0.180	5	50	5	2	0.194	0.240	0.217	0.200	5.275
reactive blue	0.150-0.180	5	50	5	3	0.182	0.218	0.198	0.197	5.914

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive blue	0.150-0.180	5	50	5	4	0.172	0.192	0.196	0.186	6.482
reactive blue	0.150-0.180	5	50	5	6	0.154	0.176	0.174	0.173	7.274
reactive blue	0.150-0.180	5	50	5	7	0.145	0.171	0.162	0.169	7.594
reactive blue	0.150-0.180	5	50	5	8	0.139	0.164	0.161	0.166	7.799
reactive blue	0.150-0.180	5	50	5	9	0.136	0.159	0.155	0.157	8.051
reactive blue	0.150-0.180	5	50	5	10	0.133	0.158	0.154	0.142	8.304
reactive blue	0.150-0.180	5	50	5	11	0.132	0.152	0.145	0.140	8.498
reactive blue	0.150-0.180	5	50	5	12	0.127	0.148	0.144	0.137	8.643
reactive blue	0.150-0.180	5	50	5	13	0.125	0.143	0.141	0.134	8.801
reactive blue	0.150-0.180	5	50	5	14	0.124	0.140	0.135	0.132	8.928
reactive blue	0.150-0.180	5	50	5	15	0.123	0.139	0.133	0.128	9.034
reactive blue	0.150-0.180	5	50	5	16	0.122	0.134	0.130	0.126	9.139
reactive blue	0.150-0.180	5	50	5	17	0.121	0.130	0.129	0.125	9.238
reactive blue	0.150-0.180	5	50	5	18	0.120	0.129	0.128	0.119	9.335
reactive blue	0.150-0.180	5	50	5	19	0.119	0.126	0.124	0.119	9.431

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive blue	0.150-0.180	5	50	5	20	0.118	0.125	0.123	0.115	9.502
reactive blue	0.150-0.180	5	50	5	21	0.117	0.124	0.122	0.114	9.554
reactive blue	0.150-0.180	5	50	5	22	0.115	0.124	0.121	0.113	9.609
reactive blue	0.150-0.180	5	50	5	23	0.113	0.123	0.120	0.112	9.648
reactive blue	0.150-0.180	5	50	5	24	0.112	0.122	0.120	0.112	9.675
reactive blue	0.150-0.180	5	50	5	25	0.111	0.122	0.120	0.112	9.699
reactive blue	0.150-0.180	5	50	5	26	0.109	0.122	0.120	0.112	9.717
reactive blue	0.150-0.180	5	50	5	27	0.109	0.122	0.119	0.111	9.732
reactive yellow	0.150-0.180	5	50	5	1	0.141	0.154	0.159	0.126	4.839
reactive yellow	0.150-0.180	5	50	5	2	0.134	0.149	0.155	0.104	5.527
reactive yellow	0.150-0.180	5	50	5	3	0.124	0.143	0.138	0.098	6.214
reactive yellow	0.150-0.180	5	50	5	4	0.107	0.141	0.130	0.089	6.817
reactive yellow	0.150-0.180	5	50	5	5	0.098	0.136	0.127	0.076	7.358
reactive yellow	0.150-0.180	5	50	5	6	0.088	0.128	0.124	0.075	7.737
reactive yellow	0.150-0.180	5	50	5	7	0.085	0.126	0.122	0.063	8.054

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive yellow	0.150-0.180	5	50	5	8	0.078	0.126	0.121	0.054	8.369
reactive yellow	0.150-0.180	5	50	5	9	0.072	0.124	0.120	0.045	8.681
reactive yellow	0.150-0.180	5	50	5	10	0.071	0.123	0.115	0.037	8.953
reactive yellow	0.150-0.180	5	50	5	11	0.069	0.120	0.114	0.028	9.205
reactive yellow	0.150-0.180	5	50	5	12	0.066	0.114	0.112	0.026	9.424
reactive yellow	0.150-0.180	5	50	5	13	0.064	0.112	0.111	0.022	9.603
reactive yellow	0.150-0.180	5	50	5	14	0.061	0.107	0.110	0.022	9.774
reactive yellow	0.150-0.180	5	50	5	15	0.058	0.104	0.107	0.021	9.925
reactive yellow	0.150-0.180	5	50	5	16	0.057	0.102	0.106	0.017	10.068
reactive yellow	0.150-0.180	5	50	5	17	0.057	0.102	0.105	0.012	10.196
reactive yellow	0.150-0.180	5	50	5	18	0.054	0.100	0.102	0.012	10.318
reactive yellow	0.150-0.180	5	50	5	19	0.053	0.099	0.098	0.010	10.435
reactive yellow	0.150-0.180	5	50	5	20	0.051	0.098	0.097	0.009	10.554
reactive yellow	0.150-0.180	5	50	5	21	0.049	0.097	0.095	0.008	10.638
reactive yellow	0.150-0.180	5	50	5	22	0.047	0.097	0.094	0.007	10.706

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive yellow	0.150-0.180	5	50	5	23	0.045	0.096	0.093	0.007	10.757
reactive yellow	0.150-0.180	5	50	5	24	0.044	0.096	0.093	0.011	10.795
reactive yellow	0.150-0.180	5	50	5	25	0.044	0.096	0.092	0.007	10.824
reactive yellow	0.150-0.180	5	50	5	26	0.044	0.095	0.092	0.007	10.835
reactive yellow	0.150-0.180	5	50	5	27	0.044	0.095	0.092	0.007	10.841

2. Contact time on adsorption experiment by peanut hull (KAC1).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	1	0.097	0.108	0.107	0.104	5.285
direct yellow	0.150-0.180	5	50	5	2	0.094	0.104	0.098	0.091	5.967
direct yellow	0.150-0.180	5	50	5	3	0.090	0.097	0.094	0.089	6.366
direct yellow	0.150-0.180	5	50	5	4	0.086	0.092	0.088	0.086	6.764
direct yellow	0.150-0.180	5	50	5	5	0.081	0.088	0.083	0.086	7.106
direct yellow	0.150-0.180	5	50	5	6	0.079	0.083	0.079	0.084	7.390
direct yellow	0.150-0.180	5	50	5	7	0.075	0.084	0.077	0.080	7.618
direct yellow	0.150-0.180	5	50	5	8	0.071	0.082	0.073	0.080	7.846
direct yellow	0.150-0.180	5	50	5	9	0.069	0.075	0.071	0.079	8.130
direct yellow	0.150-0.180	5	50	5	10	0.068	0.073	0.068	0.078	8.300
direct yellow	0.150-0.180	5	50	5	11	0.066	0.071	0.067	0.078	8.415
direct yellow	0.150-0.180	5	50	5	12	0.062	0.070	0.065	0.078	8.585
direct yellow	0.150-0.180	5	50	5	13	0.059	0.069	0.062	0.077	8.756
direct yellow	0.150-0.180	5	50	5	14	0.057	0.068	0.061	0.076	8.870

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	15	0.057	0.068	0.059	0.073	8.984
direct yellow	0.150-0.180	5	50	5	16	0.056	0.067	0.059	0.073	9.041
direct yellow	0.150-0.180	5	50	5	17	0.055	0.066	0.058	0.073	9.098
direct yellow	0.150-0.180	5	50	5	18	0.055	0.066	0.057	0.072	9.154
direct yellow	0.150-0.180	5	50	5	19	0.055	0.065	0.057	0.071	9.211
direct yellow	0.150-0.180	5	50	5	20	0.054	0.065	0.056	0.070	9.268
direct yellow	0.150-0.180	5	50	5	21	0.054	0.064	0.056	0.069	9.325
direct yellow	0.150-0.180	5	50	5	22	0.053	0.064	0.055	0.068	9.382
direct yellow	0.150-0.180	5	50	5	23	0.053	0.064	0.054	0.067	9.439
direct yellow	0.150-0.180	5	50	5	24	0.053	0.063	0.054	0.065	9.496
direct yellow	0.150-0.180	5	50	5	25	0.053	0.063	0.054	0.065	9.513
direct yellow	0.150-0.180	5	50	5	26	0.053	0.063	0.054	0.065	9.525
direct yellow	0.150-0.180	5	50	5	27	0.053	0.062	0.054	0.065	9.541
direct red	0.150-0.180	5	50	5	1	0.355	0.388	0.394	0.377	4.300
direct red	0.150-0.180	5	50	5	2	0.340	0.382	0.390	0.297	5.035

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct red	0.150-0.180	5	50	5	3	0.324	0.379	0.376	0.269	5.467
direct red	0.150-0.180	5	50	5	4	0.304	0.368	0.367	0.233	6.013
direct red	0.150-0.180	5	50	5	5	0.288	0.355	0.355	0.212	6.446
direct red	0.150-0.180	5	50	5	6	0.282	0.334	0.344	0.200	6.804
direct red	0.150-0.180	5	50	5	7	0.268	0.323	0.328	0.198	7.105
direct red	0.150-0.180	5	50	5	8	0.253	0.317	0.320	0.181	7.425
direct red	0.150-0.180	5	50	5	9	0.246	0.302	0.310	0.179	7.670
direct red	0.150-0.180	5	50	5	10	0.240	0.293	0.300	0.172	7.895
direct red	0.150-0.180	5	50	5	11	0.229	0.288	0.294	0.167	8.084
direct red	0.150-0.180	5	50	5	12	0.223	0.285	0.293	0.153	8.253
direct red	0.150-0.180	5	50	5	13	0.219	0.275	0.287	0.506	8.404
direct red	0.150-0.180	5	50	5	14	0.213	0.268	0.283	0.151	8.535
direct red	0.150-0.180	5	50	5	15	0.211	0.262	0.275	0.148	8.667
direct red	0.150-0.180	5	50	5	16	0.209	0.256	0.268	0.148	8.780
direct red	0.150-0.180	5	50	5	17	0.206	0.255	0.266	0.139	8.874

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct red	0.150-0.180	5	50	5	18	0.205	0.253	0.264	0.134	8.950
direct red	0.150-0.180	5	50	5	19	0.200	0.251	0.262	0.132	9.025
direct red	0.150-0.180	5	50	5	20	0.197	0.249	0.261	0.130	9.081
direct red	0.150-0.180	5	50	5	21	0.193	0.247	0.258	0.128	9.157
direct red	0.150-0.180	5	50	5	22	0.190	0.247	0.258	0.124	9.213
direct red	0.150-0.180	5	50	5	23	0.188	0.246	0.258	0.124	9.232
direct red	0.150-0.180	5	50	5	24	0.188	0.246	0.257	0.123	9.251
direct red	0.150-0.180	5	50	5	25	0.186	0.246	0.256	0.122	9.270
direct red	0.150-0.180	5	50	5	26	0.185	0.245	0.256	0.122	9.276
direct red	0.150-0.180	5	50	5	27	0.185	0.245	0.256	0.122	9.282
reactive blue	0.150-0.180	5	50	5	1	0.236	0.242	0.244	0.240	4.029
reactive blue	0.150-0.180	5	50	5	2	0.220	0.240	0.238	0.216	4.559
reactive blue	0.150-0.180	5	50	5	3	0.213	0.234	0.231	0.205	4.921
reactive blue	0.150-0.180	5	50	5	4	0.199	0.225	0.220	0.203	5.339
reactive blue	0.150-0.180	5	50	5	5	0.189	0.218	0.216	0.197	5.618

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive blue	0.150-0.180	5	50	5	6	0.178	0.211	0.210	0.195	5.925
reactive blue	0.150-0.180	5	50	5	7	0.176	0.203	0.202	0.194	6.148
reactive blue	0.150-0.180	5	50	5	8	0.170	0.199	0.199	0.180	6.454
reactive blue	0.150-0.180	5	50	5	9	0.168	0.194	0.196	0.180	6.566
reactive blue	0.150-0.180	5	50	5	10	0.166	0.193	0.194	0.178	6.649
reactive blue	0.150-0.180	5	50	5	11	0.164	0.192	0.194	0.176	6.705
reactive blue	0.150-0.180	5	50	5	12	0.164	0.191	0.193	0.172	6.789
reactive blue	0.150-0.180	5	50	5	13	0.162	0.190	0.191	0.171	6.845
reactive blue	0.150-0.180	5	50	5	14	0.161	0.188	0.188	0.171	6.928
reactive blue	0.150-0.180	5	50	5	15	0.160	0.186	0.186	0.170	6.984
reactive blue	0.150-0.180	5	50	5	16	0.159	0.184	0.184	0.170	7.040
reactive blue	0.150-0.180	5	50	5	17	0.158	0.183	0.183	0.169	7.095
reactive blue	0.150-0.180	5	50	5	18	0.157	0.182	0.182	0.168	7.123
reactive blue	0.150-0.180	5	50	5	19	0.156	0.182	0.181	0.168	7.151
reactive blue	0.150-0.180	5	50	5	20	0.155	0.182	0.181	0.164	7.207

Type of dye	0.150-0.180 0.150-0.180	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive blue	0.150-0.180	5	50	5	21	0.154	0.181	0.181	0.162	7.263
reactive blue	0.150-0.180	5	50	5	22	0.153	0.180	0.180	0.161	7.291
reactive blue	0.150-0.180	5	50	5	23	0.152	0.180	0.180	0.161	7.318
reactive blue	0.150-0.180	5	50	5	24	0.152	0.179	0.179	0.160	7.346
reactive blue	0.150-0.180	5	50	5	25	0.151	0.179	0.179	0.159	7.374
reactive blue	0.150-0.180	5	50	5	26	0.151	0.179	0.178	0.159	7.384
reactive blue	0.150-0.180	5	50	5	27	0.150	0.179	0.178	0.159	7.395
reactive yellow	0.150-0.180	5	50	5	1	0.145	0.153	0.154	0.150	4.484
reactive yellow	0.150-0.180	5	50	5	2	0.137	0.148	0.150	0.142	4.902
reactive yellow	0.150-0.180	5	50	5	3	0.129	0.146	0.145	0.134	5.284
reactive yellow	0.150-0.180	5	50	5	6	0.117	0.134	0.138	0.117	6.153
reactive yellow	0.150-0.180	5	50	5	7	0.113	0.130	0.132	0.116	6.396
reactive yellow	0.150-0.180	5	50	5	8	0.109	0.128	0.128	0.110	6.674
reactive yellow	0.150-0.180	5	50	5	9	0.104	0.127	0.127	0.110	6.813
reactive yellow	0.150-0.180	5	50	5	10	0.101	0.126	0.126	0.105	6.987

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive yellow	0.150-0.180	5	50	5	11	0.100	0.124	0.125	0.099	7.161
reactive yellow	0.150-0.180	5	50	5	12	0.096	0.124	0.122	0.098	7.300
reactive yellow	0.150-0.180	5	50	5	13	0.094	0.123	0.120	0.095	7.439
reactive yellow	0.150-0.180	5	50	5	14	0.093	0.121	0.118	0.093	7.543
reactive yellow	0.150-0.180	5	50	5	15	0.092	0.121	0.117	0.087	7.682
reactive yellow	0.150-0.180	5	50	5	16	0.091	0.120	0.117	0.085	7.786
reactive yellow	0.150-0.180	5	50	5	17	0.089	0.119	0.115	0.083	7.891
reactive yellow	0.150-0.180	5	50	5	18	0.088	0.118	0.114	0.081	7.995
reactive yellow	0.150-0.180	5	50	5	19	0.087	0.116	0.113	0.080	8.064
reactive yellow	0.150-0.180	5	50	5	20	0.087	0.115	0.110	0.080	8.134
reactive yellow	0.150-0.180	5	50	5	21	0.086	0.115	0.110	0.080	8.169
reactive yellow	0.150-0.180	5	50	5	22	0.085	0.115	0.109	0.079	8.203
reactive yellow	0.150-0.180	5	50	5	23	0.085	0.114	0.109	0.078	8.238
reactive yellow	0.150-0.180	5	50	5	24	0.084	0.114	0.109	0.077	8.273
reactive yellow	0.150-0.180	5	50	5	25	0.084	0.114	0.109	0.077	8.283

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive yellow	0.150-0.180	5	50	5	26	0.084	0.114	0.109	0.077	8.290
reactive yellow	0.150-0.180	5	50	5	27	0.084	0.114	0.109	0.077	8.299

3. Adsorbent weight on adsorption experiment by peanut hull(KAC431).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	1	50	5	25	0.083	0.055	0.078	0.072	8.261
direct yellow	0.150-0.180	3	50	5	25	0.043	0.032	0.037	0.024	11.847
direct yellow	0.150-0.180	5	50	5	25	0.004	0.007	0.010	0.013	14.204
direct yellow	0.150-0.180	7	50	5	25	0.001	0.001	0.001	0.002	14.896
direct red	0.150-0.180	1	50	5	25	0.235	0.247	0.306	0.254	7.633
direct red	0.150-0.180	3	50	5	25	0.192	0.157	0.119	0.231	10.054
direct red	0.150-0.180	5	50	5	25	0.042	0.073	0.083	0.088	12.973
direct red	0.150-0.180	7	50	5	25	0.037	0.065	0.076	0.083	13.153
reactive blue	0.150-0.180	1	50	5	25	0.197	0.226	0.258	0.198	4.952
reactive blue	0.150-0.180	3	50	5	25	0.163	0.132	0.173	0.165	7.768
reactive blue	0.150-0.180	5	50	5	25	0.111	0.122	0.120	0.112	9.699
reactive blue	0.150-0.180	7	50	5	25	0.110	0.106	0.103	0.111	10.082
reactive yellow	0.150-0.180	1	50	5	25	0.107	0.145	0.108	0.121	6.577
reactive yellow	0.150-0.180	3	50	5	25	0.085	0.107	0.094	0.096	8.318

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive yellow	0.150-0.180	5	50	5	25	0.044	0.096	0.092	0.007	10.824
reactive yellow	0.150-0.180	7	50	5	25	0.042	0.083	0.083	0.005	11.251

4. Adsorbent weight on adsorption experiment by peanut hull(KAC1).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	1	50	5	25	0.121	0.123	0.129	0.118	3.533
direct yellow	0.150-0.180	3	50	5	25	0.070	0.083	0.082	0.105	7.054
direct yellow	0.150-0.180	5	50	5	25	0.053	0.063	0.054	0.065	9.513
direct yellow	0.150-0.180	7	50	5	25	0.047	0.057	0.054	0.061	9.893
direct red	0.150-0.180	1	50	5	25	0.414	0.432	0.445	0.385	3.149
direct red	0.150-0.180	3	50	5	25	0.278	0.293	0.314	0.259	6.914
direct red	0.150-0.180	5	50	5	25	0.186	0.246	0.256	0.122	9.270
direct red	0.150-0.180	7	50	5	25	0.179	0.211	0.239	0.114	9.756
reactive blue	0.150-0.180	1	50	5	25	0.266	0.285	0.286	0.280	2.243
reactive blue	0.150-0.180	3	50	5	25	0.226	0.229	0.228	0.164	5.318
reactive blue	0.150-0.180	5	50	5	25	0.151	0.179	0.179	0.159	7.374
reactive blue	0.150-0.180	7	50	5	25	0.133	0.144	0.140	0.137	8.681
reactive yellow	0.150-0.180	1	50	5	25	0.163	0.186	0.186	0.169	2.692
reactive yellow	0.150-0.180	3	50	5	25	0.129	0.141	0.140	0.102	6.041

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
reactive yellow	0.150-0.180	5	50	5	25	0.084	0.114	0.109	0.077	8.283
reactive yellow	0.150-0.180	7	50	5	25	0.073	0.107	0.104	0.069	8.819

5. Particle size of peanut hull(KAC431) experiment.

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.210-0.300	5	50	5	25	0.027	0.038	0.033	0.066	11.145
direct yellow	0.180-0.210	5	50	5	25	0.017	0.022	0.023	0.031	12.834
direct yellow	0.150-0.180	5	50	5	25	0.004	0.007	0.010	0.013	14.204
direct red	0.210-0.300	5	50	5	25	0.161	0.296	0.182	0.174	9.252
direct red	0.180-0.210	5	50	5	25	0.090	0.142	0.109	0.104	11.847
direct red	0.150-0.180	5	50	5	25	0.042	0.073	0.083	0.088	12.973
reactive blue	0.210-0.300	5	50	5	25	0.174	0.180	0.187	0.168	6.899
reactive blue	0.180-0.210	5	50	5	25	0.132	0.141	0.134	0.178	8.315
reactive blue	0.150-0.180	5	50	5	25	0.111	0.122	0.120	0.112	9.699
reactive yellow	0.210-0.300	5	50	5	25	0.092	0.101	0.108	0.088	8.174
reactive yellow	0.180-0.210	5	50	5	25	0.071	0.098	0.102	0.041	9.548
reactive yellow	0.150-0.180	5	50	5	25	0.044	0.096	0.092	0.007	10.824

6. Particle size of peanut hull(KAC431) experiment.

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.210-0.300	5	50	5	25	0.075	0.082	0.076	0.088	7.482
direct yellow	0.180-0.210	5	50	5	25	0.063	0.070	0.066	0.073	8.648
direct yellow	0.150-0.180	5	50	5	25	0.053	0.063	0.054	0.065	9.513
direct red	0.210-0.300	5	50	5	25	0.284	0.323	0.352	0.198	6.821
direct red	0.180-0.210	5	50	5	25	0.216	0.285	0.292	0.133	8.451
direct red	0.150-0.180	5	50	5	25	0.186	0.246	0.256	0.122	9.270
reactive blue	0.210-0.300	5	50	5	25	0.199	0.220	0.220	0.235	5.014
reactive blue	0.180-0.210	5	50	5	25	0.157	0.198	0.196	0.165	6.822
reactive blue	0.150-0.180	5	50	5	25	0.151	0.179	0.179	0.159	7.374
reactive yellow	0.210-0.300	5	50	5	25	0.124	0.134	0.130	0.117	6.153
reactive yellow	0.180-0.210	5	50	5	25	0.101	0.115	0.114	0.082	7.795
reactive yellow	0.150-0.180	5	50	5	25	0.084	0.114	0.109	0.077	8.283

7. Initial dye concentration on dye adsorption experiment by peanut hull(KAC431).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	10	5	25	0.002	0.002	0.008	0.004	14.615
direct yellow	0.150-0.180	5	30	5	25	0.003	0.004	0.009	0.007	14.484
direct yellow	0.150-0.180	5	50	5	25	0.004	0.007	0.010	0.013	14.204
direct red	0.150-0.180	5	10	5	25	0.033	0.058	0.074	0.085	13.224
direct red	0.150-0.180	5	30	5	25	0.036	0.063	0.075	0.088	13.146
direct red	0.150-0.180	5	50	5	25	0.042	0.073	0.083	0.088	12.973
reactive blue	0.150-0.180	5	10	5	25	0.106	0.116	0.115	0.109	9.895
reactive blue	0.150-0.180	5	30	5	25	0.109	0.117	0.117	0.111	9.816
reactive blue	0.150-0.180	5	50	5	25	0.111	0.122	0.120	0.112	9.699
reactive yellow	0.150-0.180	5	10	5	25	0.035	0.067	0.068	0.004	11.967
reactive yellow	0.150-0.180	5	30	5	25	0.042	0.082	0.085	0.005	11.254
reactive yellow	0.150-0.180	5	50	5	25	0.044	0.096	0.092	0.007	10.824

8. Initial dye concentration on dye adsorption experiment by peanut hull(KAC1).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	10	5	25	0.051	0.052	0.052	0.060	9.962
direct yellow	0.150-0.180	5	30	5	25	0.052	0.056	0.053	0.061	9.793
direct yellow	0.150-0.180	5	50	5	25	0.053	0.063	0.054	0.065	9.513
direct red	0.150-0.180	5	10	5	25	0.176	0.220	0.233	0.091	9.914
direct red	0.150-0.180	5	30	5	25	0.180	0.232	0.244	0.110	9.706
direct red	0.150-0.180	5	50	5	25	0.186	0.246	0.256	0.122	9.270
reactive blue	0.150-0.180	5	10	5	25	0.109	0.143	0.142	0.110	9.246
reactive blue	0.150-0.180	5	30	5	25	0.122	0.152	0.152	0.112	8.853
reactive blue	0.150-0.180	5	50	5	25	0.151	0.179	0.179	0.159	7.374
reactive yellow	0.150-0.180	5	10	5	25	0.057	0.105	0.096	0.060	9.428
reactive yellow	0.150-0.180	5	30	5	25	0.061	0.108	0.102	0.073	8.988
reactive yellow	0.150-0.180	5	50	5	25	0.084	0.114	0.109	0.077	8.283

9. Initial pH on dye adsorption experiment by peanut hull(KAC431).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	25	0.004	0.007	0.010	0.013	14.204
direct yellow	0.150-0.180	5	50	7	25	0.034	0.026	0.047	0.027	11.867
direct yellow	0.150-0.180	5	50	9	25	0.054	0.047	0.081	0.069	9.153
direct red	0.150-0.180	5	50	5	25	0.042	0.073	0.083	0.088	12.973
direct red	0.150-0.180	5	50	7	25	0.211	0.123	0.157	0.163	10.371
direct red	0.150-0.180	5	50	9	25	0.302	0.288	0.231	0.250	7.428
reactive blue	0.150-0.180	5	50	5	25	0.111	0.122	0.120	0.112	9.699
reactive blue	0.150-0.180	5	50	7	25	0.143	0.190	0.163	0.134	7.814
reactive blue	0.150-0.180	5	50	9	25	0.226	0.192	0.206	0.232	5.217
reactive yellow	0.150-0.180	5	50	5	25	0.044	0.096	0.092	0.007	10.824
reactive yellow	0.150-0.180	5	50	7	25	0.077	0.108	0.090	0.081	8.762
reactive yellow	0.150-0.180	5	50	9	25	0.111	0.135	0.119	0.122	6.483

10.Initial pH on dye adsorption experiment by peanut hull(KAC1).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	25	0.053	0.063	0.054	0.065	9.513
direct yellow	0.150-0.180	5	50	7	25	0.073	0.081	0.079	0.099	7.265
direct yellow	0.150-0.180	5	50	9	25	0.105	0.111	0.109	0.124	4.483
direct red	0.150-0.180	5	50	5	25	0.186	0.246	0.256	0.122	9.270
direct red	0.150-0.180	5	50	7	25	0.269	0.288	0.328	0.231	7.106
direct red	0.150-0.180	5	50	9	25	0.374	0.405	0.417	0.323	4.256
reactive blue	0.150-0.180	5	50	5	25	0.151	0.179	0.179	0.159	7.374
reactive blue	0.150-0.180	5	50	7	25	0.189	0.223	0.224	0.218	5.252
reactive blue	0.150-0.180	5	50	9	25	0.219	0.257	0.251	0.235	4.006
reactive yellow	0.150-0.180	5	50	5	25	0.084	0.114	0.109	0.077	8.283
reactive yellow	0.150-0.180	5	50	7	25	0.117	0.147	0.144	0.108	5.982
reactive yellow	0.150-0.180	5	50	9	25	0.150	0.165	0.169	0.144	4.017

11.Dye desorption of adsorption.

11.1 Dye desorption of peanut hull(KAC431)

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of desorbed dye after desorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	25	0.006	0.007	0.010	0.011	2.700
direct red	0.150-0.180	5	50	5	25	0.004	0.007	0.010	0.013	2.700
reactive blue	0.150-0.180	5	50	5	25	0.004	0.004	0.080	0.007	1.720
reactive yellow	0.150-0.180	5	50	5	25	0.006	0.008	0.011	0.012	2.607

11.2 Dye desorption of peanut hull(KAC1).

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of desorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	25	0.005	0.007	0.009	0.010	2.537
direct red	0.150-0.180	5	50	5	25	0.008	0.007	0.009	0.011	2.653
reactive blue	0.150-0.180	5	50	5	25	0.001	0.001	0.001	0.002	1.193
reactive yellow	0.150-0.180	5	50	5	25	0.002	0.003	0.007	0.004	1.307

Table A2 Conditions and results of multicomponent experiments.

Type of dye	Particle size (mm)	Adsorbent weight (g)	Int. Conc. (mg/l)	pH	Time (hr)	Absorbance of unadsorbed dye after adsorption				Adsorbed dye (mg/g)
direct yellow	0.150-0.180	5	50	5	25	0.113	0.114	0.111	0.111	7.149
direct red	0.150-0.180	5	50	5	25	0.121	0.122	0.121	0.121	6.513
reactive blue	0.150-0.180	5	50	5	25	0.150	0.151	0.149	0.151	4.485
reactive yellow	0.150-0.180	5	50	5	25	0.136	0.137	0.137	0.137	5.421

Appendix B

Calibration Curve of Dye Solution

Average slope value obtained from the calibration curve plotted between the absorbance of the dye solutions and the dye concentrations are shown in Table B1 to B4.

Table B1 Calibration curve of Direct Yellow12 at 405 nm

pH of dye	Concentration (mg/l)	Absorbance	Slope	R^2
5	0	0	0.0032	0.9999
	10	0.033		
	20	0.064		
	30	0.097		
	40	0.128		
	50	0.16		
7	0	0	0.0032	0.9997
	10	0.034		
	20	0.064		
	30	0.096		
	40	0.127		
	50	0.16		
9	0	0	0.0032	1
	10	0.032		
	20	0.064		
	30	0.095		
	40	0.128		
	50	0.16		

Average slope of Direct Yellow12 is 0.0032. Figure B1 to B3 show the calibration curve of Direct Yellow12 at pH5, pH7, and pH9, respectively.

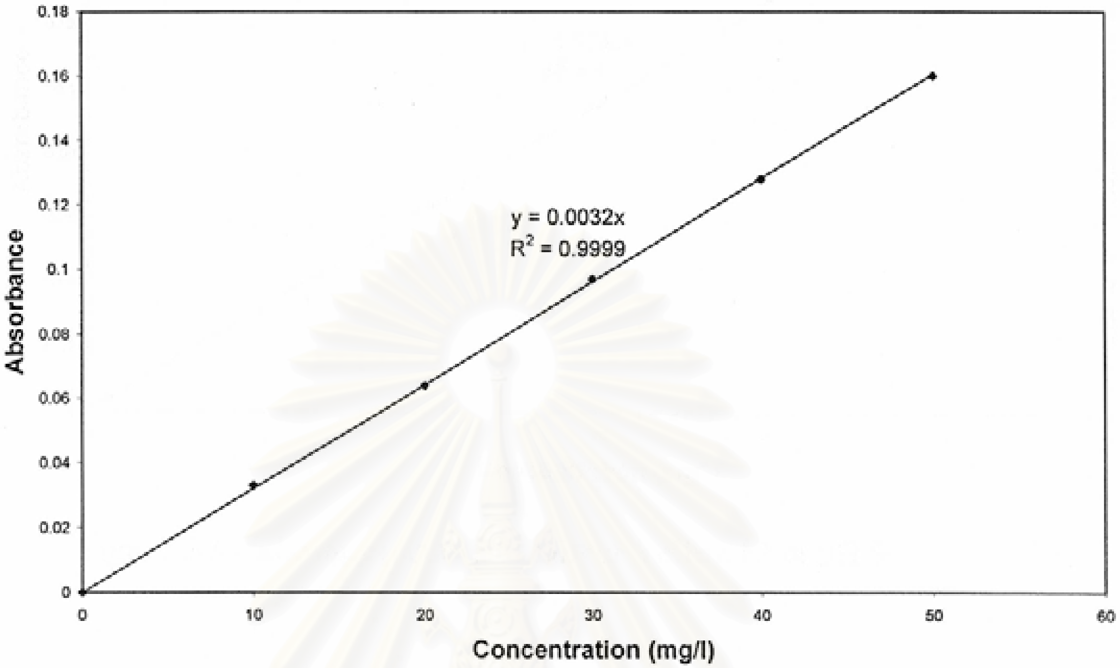

Figure B1 Calibration curve of Direct Yellow12 at pH 5

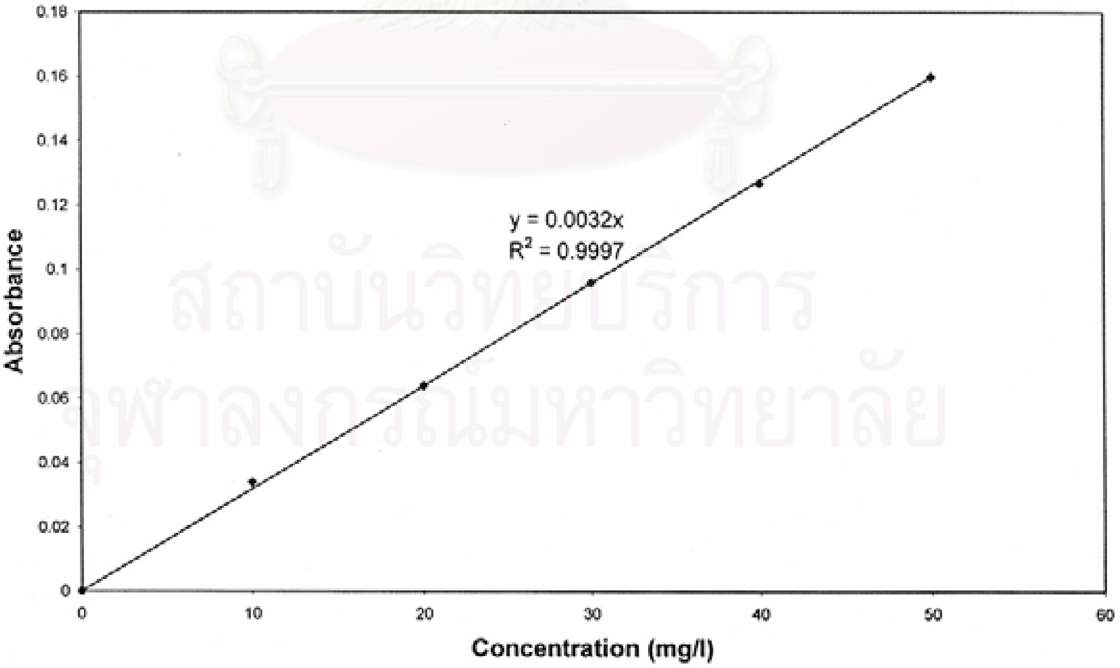

Figure B2 Calibration curve of Direct Yellow12 at pH 7

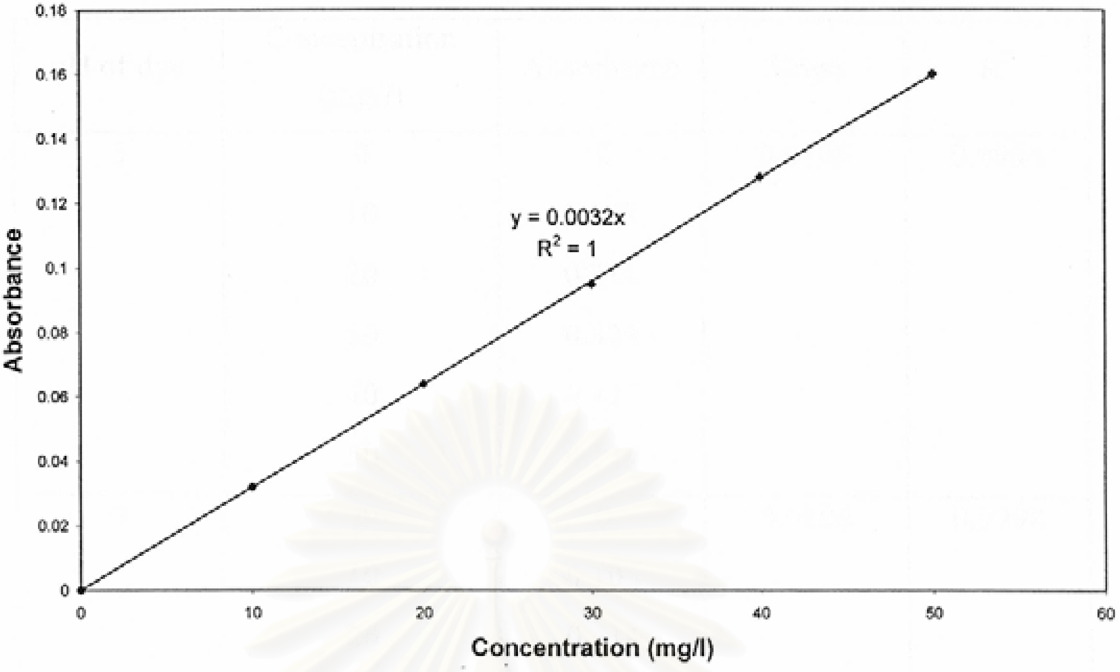

Figure B3 Calibration curve of Direct Yellow12 at pH 9

Table B2 Calibration curve of Direct Red81 at 497 nm

pH of dye	Concentration (mg/l)	Absorbance	Slope	R^2
5	0	0	0.0106	0.9996
	10	0.103		
	20	0.214		
	30	0.323		
	40	0.423		
	50	0.529		
7	0	0	0.0106	0.9998
	10	0.103		
	20	0.214		
	30	0.323		
	40	0.423		
	50	0.529		
9	0	0	0.0106	0.9997
	10	0.101		
	20	0.214		
	30	0.322		
	40	0.425		
	50	0.528		

Average slope of Direct Red81 is 0.0106. Figure B4 to B6 show the calibration curve of Direct Red81 at pH5, pH7, and pH9, respectively.

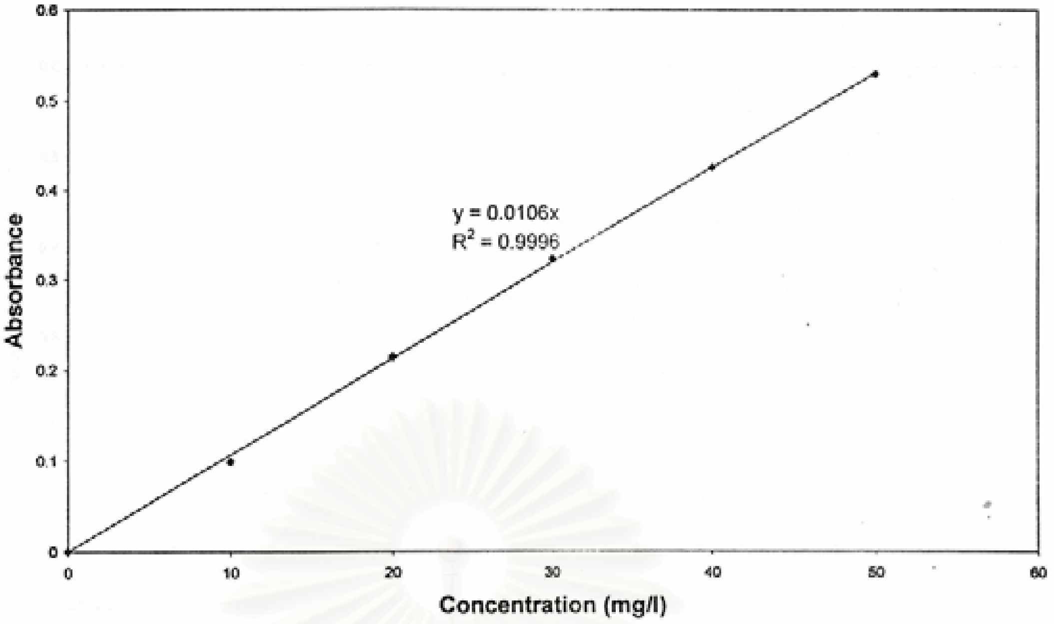

Figure B4 Calibration curve of Direct Red81 at pH 5

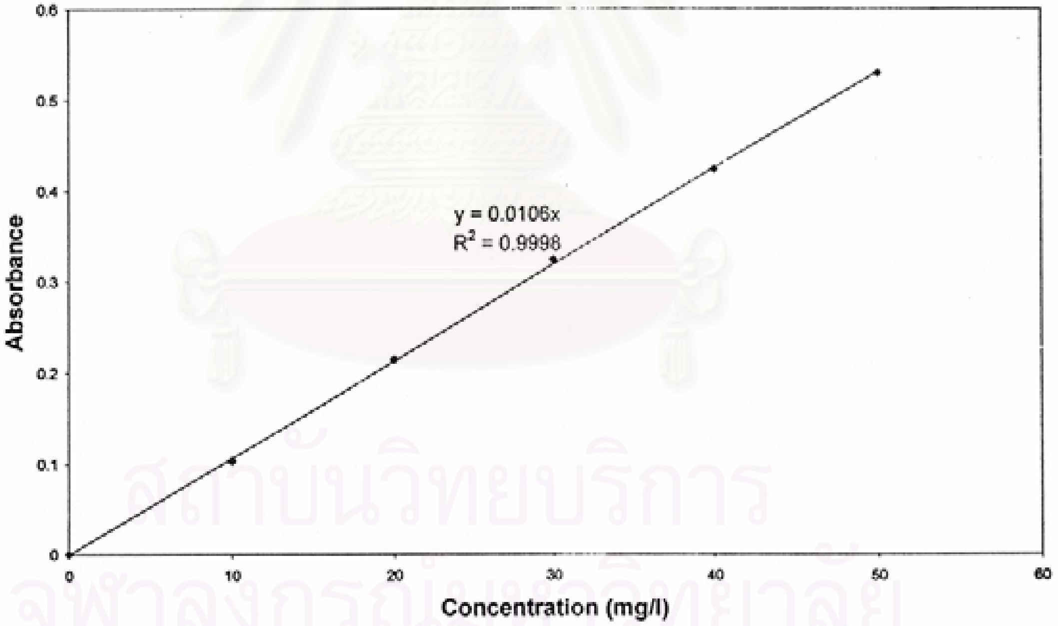

Figure B5 Calibration curve of Direct Red81 at pH 7

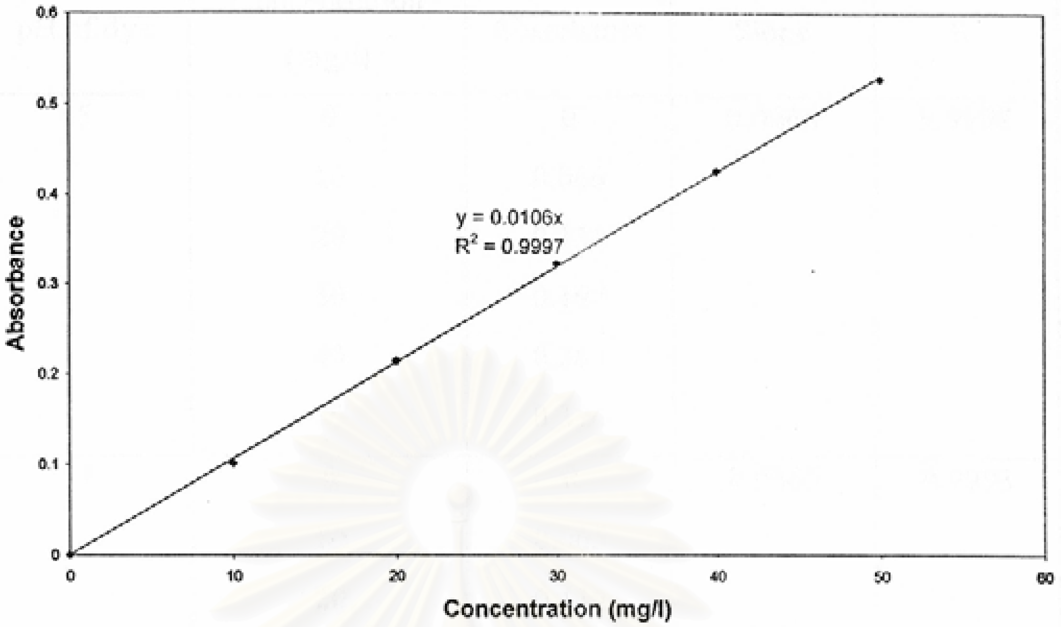

Figure B6 Calibration curve of Direct Red81 at pH 9

Table B3 Calibration curve of Reactive Blue19 at 595 nm

pH of dye	Concentration (mg/l)	Absorbance	Slope	R^2
5	0	0	0.0066	0.9998
	10	0.066		
	20	0.134		
	30	0.197		
	40	0.264		
	50	0.326		
7	0	0	0.0065	0.9993
	10	0.065		
	20	0.134		
	30	0.198		
	40	0.264		
	50	0.321		
9	0	0	0.0065	0.9993
	10	0.065		
	20	0.134		
	30	0.198		
	40	0.264		
	50	0.321		

Average slope of Reactive Blue19 is 0.0065. Figure B7 to B9 show the calibration curve of Reactive Blue19 at pH5, pH7, and pH9, respectively.

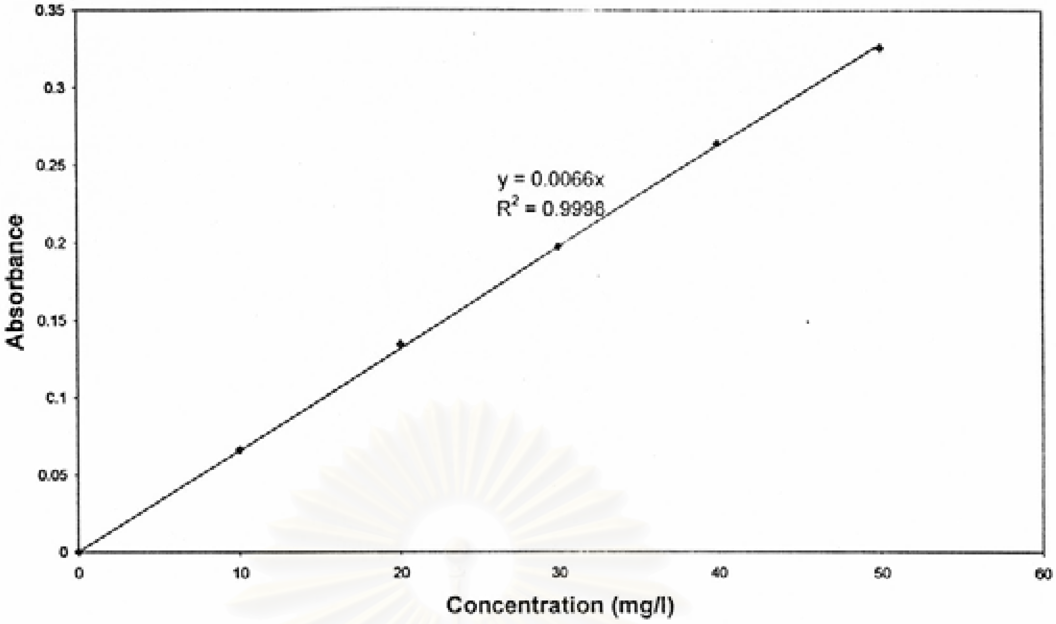

Figure B7 Calibration curve of Reactive Blue19 at pH 5

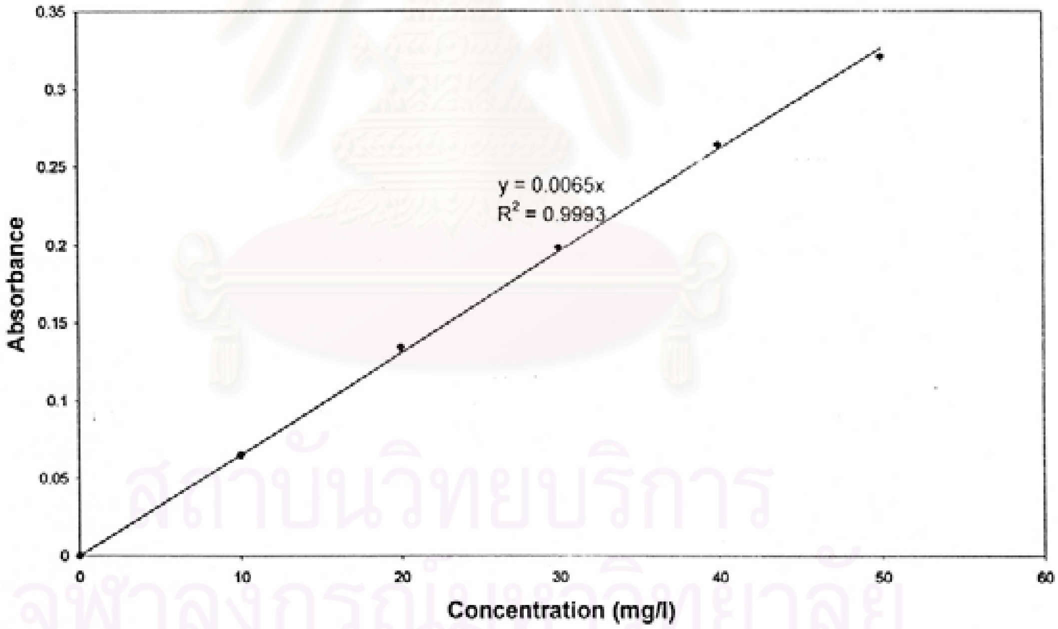

Figure B8 Calibration curve of Reactive Blue19 at pH 7

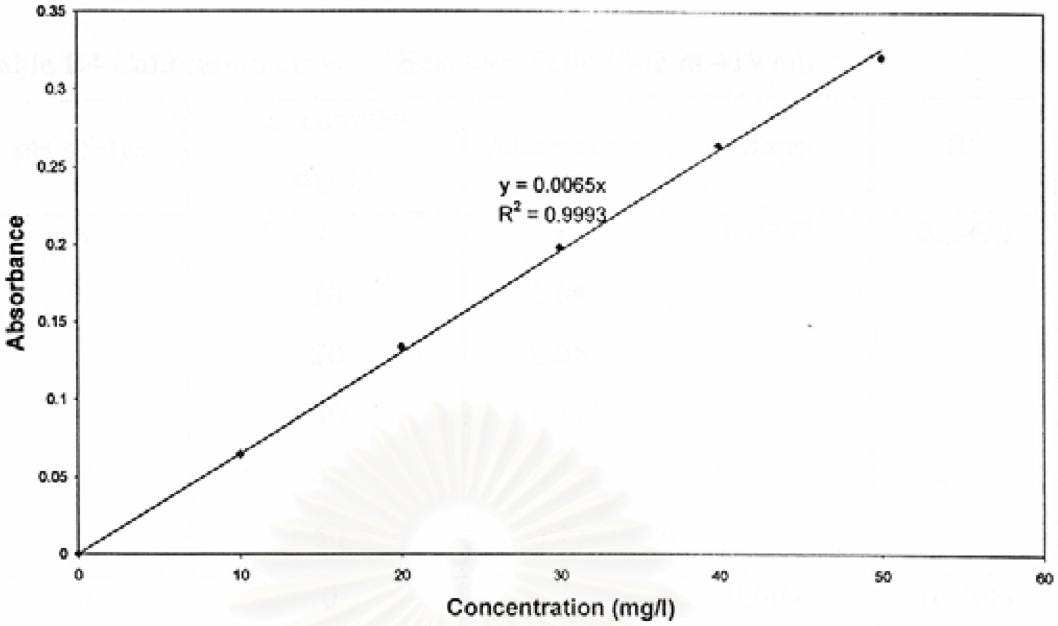

Figure B9 Calibration curve of Reactive Blue19 at pH 9

Table B4 Calibration curve of Reactive Yellow145 at 419 nm

pH of dye	Concentration (mg/l)	Absorbance	Slope	R^2
5	0	0	0.0043	0.9996
	10	0.046		
	20	0.087		
	30	0.128		
	40	0.172		
	50	0.213		
7	0	0	0.0043	0.9996
	10	0.046		
	20	0.087		
	30	0.129		
	40	0.173		
	50	0.214		
9	0	0	0.0043	0.9994
	10	0.045		
	20	0.088		
	30	0.126		
	40	0.173		
	50	0.213		

Average slope of Reactive Yellow145 is 0.0043. Figure B10 to B12 show the calibration curve of Reactive Yellow145 at pH5, pH7, and pH9, respectively.

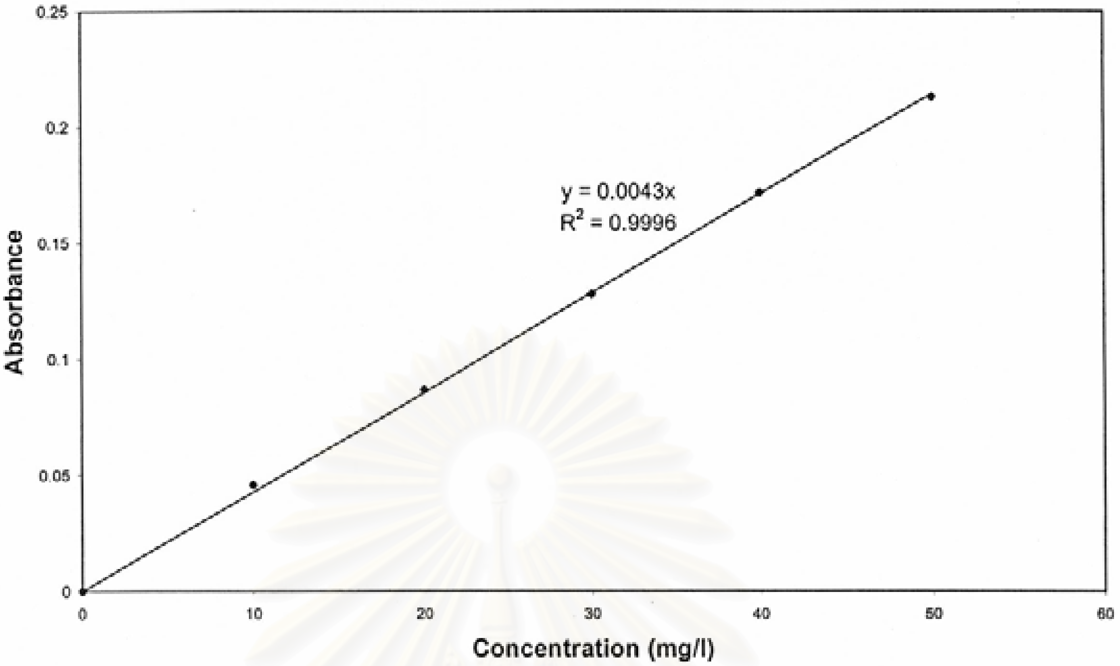

Figure B10 Calibration curve of Reactive Yellow145 at pH 5

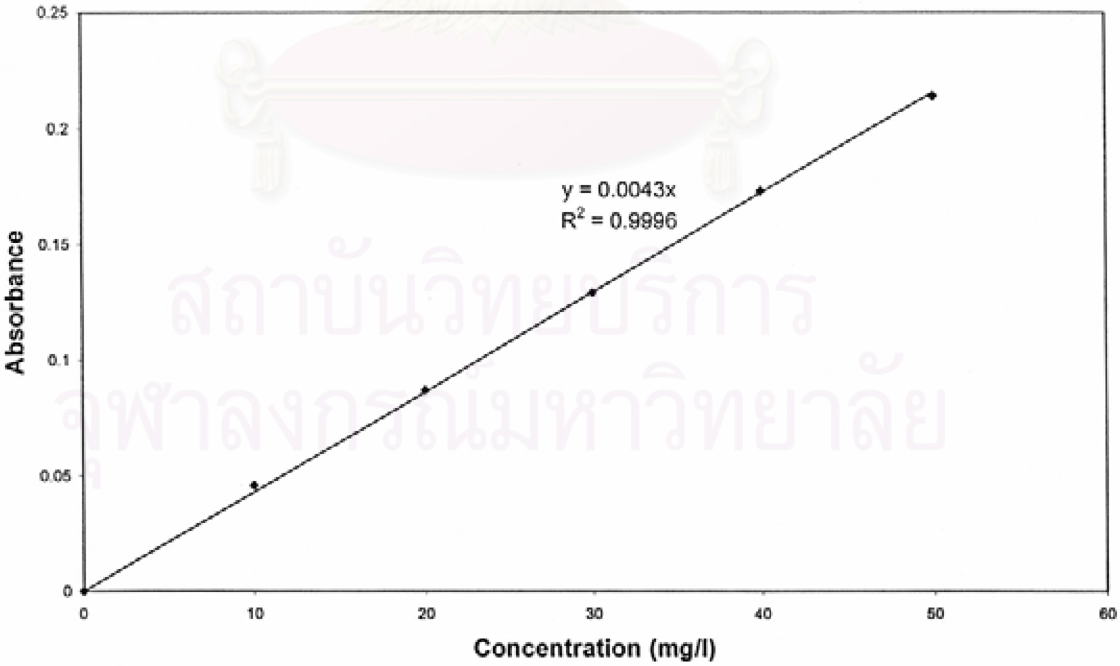

Figure B11 Calibration curve of Reactive Yellow145 at pH 7

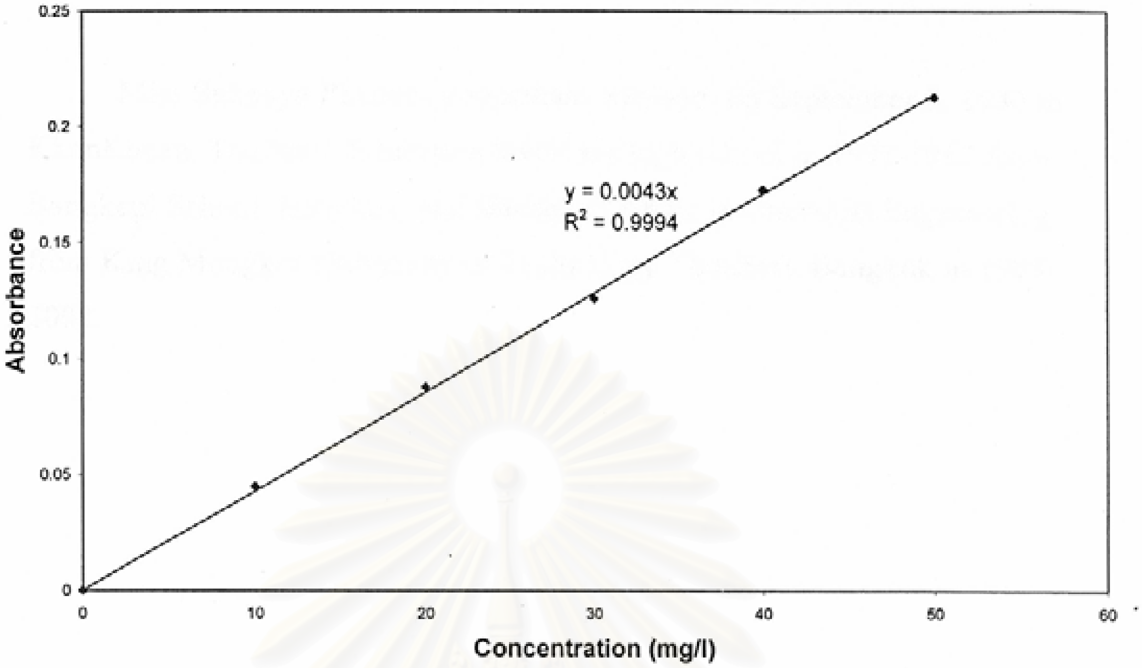

Figure B12 Calibration curve of Reactive Yellow145 at pH 9

VITA

Miss Sukanya Phanom-ooppatham was born on September 3, 1980 in KhonKhean, Thailand. Education levels are high school in 1992-1997 from Bangkapi School, Bangkok, and Bachelor Degree in Chemical Engineering from King Mongkut University of Technology Thonburi, Bangkok in 1999-2002.