TREATMENT EFFICIENCY OF SILK DYEING WASTEWATER FROM HOUSEHOLD PRODUCTION BY USING SUGAR CANE BAGASSE PACKED COLUMN

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Thesis
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Maneenuch Haisirikul

TREATMENT EFFICIENCY OF SILK DYEING WASTEWATER FROM HOUSEHOLD PRODUCTION BY USING SUGAR CANE BAGASSE PACKED COLUMN

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ABSTRACT

The objectives of this study were to investigate the treatment efficiency of silk dyeing wastewater from household production by using sugar cane bagasse packed column. The experiment was of a factorial experimental research design. The differences of sugar cane bagasse sizes, depths and flow rates in the packed column were tested for the optimum operating condition of wastewater treatment.

The results showed that color removal efficiency decreased as the sugar cane bagasse size and flow rate increased. However, it increased as the increase of sugar cane bagasse depth. Sugar cane bagasse could remove the color and Suspended Solids (SS) but increased the Chemical Oxygen Demand (COD). The pH value of the effluent slightly decreased and then slightly increased when the volume treated and breakthrough time were increased. The optimum operating condition for the color removal of 97.30% was determined as the sugar cane bagasse size of 0.5 cm, the adsorbent depth of 90 cm and the flow rate of 10 ml/min. The volume treated and breakthrough time at 90% breakpoint were 577.57 ml and 59.65 minutes, respectively. At the optimum operating condition, the treatment efficiency of actual silk dyeing wastewater by sugar cane bagasse with chemical preparation, simple preparation (dry in oven) and simple preparation (dry with sun light) was compared. The color removal efficiencies of three different preparation types were 89.59%, 93.01% and 78.22%, respectively. The volume treated and breakthrough time at 90% breakpoint of simple preparation (dry with oven) was 59.78 ml and 5.98 minutes but those of chemical preparation and simple preparation (dry with sun light) were non-detected. All the COD, SS and Total Dissolved Solids (TDS) of sugar cane bagasse preparation types exceeded the effluent standards required by the Ministry of Industry of Thailand. Only, pH from simple preparation (dry with sunlight) could achieve the standards.

The results suggest that sugar cane bagasse can be used for the treatment of silk dyeing wastewater with different levels of efficiency. In addition, the simple preparation of sugar cane bagasse (dry with oven) is optimum.

KEY WORDS: ADSORPTION / PACKED COLUMN / SUGAR CANE BAGASSE / SILK DYEING WASTEWATER

126 pp.

ประสิทธิภาพการบำบัดน้ำเสียจากการย้อมไหมระดับครัวเรือนโดยการใช้ชานอ้อยในระบบคอลัมน์ (TREATMENT EFFICIENCY OF SILK DYEING WASTEWATER FROM HOUSEHOLD PRODUCTION BY USING SUGAR CANE BAGASSE PACKED COLUMN)

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาประสิทธิภาพการบำบัดน้ำเสียจากการย้อมไหมระดับครัวเรือนโดยการใช้ชานอ้อยในระบบคอลัมน์ โดยเป็นการทดลองแบบแฟกตอเรียล ศึกษาความแตกต่างของขนาดชานอ้อย, ความสูงของชั้นชานอ้อยและอัตราการไหลในระบบคอลัมน์เพื่อหา สภาวะการทำงานที่เหมาะสมในการบำบัดน้ำเสีย

ผลการทดลองแสดงว่า ประสิทธิภาพการกำจัดสีลดลงเมื่อขนาดชานอ้อยใหญ่ขึ้นและอัตราการไหลเพิ่มขึ้น อย่างไรก็ตามประสิทธิภาพการกำจัดสีเพิ่มขึ้นเมื่อเพิ่มความสูงของชั้นชานอ้อย ชานอ้อยสามารถกำจัดสีและลดค่าของแข็งแขวนลอยแต่ทำให้ค่าซีโอดีเพิ่มขึ้น ค่าพีเอชของน้ำที่ออกจากระบบมีค่าลดลงเล็กน้อยและเพิ่มขึ้นอย่างช้าๆเมื่อปริมาณน้ำที่ผ่านการบำบัดมากขึ้นหรือเวลาในการบำบัดนานขึ้น สภาวะการทำงานที่เหมาะสมเพื่อให้ได้ประสิทธิภาพการกำจัดสี 97.30% ได้จากชานอ้อยขนาด 0.5 เซนติเมตร ชั้นชานอ้อยสูง 90 เซนติเมตร และอัตราการไหล 10 มิลลิลิตรต่อนาที โดยมีปริมาณน้ำและเวลาที่ประสิทธิภาพการกำจัดสีที่90%คือ 577.57 มิลลิลิตรและ 59.65 นาทีตามลำดับ การเปรียบเทียบประสิทธิภาพบำบัดน้ำเสียจากการย้อมไหม ด้วยชานอ้อยที่ปรับสภาพด้วยวิธีการเคมี, วิธีการอย่างง่าย(ทำแห้งโดยการอบ) และ วิธีการอย่างง่าย(ทำแห้งโดยแสงแดด) ณ สภาวะการทำงานที่เหมาะสมพบว่า ประสิทธิภาพการกำจัดสีของการปรับสภาพทั้ง 3 วิธี คือ 89.59%, 93.01% และ 78.22% ตามลำดับ ปริมาณน้ำและเวลาที่ประสิทธิภาพการกำจัดสีที่90% ของชานอ้อยที่ปรับสภาพด้วยวิธีการอย่างง่าย(ทำแห้งโดยการอบ)คือ 59.78 มิลลิลิตรและ 5.98 นาที แต่ชานอ้อยที่ปรับสภาพด้วยวิธีการเคมีและวิธีการอย่างง่าย(ทำแห้งโดยแสงแดด)ไม่สามารถหาค่านี้ได้ การปรับสภาพชานอ้อยทั้ง 3 วิธีมีค่าซีโอดี, ค่าของแข็งแขวนลอย และ ค่าของแข็งละลายน้ำสูงเกินมาตรฐานน้ำทิ้งโรงงานอุตสาหกรรม มีเพียงค่าพีเอชของชานอ้อยที่ปรับสภาพด้วยวิธีการอย่างง่าย(ทำแห้งโดยแสงแดด)เท่านั้นที่อยู่ในช่วงที่กำหนดในมาตราน้ำทิ้งโรงงานอุตสาหกรรม

จากผลการทดลองพบว่า ชานอ้อยสามารถใช้เพื่อการบำบัดน้ำเสียจากการย้อมไหมโดยมีประสิทธิภาพแตกต่างกัน นอกจากนี้ วิธีการปรับสภาพอ้อยที่เหมาะสมคือ วิธีการอย่างง่าย(ทำแห้งโดยการอบ)

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LIST OF ABBREVIATIONS

ADMI	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
cm	Centimeter
COD	Chemical Oxygen Demand
°C	Degree Celsius
g	Gram
GF/C	Glass Fiber Filter
L	Liter
mg	Milligram
min	Minute
ml	Milliliter
mm	Millimeter
pH	Positive Potential of The Hydrogen Ions
S.D.	Standard Deviation
SS	Suspended Solids
SU	Space Unit
TDS	Total Dissolved Solids

CHAPTER I
INTRODUCTION

1.1 Background

Silk is a famous product of Thailand. It presents outstanding Thai traditional culture and intelligence from generation to generation. Silk production is widespread in the Northeast and the North of Thailand. In the past, villagers spend rest times beyond paddy field or major occupation to produce silks for using in their family. Nowadays silk product is the trade and categorized as important goods of Thailand for export. In addition, the government supplements and permits this project to be One Tumbon One Product (OTOP). It is appearance especially in Thailand and become The Her Majesty Queen Sirikit’s project in finally. As a result, a part of villagers change their career to silk producers. In the future silk production will magnify from household activities to a small factory in the local area. At the silk production, the process include the steps of cultivation of the silkworm, reeling of silk, gum removal, bleaching, dyeing and weaving.

The main environmental problems in silk production process were the dyeing stage because this step requires using chemicals and large quantity of water. Dyes that are not exhausted onto fibers can be discharged directly to receiving water body such as canal, stream or idle land nearby their house. Those effluent discharges are notorious due to their strong color, high suspended solids (SS) and other organic contents (1).

Small industries or household activities do not register with the Department of industrial works. As a result, the Department of industrial works could not control their industrial effluents. Color is the most obvious indicator of water pollution. Dyeing wastewater caused a severe problem. It negatively affects the aesthetic of the water environment, photosynthetic activities of aquatic plants and activity of aquatic animals because of its toxicity and reduction of light penetration (2). High concentrations of color increased BOD of the receiving waters which impact the ecosystem in water source and cause environmental pollution (3). Effluents from dyeing were rich in color. These effluents readily deteriorate the quality of the receiving water body and soil.

The ingestion of such wastewater by humans causes pain, skin irritation, vomiting, severe headaches and acute diarrhea. Such effluents are also responsible for water-borne diseases exhibiting symptoms. Most of dye are azo compound, can change to an amine group which are hazardous substance and change to carcinogen substances when transmit to human body. Therefore, color elimination of dyeing wastewater is important (4).

Decolorization can be done by many methods such as physical, chemical and biological method. The chemical method is relatively expensive; biological method is hardly effective because most high molecular weight colored compounds are resistant to biological degradation. Search for more effective and less expensive methods for decolorization as well as pollutant reduction was needed (5).

Adsorption holds a promising result in the treatment of wastewater, as it was simply designed, easy to handle, and choice of adsorbent. Commercially, activated carbon has long been used as a standard adsorbent for color removal, in spite of its widespread use in various cleaning procedures. However, its use is usually limited due to high cost and problems of regeneration.

There are many agricultural areas in the Northeast of Thailand and also produce silk. They have much residue agricultural waste but a little useful. Therefore, the uses of agricultural waste material as an adsorbent for the removal of color in silk dyeing wastewater need to be explored.

This study investigated the efficiency of sugar cane bagasse on the treatment of silk dyeing wastewater, using continuous system. The optimal operation conditions of the process such as size and depth of packing adsorbent, flow rate, volume treated and breakthrough time also were determined.

1.2 Objectives of the Study

1.2.1 General Objective

To investigate the treatment efficiency from silk dyeing wastewater by using sugar cane bagasse packed column.

1.2.2 Specific Objectives

1. To compare the treatment efficiency of synthetic silk dyeing wastewater by using different sugar cane bagasse sizes in packed column.

2. To compare the treatment efficiency of synthetic silk dyeing wastewater by using different sugar cane bagasse depths in packed column.

3. To compare the treatment efficiency of synthetic silk dyeing wastewater by using sugar cane bagasse packed column at different flow rates.

4. To compare the treatment efficiency of silk dyeing wastewater by using different types of sugar cane bagasse preparation in packed column at optimum operating condition.

1.3 Hypotheses of the Study

1. The treatment efficiency by using the small sugar cane bagasse size is more efficient than the large sugar cane bagasse size.

2. The treatment efficiency at the higher sugar cane bagasse depth is more efficient than the lower sugar cane bagasse depth.

3. The treatment efficiency at the low flow rate is more efficient than the high flow rate.

4. The treatment efficiency by means of the chemical preparation is more efficiency than the simple preparation (dry with oven) and the simple preparation (dry with oven) is more efficiency than the simple preparation (dry with sun light).

1.4 Variables of the Study

1.4.1 Experimental Part 1

1.4.1.1 Independent variable

- Sugar cane bagasse sizes
- Sugar cane bagasse depths
- Flow rates

1.4.1.2 Dependent variables

- Color
- COD
- SS
- pH
- Volume treated at 90% breakpoint
- Breakthrough time at 90% breakpoint

1.4.1.3 Control variable

- Diameter of column
- Bulk density of sugar cane bagasse
- Room temperature
- Color intensity of influent

1.4.2 Experimental Part 2

1.4.2.1 Independent variable

- Types of sugar cane bagasse preparation

1.4.2.2 Dependent variables

- Color
- COD
- SS
- TDS
- pH
- Volume treated at 90% breakpoint
- Breakthrough time at 90% breakpoint

1.4.2.3 Control variable

- Sugar cane bagasse sizes
- Sugar cane bagasse depths
- Diameter of column
- Bulk density of sugar cane bagasse
- Room temperature
- Color intensity of influent

1.5 Research Definition

1.5.1 Adsorbent: The solid phase onto which the accumulation at the interface occurs. In this study, sugar cane bagasse is an adsorbent used for treatment of synthetic silk dyeing waste water and actual silk dyeing wastewater.

1.5.2 Sugar cane bagasse: By product of sugar cane after squeeze which is waste product from the sugar industry. In this study, it was collected from a market as solid waste.

1.5.3 Sugar cane bagasse packed column: A column containing the adsorbent (sugar cane bagasse) which is packed or stationary during operation.

1.5.4 Synthetic silk dyeing wastewater: A solution containing synthetic silk dyestuff.

1.5.5 Actual silk dyeing wastewater: Wastewater from bath dyeing process by using synthetic silk dyestuff, wastewater from bleaching process is not included**.** It was collected from the Ban Nhongtakai female silk weavers cooperative society in Buriram province.

1.5.6 Flow rate: Wastewater flow rate feed into the adsorption column.

1.5.7 Type of sugar cane bagasse preparation: Preparation of sugar cane bagasse before sugar cane bagasse was used as adsorbent. In this study, three types of sugar cane bagasse were studied namely; chemical preparation, simple preparation (dry with oven) and simple preparation (dry with sunlight).

1.5.8 Treatment efficiency: Silk dyeing wastewater treatment ability by sugar cane bagasse in term of color removal efficiency, volume treated and breakthrough time at 90% breakpoint, COD, SS, TDS and pH.

1.5.9 The color removal efficiency: The percentages of color removal by sugar cane bagasse, which can be calculated from:

$$\%\ \text{color removal} = \frac{C_i - C_e}{C_i} \times 100\%$$

Where C_i = Color intensity of influent

C_e = Color intensity of effluent

1.5.10 Volume treated: Volume of treated wastewater when the effluent color intensity is equal to the justified color intensity for breakthrough.

1.5.11 Breakthrough time: The time taken when the effluent color intensity starts to rise or occurred when the effluent color intensity was first detectable.

1.5.12 Optimum operating condition: Sugar cane bagasse size, sugar cane bagasse depth and flow rate which resulted the color removal efficiency over than 90% and the volume treated was highest.

1.6 Scope of the Study

1.6.1 The experiment was performed at the laboratory of Department of Environmental Health Science, Faculty of Public Health, Mahidol University.

1.6.2 Synthetic silk dyeing wastewater was used for this study, the characteristics of a solution and preparation was illustrated in chapter III.

1.6.3 Actual silk dyeing wastewater from the Ban Nhongtakai female silk weavers cooperative society in Buriram province was used for this study, the collection and storage were illustrated in chapter III.

1.6.4 The Characteristics of effluence were investigated namely; color, COD, SS, TDS, pH, volume treated and breakthrough time.

1.6.5 The color removal efficiency was determined in term of Space Unit (SU)

1.6.6 The adsorption process was studied in term of total adsorption. Chemical adsorption and physical adsorption were not classified.

1.7 Expected Outcome

It will be an alternative for household activities to use this low operation cost and high efficiency method to treatment of silk dyeing wastewater. In addition, the utilization of agricultural waste could be used as a useful adsorbent for treatment of silk dyeing wastewater.

1.8 Limitation of the Study

1. This experiment was setup in laboratory scale. Column experiments were conducted using acrylic column number 503 that internal diameter of 4.4 cm and height of 100 cm.
2. Sugar cane bagasse sizes were prepared manually and were controlled in dry before soak. After soak and dry again, size would be in error less than 10%.
3. Characteristics of synthetic silk dyeing wastewater prepared by control range of color intensity. However, synthetic silk dyeing wastewater was prepared several batches. Thus it might have specifics characteristics at each batch.
4. Characteristics of actual silk dyeing wastewater were varies and depend on production processes. Thus the sampled wastewater might have specific characteristics at only period of sampling and source.
5. TDS value was not analyzed in experimental part 1 because an equipment obstruction was occurred.

1.9 Conceptual Framework

Independent variables | **Dependent variables**

Experimental Part 1

Sugar cane bagasse sizes (cm)

- 0.5
- 1
- 2

Sugar cane bagasse depths (cm)

- 30
- 60
- 90

Flow rate (ml/min)

- 5
- 10
- 15

→

Treatment efficienct

- Color
- COD
- SS
- pH
- Volume treated at 90% breakpoint
- Breakthrough time at 90% breakpoint

↓

Experimental Part 2

Types of sugar cane bagasse preparation at selected optimum operating condition

- Chemical preparation
- Simple preparation (dry with oven)
- Simple preparation (dry with sunlight)

→

Treatment efficienct

- Color
- COD
- SS
- TDS
- pH
- Volume treated at 90% breakpoint
- Breakthrough time at 90% breakpoint

CHAPTER II
LITERATURE REVIEW

2.1 Silk Production

Cultivation of the Silkworm

Silk is the only natural filament fiber that has significant commercial value. Produced by a caterpillar known as a “silkworm”, silk can be obtained either from cultivated silkworms (Bombyx mori) or wild species. By far the largest quantity of silk comes from sericulture, the controlled growth of domesticated silkworms to produce the silk fiber. Whether the silkworms be domesticated or wild, they go through four basic stages of development:

1. Laying of the eggs by the silk moth.
2. Hatching of the eggs into caterpillars which feed on mulberry leaves.
3. Spinning of a cocoon by the caterpillar.
4. Emerging of the silk moth from the cocoon.

For about a month the worm grows, shedding its skin four times. When fully grown, worms are about 3½ inches in length. When its size and activity show that the worm is about ready to begin to spin a cocoon, the silk worm is transferred to a surface of twigs or straw. From two sacs located in the lower jaw, the worm extrudes a substance made up of two strands of silk (fibroin) and a gummy material (sericin) that holds them together. Moving its head in the shape of a figure eight, the worm surrounds itself with a cocoon of perhaps 1,000 meters of fiber. The completed cocoon is about the size of peanut shell and takes 2 to 3 days to spin. If the worm is permitted to live, it will change into a pupa or chrysalis and then to a moth. After 2 weeks the moth breaks through the cocoon and emerges, mates, lays eggs, and begins the cycle again.

Only those moths selected as breeding stock are permitted to complete the cycle. These are selected from the largest and heaviest cocoons. The remainders of the cocoons are subjected to dry heat that kills the pupa (6).

Reeling of Silk

The whole, unbroken cocoons as are sorted according to color, texture, size, shape, and other factors that will affect the quality of the fiber. Reeling of silk is, to a large extent, a hand operation done in a factory called a filature. Several cocoons are placed in the container of water of about 140 ºF. This warm water serves to soften the sericin, the gum that holds the filaments of silk together. Little of this gum is actually removed in reeling. The outer fibers are coarse and short and not useful in filament silk. They are separated and are used for spun silk, which is made from short fiber lengths. The filaments from four or more cocoons are held together to form a strand of yarn. As the reeling continues, a skilled operator adds or lets off filaments as needed to make a smoother strand of uniform size (6).

Silk Yarns

The making of silk filament yarns is called throwing. Reeling silk filaments can be combined into yarns immediately. Short, staple-length silk fibers must be spun. Short outside fiber of silk worm’s cocoon, the inner fibers from cocoon, and the fiber from pierced cocoons are known as frisons and are made into spun silk yarns. Fiber are cut into fairly uniform lengths, combed, and twisted into yarns in the same way that other staple fiber are spun (6).

Gum Removal

As mentioned earlier, the sericin that holds the silk filaments in place in the cocoon is softened but not removed in reeling. This gummy material makes up about 25 percent of the weight of raw silk. It is removed before throwing, after throwing, or after the fabric has been woven. A soap solution is used to wash the gum from the silk. In some silk fabrics, called raw silk, the sericin has not been removed (6).

The Bleaching and Dyeing Process

In preparation for dyeing and finishing silk fabrics are scoured and usually bleached. In addition to removing the soil or additives used while weaving silk, scouring removes any sericin that remains on the silk. Often a quantity of the natural gum has been allowed to remain on silk fiber to give it additional body and to make it easier to handle in spinning and weaving. Although raw silk fabrics the gum is retained purposely to provide body or produce a different texture, most silk fabrics are degummed as a part of finishing process. The resultant fabric has a much softer hand and a whiter appearance. Silk is usually bleached with dilute solutions of hydrogen peroxide. Silk is traditionally dyed in a batch process. The medium most often used to dissolve or disperse dyes is water. The dye solution, called the “dye liquor”, is agitated or circulated to increase the migration of dye to the fiber surface. The attraction or affinity of the dye for a particular fiber is influenced by several factors. Different dye types are attracted chemically or physically to specific fibers. Fibers often undergo swelling in aqueous dyeing processes, increasing dye absorption (6).

In the present powder packages chemical dyestuff were used in household dyeing. For dyeing silk 1 kg will be used chemical dyestuff depended on level of shade color. It use between 1 to 20 packs of chemical dyestuffs (10g per pack). Dyeing process is beginning with pour water in dye bath to submerge silk (1: 20-30), and then add chemical dyestuff or other dyeing chemicals. When warmed water, bring damp silk to dye for 20 minutes and then add acetic acid 2 table spoons. Turn down of heat and boil until the dye water look clear and bring silk to wash 3 – 4 times or wash until washing water’s clear and then bring it to dry in the sun (7).

Dyeing process and reactions (8)

The dye process consists of at least four stages:

(a) The dyestuff in the dyebath diffuses to the fiber surface.

(b) The dyestuff molecule adsorbs on the fiber surface.

(c) The dyestuff on the fiber surface diffuses into the inner part of the fiber.

(d) The dyestuff molecule attaches with the fiber.

Dyebath reuse, in which the dye liquor is replenished with dye and the same bath used for another run of fabric, has been highly successful in dyeing products.

Since products are large piece of fabric, with a high weight of fibers, dyeing processes require significant volumes of water. Recycling dyebaths can reduce the dyehouse effluent. To maintain good quality in the dyeing, the bath should be filtered between runs to remove loose fiber and spin finishes from the fibers (6).

2.2 Dyestuffs

2.2.1 Chemical structure of dyestuffs

The dyestuff molecule consists of two major components: dye chromophore group and dye functional group or auxochrome.

(1) Dye chromophore group

This component of the molecule consists of double bonds which make color of the dye. When the dyestuff molecule is exposed to the light, the structure of the chromophore oscillates because it absorbs the light at some wavelengths. There are twelve chromophore groups. Some of them are shown in Table 2-1. Azo group is the most widely used, about fifty percent of all dyes (9).

Table 2-1 Examples of chromophore group in dyestuff and their chemical structure (10)

Chromophore group	Chemical structure
Nitroso group	-NO or =N-OH
Nitro group	-NO_2 or =NOOH
Azo group	-N=N-
Ethylene group	>C=C<
Carbonyl group	>C=O
Sulfur group	>C=S or –C-S-S-C-
Carbonyl-nitrogen group	C=NH or CH=N

(2) Dye functional group or Auxochrome

Auxochrome is the group of atoms in the molecule which is essential to augment and enhance the color of the dyestuffs. These groups normally increase the intensity of the color and shift the absorption to longer wavelengths of the light. They are responsible for the bond between the dyestuff molecule and the fiber. This structure usually consists of a benzene ring attached with a reactive group such as SO3-, Na+, COOH-, OH- and NH2+. The attachment between these functional groups and the fiber was though covalent or ionic bonds, van der Waal's forces or the dyestuff molecules permeation into the fiber (9). The examples of auxochrome group and their chemical structures are shown in Table 2-2.

Table 2-2 Examples of auxochrome group in dyestuff and their chemical structures (11)

Auxochrome group	Chemical structure
Amino group	NR_2,-NHR,-NH_2
Hydroxyl	-OH
Iodo	-Br
Methoxy	-I
Carbonyl	-COOH
Sulfonyl	-SO_3H

2.2.2 Classification of dyes

There are 10 of the most widely used dyes classified by the method of application to the fiber, characteristics of the dye, typical associated fiber, dye-fiber attachment mechanism and typical method of application are also presented in Table 2-3.

Table 2-3 Classification of dyes (12)

Dye Class	Characteristics	Typical Associated Fiber	Dye fiber Attachment Mechanism	Typical method of application
Acid dye	Anionic High water solubility Poor wet fastness	Nylon, Wool	Ionic bond	Fiber placed in acidified aqueous media pH 3-5. Fiber assume a positive charge dye added and temp to 50-110 °C
Metal Complex acid dye	Anionic Low water solubility Good wet fastness	Nylon, Wool	Ionic bond	As with acid dyes pH 5-7
Direct dye	Anionic High water solubility Poor wet fastness	Cotton, viscose	Ionic bond	Fiber placed in dyebath slightly alkali add dye electrolyte (Nacl, Na_2SO_4) to displaced dye to fiber, temp to 98 °C
Basic or Cationic dye	Cationic High water solubility	Acrylics	Ionic bond	Fiber place in acidified aqueous dyebath pH 4-6. Dye added and temp. increased from 100-105 °C Dye diffuse to fiber
Disperse dye	Colloidal dispersion Very low water solubility Good wet fastness	Polyester, Nylon, Acrylics, Cellulose	Colloidal impregnation adsorption	Fiber place in acid dyebath pH 4.5. Dye added, temp to 130 °C cause dye migration into fiber
Reactive dye	Anionic High water solubility 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

Table 2-3 Classification of dyes (Continued)

Dye Class	Characteristics	Typical Associated Fiber	Dye fiber Attachment Mechanism	Typical method of application
Sulphur dye	Colloidal after reaction in fiber, Insoluble Wet fastness	Cotton, Viscose	Dye precipitated in situ fiber	Fiber placed in dyebath. Dye dissolved in alkaline sodium sulphur. Dye displaced to fiber with electrolyte
Vat dye	As per sulphur dye	Cotton, Viscose	Dye precipitated in situ fiber	As per sulphur dye
Asoic dye	As per sulphur dye	Cotton, Viscose	Dye precipitated in situ fiber	Fiber placed in dyebath. Dye chromophore. Added boiled to precpitate
Mordant or chrome dye	Anionic Water soluble Good wet fastness	Wool	Fiber-chrome dye complex	Fiber placed in acid dyebath. Add sodium chromate. Add dye temp at 98°C

2.2.3 Acid dyes

Acid dyes are made for dyeing wool, silk and nylon. They have one to four negatively charged functional groups. Acid dyes were water-soluble anionic dyes with different chromophore (color-Bearing) groups substituted with acidic functional groups such as nitro, carboxyl-, and sulfonic acid. By adding a sulfonic group, the water-insoluble dyes become soluble (4). Applied in acid solution, they react chemically with the basic groups in the fiber structure to form ionic bonds. Because wool has both acid and basic groups in its structure, acid dyes can be used successfully on wools. These dyes are also utilized for dyeing nylon and, to a lesser extent, for acrylics, some modified polyesters, polypropylene and spandex. They have little affinity for cellulosic fibers. Colorfastness of acid dyes varies a good deal, depending on the color and the fiber to which the dye has been applied.

Metal complex dyes, or premetallized dyes, are usually classified with acid dyes. These are dyes that have been reacted with a metal mordant, such as chromium or cobalt, before application to the fiber. The resulting dyes are very stable, with excellent light and wash fastness, but the resulting colors are not as bright as those of unmetallized acid dyes. Major applications are for protein fibers and nylons.

2.3 Color and Its Measurement

The visible region of the spectrum consists of electromagnetic radiation wavelengths covering the range 400 nm to about 800 nm. Radiation below 400 nm as invisible and lies in the ultraviolet region, that above 800 nm was also invisible and lies in the infrared (13).

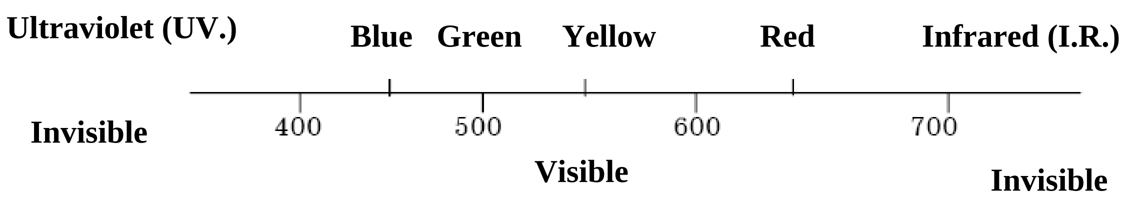


Figure 2-1 Visible wavelengths

While light, i.e. radiation more or less evenly spread over the range 400-800 nm, may be split into the color of the spectrum by means of a prism of diffraction grating, the spectral color being violet, indigo, blue, green, yellow, orange and red.

When a color surface was illuminated by a beam of white light certain wavelengths were absorbed and the reflected light, being deficient tin the absorbed wavelengths, induces the sensation of color on striking the retina of a normal eye. Thus an orange surface will absorb radiation chiefly from the region 550-650 nm. The reflected light will thus be enhanced as regards the yellow/red region, 600 nm and beyond, and so an orange hue will be seen. If this orange surface was now illuminated solely by green light, i.e. of wavelengths corresponding light is deficient in certain wavelength then apparent change of hue will occur compared with that seen under "normal" while light. It was a matter of common experience that the same colored object changes greatly in appearance according to whether it was viewed in daylight, under a mercury vapor lamp, in sodium light or other artificial illumination.

Black surfaces absorb light of wavelengths covering the whole visible range, white surfaces reflect light more or less evenly over entire visible region. Grey surfaces were the result of general absorption of part of the incident white light.

All color substances, dyes and pigments have the power of absorbing radiation selectively from the visible region, such absorption being characteristic of the molecular species concerned. The following Table 2-4 showed the relationship between absorbed radiation and color seen for a set of specially chosen substances each is having a single narrow absorption band (13).

Table 2-4 Relationship between color absorbed and color seen

Wavelength (nm)	Color absorbed	Color seen
400-435	Violet	Yellow-green
435-480	Blue	Yellow
480-490	Green-blue	Orange
490-500	Blue-green	Red
500-560	Green	Purple
560-580	Yellow-green	Violet
580-595	Yellow	Blue
595-605	Orange	Green-blue
605-750	Red	Blue-green

The color of a water sample can be reported as:-

(1) True color is homogeneous dissolved color cause from dissolved organic compound in water.

(2) Apparent color is color of water that can be treated by physical methods. It caused by reflex of suspended materials in water or reflex of the arching sky.

Color of water of dyeing wastewater caused from using dyeing chemical in dyeing process. Particulate of dyeing chemical will be dissolved and suspended in wastewater that caused color problem. Particulate from dyeing chemical can not be destroyed by natural sedimentation. Normally color of water will be caused true color in wastewater (14). Not only is color often difficult to remove but the measurement of color itself is a complicated task.

There are several techniques available for measuring color. The American Public Health Association (APHA) platinum-cobalt method whereby a unit of color is defined as that produced by 1 mg/L platinum in the form of the chloroplatinate ion is the best known and most widely used method. However, this technique was develop to measure the reddish-yellow hues often associated with natural water and was not very suitable for the determination of color in complex industrial discharges (15).

To overcome the difficulties associated with the APHA method, the American Dye Manufacturers Institute (ADMI) has developed another technique. The ADMI color value is related to the concentration of specific dyes in a meaningful manner but not favorite because it’s difficult to use and only can be measure as absorbance characteristics in Dominant Wavelength, Hue, Percent Luminance and Purity (14).

Spectrophotometric analysis is the determination of the structure or quantity of substances by measuring their capacity to absorb light of various wavelengths. Also called spectrophotometry.

Spectrophotometry is a method of color analysis is based on an absorption or attenuation by matter of electromagnetic radiation of a specified wavelength or frequency. A spectrophotometer makes use of the transmission of light through a solution to determine the concentration of solute within the solution. Spectrophotometers were based on a simple design of passing light of a known wavelength through a sample and measuring the amount of light energy that is transmitted. This was accomplished by placing a photocell on the other side of the sample. All molecules absorb radiant energy at one wavelength or another. Those that absorb energy from within the visible spectrum were known as pigments. Proteins and nucleic acids absorb light in the ultraviolet range (16).

2.4 Decolorization / 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 (17).

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 is a more powerful oxidant than 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, many dissolved solids also precipitate out of solution, like the 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 test 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 flock 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 solid and is measure 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

This is a chemical process in which media substance forms the colloids or molecules in gas or liquid on its surface. It could be said that the process of mass transfer from liquid or gas into the surface of solid, more details would be explained next topic.

2.5 Adsorption Theory

2.5.1 General of adsorption

Adsorption is the process of collecting soluble substances that are mixing in a solution on a suitable interface. The interface can be liquid-liquid, liquid-solid, gas-liquid or gas-solid. The only liquid-solid adsorption is widely used in water and wastewater treatment. The adsorbate is the substance being removed from the liquid phase to the interface. The adsorbent is the solid phase onto which the accumulation occurs. Activated carbon is the most commonly used adsorbent.

Natural organic materials, which have the largest distribution and are widely used around the world. The materials include straw, hay reeds, sea grass, peat, sawdust and gorse, together with other available local materials such as sugar cane bagasse or dried palm fronds. Synthetic materials have many different properties, and by alterations in their compositions. Polyurethane, polyether, fibres made of various materials, nylon and Oliophilicresins (18).

The primary driving force between the adsorbate and the adsorbent is the electrostatic attraction and repulsion which can be either physical or chemical. The adsorption processes may be classified as physical or chemical, depending on the nature of the forces involved (19).

Physical adsorption is the intermolecular forces that interact between the adsorbate and the adsorbent. These forces include the van der Waals force and hydrogen bonding. In liquid phase, the van der Waals force is the primary physical driving force. Physical adsorption is a reversible reaction and includes mono and multilayer coverage because it dose not involve the sharing of electrons. Generally, this force has a low energy of adsorption and is not site specific.

Chemical adsorption is based on the electrostatic force and has the mechanism similar to physical adsorption. Chemical adsorption involves the transfer of electrons and the formation of chemical bonds between the adsorbate and adsorbent. It is irreversible reaction and has high energy of adsorption. Chemical adsorption involves monolayer coverage and the reaction occurs at specific sites.

2.5.2 Adsorption factors

2.5.2.1 Nature of adsorbent

Particle size

The surface area of nonporous adsorbents increases with decreasing particle size and so does the adsorptive capacity. For highly porous adsorbents such as activated carbon, most of the surface area is in the internal pore structure. As a result, the adsorptive capacity is independent of the particle size.

Surface area and pore structure

The surface area is one of the factors affecting the adsorptive capacity of an adsorbent. The adsorption of solutes increases with increasing surface area. However, only surface area is inadequate to explain the adsorptive capacity of porous media such as activated carbon. The pore structure supports the surface area result in increasing the adsorptive capacity. If the adsorbate molecule can penetrate into a pore of the adsorbent, the adsorptive capacity will decrease.

Chemistry of the surface

The presence of specific functional groups on the surface of the adsorbent affects the adsorption capacity of adsorbent. For example, the presence of surface oxides consisting of acidic functional groups reduces the adsorptive capacity for the adsorption of organic compound. This is due to the preferential adsorption of water and hence blockage of a part of the surface. On the other hand, the presence of surface oxides consisting of carbonyl groups increases the adsorptive capacity of the adsorption of aromatic compounds. This is due to the interaction of aromatic ring π electrons with the carbonyl groups by a donor-acceptor mechanism involving the carbonyl oxygen as the electron donor and the aromatic ring as the acceptor (20).

2.5.2.2 Nature of adsorbate

Solubility

Solubility is one of the most important factors affecting the adsorptive capacity. In general, a higher solubility indicates low adsorptive capacity because the bond between the solute and the solvent breaks before the adsorption can occur.

Polarity

The polarity of adsorbent has a similar effect on adsorption as solubility; higher polarity results in less adsorption ability.

Molecular weight and size of adsorbate molecule

The molecular weight and size of adsorbate molecule affect the adsorptive capacity. Higher molecular weights are usually associated with large molecular sizes (longer lengths of molecular chain) and low solubility. Therefore, absorbates with higher molecular weights and larger molecular size tend to have more adsorptive capacity (20).

2.5.2.3 Effect of pH

The adsorption of weak electrolytes, both acids and bases, by activated carbon from aqueous system is affected by the solution pH. This is because it changes in the characteristics of the adsorbent and the solute molecules. At pH values greater than the pK_a of a weak organic acid, the adsorptive capacity is greatly reduced. It increases with a decrease in pH and a maximum adsorption capacity occurs when the pH is equal to pK_a. At pH values lower than the pK_a, the adsorptive capacity usually decreases with decreasing pH.

2.5.2.4 Effect of temperature

Higher temperatures usually provide less equilibrium adsorptive capacity because the adsorption process is always exothermic.

2.5.3 Adsorption kinetics

The removal of organic compounds by physical adsorption on porous adsorbents involves a number of steps, each of which can affect the rate of removal (21).

1) Bulk solution transport: Adsorbate must be transported from bulk solution to the boundary layer of water surrounding the adsorbent particle. The transport occurs by diffusion if the adsorbent is suspended in quiescent water.

2) Film diffusion transport: Adsorbate must be transported by molecular diffusion through the stationary layer of water (hydrodynamic boundary layer) that surrounds adsorbent particles when water is flowing past them. The distance of transport, and thus time for this step, is determined by the rate of flow past the particle the higher the rate of flow, the shorter the distance.

3) Pore transport: After passing through the hydrodynamic boundary layer, adsorbate must be transported through the adsorbent's pores to available adsorption sites. Intraparticle transport may occur by molecular diffusion through the solution in the pores (pore diffusion) or by diffusion along the adsorbent surface (surface diffusion) after adsorption takes place.

4) Adsorption: After transport to an available site, the adsorption bond is formed between the adsorbate and adsorbent. This step is very rapid for physical adsorption, and as a result one of the preceding diffusion steps will control the rate at which molecules are removed from solution. If adsorption is accompanied by a chemical reaction may be slower than the diffusion step and thereby control the rate of compound removal.

The rate of adsorption depends on the rate at which the molecules move or diffuse in solution or the rate at which the molecules can reach available surface by diffusing through the film and the pore (22).

2.6 The Breakthrough Curve and Mass Transfer for Adsorption Column

When wastewater was passed through a bed of adsorbent, a wave front or mass transfer zone was formed by continuous adsorption of the solute in the bed. Figure 2.2 illustrates the change of concentration of adsorbed species on the surface of the adsorbent with bed depth. The solute was rapidly adsorbed on the top layer of the bed until the amount adsorbed was in equilibrium with influent contaminant concentration. At this time, the adsorbent is loaded to capacity, and that portion of the bed was exhausted. Below this zone was second zone where dynamic adsorption was occurring; that was, the contaminant was being transferred from the liquid solute to the adsorbed phase. This zone is call mass transfer zone, and its depth is controlled by many factors, depending on the contaminant being adsorbed, characteristics of the adsorbent and hydraulic factors. The depth of the mass transfer zone was a measure of physical/chemical resistance to mass transfer. Once formed, the mass transfer zone moves down through the adsorbent bed until it reaches the bottom, whereupon the effluent concentration of the contaminant in the aqueous phase begins to rise (4). (Figure 2-3)

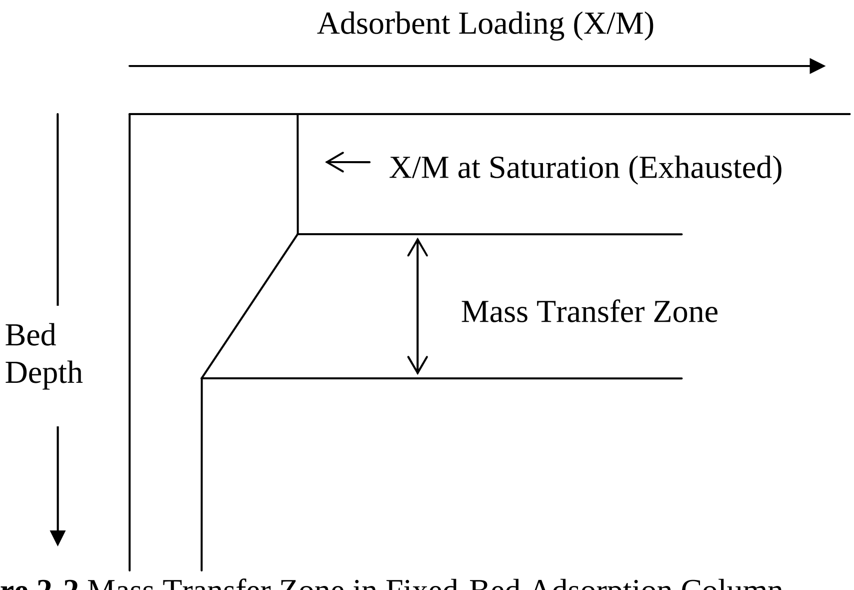


Figure 2-2 Mass Transfer Zone in Fixed-Bed Adsorption Column
Reproduced from Samuel D. Faust and Osman M. Aly, 1987 (23)

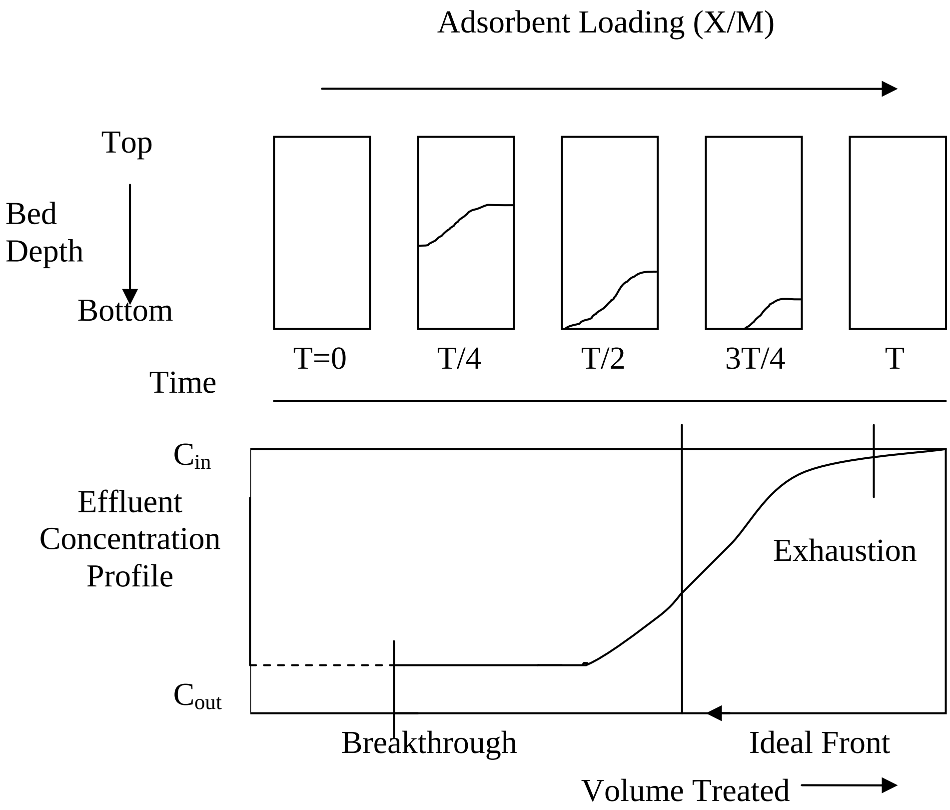


Figure 2-3 Breakthrough Curve of Adsorption Column
Reproduced from Samuel D. Faust and Osman M. Aly, 1987 (23)

Figure 2-3 shows the concentration gradient of adsorbed material (X/M) in an adsorber as the mass transfer zone moves down the column with time. As the mass transfer zone reaches the bottom of the column, breakthrough of the contaminant occurs, as noted by detectable increase in effluent concentration. When the adsorbent was operated to exhaustion (at equilibrium, $C_{in} = C_{out}$), the breakthrough curve (plot of effluent concentration with time) takes on the classic S shape that was controlled by the shape and length of the mass transfer zone. Steeper slopes for the breakthrough curves were obtained for systems that exhibit high film transfer coefficients, high internal diffusion coefficients, or flat Freundlich adsorption isotherm that was, smaller 1/n values.

2.7 Sugar Cane Bagasse

Sugar cane processing is focused on the production of cane sugar (sucrose) from sugar cane. Other products of the processing include bagasse, molasses, and filter cake. Sugar cane bagasse is the residual woody fiber after sugar cane stalk has been crushed and the juice removed. Each year more than 40-60 million tons of sugar cane bagasse is generated in Thailand, mainly in Northeastern and Central.

Sugar cane bagasse is used for several purposes: fuel for the boilers and lime kilns, production of numerous paper and paperboard products and reconstituted panel board, agricultural mulch, and as a raw material for production of chemicals. Sugar cane bagasse and sugar cane bagasse residue are primarily used as a fuel source for the boilers in the generation of process steam. Thus, sugar cane bagasse is a renewable resource. It is a fibrous, low density material with a very wide range of particle sizes and high moisture content. It is difficult to characterize properties of sugar cane bagasse particles in the usual ways (i.e. by particle density, size, drag coefficient, etc.) (24).

Chemical and physical composition of sugar cane bagasse calculated percent by weight, which data is taken from Thailand and abroad as 55% true fiber, 20% pith, 20% vessel and 5% non-fiber, approximately density 160 kg/m^3. Chemical composition analysis used technical association of the pulp and paper industry standard method. The cut sugar cane bagasse was ground and screened to prepare 40-60 mesh size particles. The results are shown in the Table 2-5 (25).

Table 2-5 Sugar cane bagasse chemical composition

Composition	ratio (% by weight)
Cellulose	47.000
Lignin	19.500
Pentosans	25.100
Ash	1.400
SiO_2	0.650
Fe_2O_2	0.031
CaO	0.046
MgO	0.016
Humidity	6.257

Several researchers attempt to use an agricultural byproduct, sugar cane dust, as a sorbent. Sugar cane dust is a complex material basically containing lignin and cellulose as the major constituents (26). Cellulose can be a sorbent for removing dyes from solution (27). A strong anion-exchange resin was prepared from sugar cane bagasse, a lignocellulosic by-product of sugar cane processing, which effectively and inexpensively decolorizes dye house wastewater in an environmentally benign manner (28). Sugar cane bagasse has been studied for removing acid dyes such as acid red 114 and acid blue 25 , basic dyes such as basic red 22, basic blue 69 (29), malachite green, methylene blue, crystal violet, rhodamine B (30), basic violet 10, basic violet 1, and basic green 4 (31), direct dyes (26), and reactive dyes (28).

2.8 Previous Related Researches

Pookajorn (32) studied the optimal condition for water-soluble dye removal using modified water hyacinth resin (strong acid resin, strong basic resin, and weak acid resin). Three types of commercially similar blue dyes (acid, direct, and reactive) were used as synthetic wastewater. The results showed that the strong acid water hyacinth resin exchange of ions was 0.68meq/g. and gave the most effective treatment. The quality of the effluent is in accord with the industrial wastewater standard in every parameter except for pH.

Srimoongkhoon (25) studied the possibility of utilizing sugar cane bagasse and sugar cane bagasse fly ash as adsorbents for the removal of heavy metals from wastewater. The optimum size of sugar cane bagasse and sugar cane bagasse fly ash were determined from surface area, pore volume and pore size. The optimum size of sugar cane bagasse was 180-250 µm which had surface area 9.67 m^2/g, pore volume 0.04 cm^3/g. and pore size 17.17 nm. The optimum size of sugar cane bagasse fly ash was also 180-250 µm with surface area at 3.35 m^2/g, pore volume 0.04cm^3/g and pore size 47.34 nm. The percentage removals of heavy metals from wastewater with single metal ion treated with sugar cane bagasse were 29.14% for chromium, 88.62% for cadmium and 95.18% for lead. The percentage removals of heavy metals from wastewater with multi metal ions treated with sugar cane bagasse were 11.98% for chromium, 78.55% for cadmium and 94.77% for lead. The percentage removal of chromium, cadmium and lead from wastewater with single metal ion treated with sugar cane bagasse fly ash were 9.63%, 97.21% and 99.30%, respectively. The percentage removal of chromium, cadmium and lead from wastewater with multi metal ions treated with sugar cane bagasse fly ash were 9.04%, 98.56% and 81.10%, respectively.

Chaiyabut (15) studied the removal efficiency of color and COD from dyeing wastewater in the textile industry using Electric Arc Furnance (EAF) dust. A laboratory scale with a continuous model was used to determine the optimum treatment condition by varying contact time (10, 20 and 30 minutes), settling time (60, 90 and 120 minutes) and EAF dust dosages (200, 250 and 300 g/L). The optimum treatment condition was at the contact time of 20 minutes, 90 minutes settling time and

250 g/L of EAF dust dosages which yielded Color and COD removal efficiencies of 87.35% and 66.86%, respectively. Under the optimum condition, the color, COD, SS and Zinc in the effluent all met the required effluent standards stipulated by the Ministry of Industry of Thailand.

Kongdang (4) determined the efficiency of color and COD removal from dyeing wastewater using sugar cane bagasse ash as an adsorbent. The experiments were conducted by packing sugar cane bagasse ash in an adsorption column with the height of 50 or 80 cm, and then by applying a continuous down flow of wastewater through the column with overflow rates of 4 m^3/m^2/day and 8 m^3/m^2/day, respectively. The optimum operating conditions were the overflow rate of 4 m^3/m^2/day and the packing adsorbent height of 80 cm, resulting in color and COD removal efficiencies of 80.01% and 52.72%, respectively.

Tipprasertsin (33) investigated the ability of treated flute reed to adsorb synthetic reactive dye solution and textile wastewater in batch and fixed bed systems. The results of the batch experiments showed that the adsorption capacity increased as the particle size decreased. The smaller particle size required less contact time to reach equilibrium because it had a higher rate of adsorption. The desorption studies confirmed that the adsorption of reactive dye by treated flute reed was due to ion exchange. For the fixed bed system, the breakthrough volume increased with decreasing particle size, initial reactive dye concentration, and flow rate and increasing bed depth. The bed depth of 45 cm and flow rate of 0.6 ml/min provided a maximum adsorption capacity. In the actual dyeing and printing textile wastewater experiments, the treated flute reed reduced SS from 1,296 to 8 mg/L and color from 1,715,000 to 191 ADMI but increased COD from 2,688 to 4,032 mg/L. The COD in crease resulted from the leaching of organics from the treated flute reed. The pH value dropped from 11.80 to 3.07 and from 8.69 to 3.30 during the dyeing and printing wastewater experiment, respectively. As a result, the pH of dyeing and printing textile wastewater after the treatment with flute reed would need to be adjusted before discharging to receiving waters.

Singhakant (34) investigated the effectiveness of pre-treatment flute reed for color removal from reactive dyes solution by adsorption and study the optimum conditions for color adsorption. The results showed that formaldehyde treated flute reed was the most effective sorbent compared to the distilled water and alkaline treatment. The optimum conditions for color adsorption were pH 3 and high temperature. Adsorption isotherm at various temperatures indicated that dye adsorption by formaldehyde treated flute reed was mainly endothermic chemisorption. The total charge of flute reed was negative and formaldehyde treated flute reed had a more positive charge. The desorption result indicated that reactive dye adsorption by formaldehyde treated flute reed was partly physisorption. The Fourier Transform Infrared (FTIR) spectrometer indicated that the reactive dye adsorption by treated flute reed occurred by ion exchange. Reactive dye wastewater adsorption by formaldehyde treated flute reed could remove color by 37%.

Singhtho (21) compared the efficiency of basic, direct and reactive dye removal by treatment of narrow-leaved cattail. The type of treatment and the various pH levels had little effect on basic dye removal. All types of treatment still had a negative charge and the basic dyes still had a positive charge at a wide pH range. For direct and reactive dyes removal, FH-NLC and pH 3 showed the highest efficiency. Increasing of q max, ΔH and b constant values from the Langmuir equation and k constant values from the Freundlich equation indicated the chemisorption mechanism for basic, direct and reactive dyes. The desorption percentage of FH-NLC indicated the chemisorption mechanism for basic and direct dye and some physisorption for reactive dye.

Thangamani et al (35) used carbon prepared from silk cotton hull to remove a textile dye (reactive blue MR) from aqueous solution by an adsorption technique under varying conditions of agitation time, dye concentration, adsorbent dose and pH. Adsorption depended on solution pH, dye concentration, carbon concentration and contact time. Equilibrium was attained with in 60 minute. Adsorption followed both Langmuir and Freundlich isotherm models. The adsorption capacity was found to be 12.9 mg/g at an initial pH of 2±0.2 for the particle size of 125–250 µm at room temperature (30±2 ºC).

Noroozi et al (36) have investigated silkworm pupa, as an adsorbent for the removal of Basic Blue 41. The amino acid nature of the pupa provided a reasonable capability for dye removal. Equilibrium adsorption isotherms and kinetics were investigated. The adsorption equilibrium data were analyzed by using various adsorption isotherm models and the results have shown that adsorption behavior of the dye could be described reasonably well by either Langmuir or Freundlich models. The characteristic parameters for each isotherm have been determined. The monolayer adsorption capacity was determined to be 555 mg/g. Kinetic studies indicated that the adsorption follows pseudo-second-order kinetics with a rate constant of 0.0434 and 0.0572 g/min mg for initial dye concentration of 200 mg/L at 20 and 40 ºC, respectively. Kinetic studies showed that film diffusion and intra-particle diffusion were simultaneously operating during the adsorption process. The rate constant for intra-particle diffusion was estimated to be 1.985 mg/g min$^{0.5}$.

Sivaraj et al (37) have studied the effectiveness of orange peel in adsorbing Acid violet 17 from aqueous solutions as a function of agitation time, adsorbent dosage, initial dye concentration and pH. The adsorption follows both Langmuir and Freundlich isotherms. The adsorption capacity Q_0 was 19.88 mg/g at initial pH 6.3. The equilibrium time was found to be 80 min for 10, 20, 30 and 40 mg/L, dye concentration respectively. A maximum removal of 87% was obtained at pH 2.0 for an adsorbent dose of 600 mg/50 ml of 10 mg/L dye concentration. Adsorption increases with increase in pH. Maximum desorption of 60% was achieved in water medium at pH 10.0.

Sobhon et al (38) researched to remove basic dyes by rice husk, an agricultural waste. The results showed that 30 mg/L of Basic blue 41, Basic violet 7 and Basic red 14 were adsorbed to 99%, 98% and 94%, respectively, within 5 minutes by 75 mm of rice husk at pH of system 6.0. The maximum adsorption capacity of rice husk to adsorb Basic 41, Basic violet 7 and Basic red 14 were 140, 160 and 52 mg/g, respectively.

McKay et al (29, 39, 40) studied the desorption and regeneration of dye colors from low-cost sorbent materials, that were rice husk, teak wood bark, cotton waste, hair, coal and bentonite clay. Particle sizes of them were 150-500 µm and they were shaken for 4 hrs at condition 2 gram adsorbent : 200 ml and 100 ppm of dyes solution. The efficiency of dyes removal were 91% for basic dye, 96% for basic dye, 69% for basic and direct dye, 78% for basic dye, 56% of direct dye and more than 83.5% for basic, direct and disperse dye, respectively. The kinetics of the adsorption of four dyestuffs onto sugar cane bagasse pith was also studied. Two basic dyes, Basic Blue 69 and Basic Red 22, and two acid dyes, Acid Blue 25 and Acid Red 114, were used in an agitated batch adsorber. Sugar cane bagasse pith was found to have the following monolayer equilibrium saturation capacities: 158, 77, 23 and 22 mg dye per gram pith. The effects of agitation, initial dye concentration, pith mass, pith particle size range and dye solution temperature were investigated. The equilibrium data were analyzed using Langmuir, Freundlich and Jossens isotherms. A model is proposed to determine the external mass transfer coefficients, k_f, for the systems and these are correlated with the system variable by the following equation: k_f = A(variable)^B.

El-Geundi (41) studied the adsorption of two basic dyestuffs and two acid dyestuffs onto maize cob. Maize cob as an adsorbent has high adsorption capacity for basic dyes (160 and 94.5 mg dye per gram maize cob) but low capacity for acid dyes (47.7 and 41.4 mg dye per gram maize cob). The effect of the system variables on the adsorption of dye solution has been studied, increasing the rate of agitation and the maize cob mass increase the rate of dye adsorption. Increasing particle size decreases the adsorption rate.

Robinson et al (42) studied the reactive dyes removal efficiency by using corncob and barley husk. The effects of initial dye concentration, biosorbent particle size, dose of biosorbent, effective adsorbance, and dye removal kinetics were examined. The results showed that 1 gram of corncob and particle size < 600 µm were the optimum weight and particle size for reactive dyes removal. The highest percentage of dye removal was 92% in 48 hours. One gram of barley husk and the particle size of 1×4 mm were the best conditions for removal of dyes at 92% in 48 hours.

Namasivayam et al (43) studied the adsorption of rhodamine-B and acid violet by coir pith carbon. The adsorption followed both Langmuir and Freundlich isotherms. The adsorption capacity was found to be 2.56 mg and 8.06 mg dye per gram of the adsorbent for rhodamine-B and acid violet, respectively. Adsorption of dyes followed first order rate kinetics. Acidic pH was favorable for the adsorption of acid violet and alkaline pH was favorable to rhodamine-B. The effect of pH on desorption opposite to the adsorption results indicating that the major adsorption mechanism were ion exchange and physical adsorption.

Poots et al (44, 45) have investigated the adsorption of Telon Blue (Acid Blue 25) on peat. The results showed peat to be suitable adsorbent for acid blue dye. The specific surface areas available for dye adsorption are lower than values reported for activated carbon. However, the cost of peat is small compared with activated carbon and no activated process is required. The ability of wood to adsorb Telon Blue was also investigated and wood was found to be a good adsorbent for the dyes. Since wood is relatively inexpensive, regeneration is not necessary and the spent wood can be disposed by burning.

Konduru et al (2) investigated for dye removal, that were peat, steel plant slag, bentonite clay and fly ash were utilized for this study and their performance evaluated against that of granular activated carbon. The results showed high removals of acid dyes by fly ash and slag while peat and bentonite exhibited high basic dye removals. For the acid and basic dyes, the removals were comparable with that of granular activated carbon, while for the disperse dyes, the performance was much better than that of granular activated carbon.

Low et al (46) studied the ability of an aquatic plant, Hydrilla verticillata, to remove two basic dye, methylene blue and basic blue, from aqueous solutions. The results showed that dried Hydrilla verticillata was able to remove the dyes efficiently and rapidly. Equilibrium data can be fitted with Langmuir isotherm with maximum sorption capacity for methylene blue and basic blue of 198 and 127 mg/g, respectively. The efficiency of dye removal was more than 75%.

Asfour et al (47) studied the adsorption of basic blue dye on hardwood sawdust. The capacity of hardwood for the adsorption of basic dye was found to increase by decreasing the particle size and increasing the temperature. In comparison between the adsorptive capacity (for standard values) of hardwood sawdust and activated carbon, as standard adsorption, under identical conditions that the relative cost of hardwood adsorbent is on 8.4% that of activated carbon.

Kluaymai-na-Ayudhya et al (48) studied rice husk for the removal of Sirius Blue Direct KGRLN and Black Acid 172, which are direct and acid dyes containing

Cu and Cr, respectively. This research showed the ability to remove Sirius Blue Direct KGRLN (215 mg/L) and Black Acid 172 (164 mg/L) to 88% and 95%, respectively, without disintegration of heavy metals. Furthermore, the changing of the maximum capacities and high value of the enthalpy indicated that the adsorption mechanism of the metal complex dyes might be both physical and chemical adsorption.

Demirba et al (49) investigated the use of perlite for the removal of victoria blue from aqueous solution at different concentration, ionic strength, pH and temperature. It is found that the adsorption capacity of perlite samples for the removal of victoria blue increased by increasing pH and temperature and decreased by expansion and ionic strength. The adsorption isotherm is concluded that victoria blue is physically adsorbed onto the perlite. The removal efficiency and dimensionless seperation factor have shown that perlite can be used for removal of victoria blue from aqueous solutions, but unexpanded perlite is more effective.

CHAPTER III
MATERIALS AND METHODS

3.1 Research Design

This study was a factorial experimental research design. The aim of this research was find out the optimum sugar cane bagasse size, sugar cane bagasse depth, flow rate and type of sugar cane bagasse preparation on the treatment of silk dyeing wastewater. The efficiency of the continuous system was analyzed in terms of the removal efficiencies comparing the influent and effluent color, volume treated and breakthrough time at 90% breakpoint. COD, SS, TDS and pH of effluent were compared with influent and the required effluent standards stipulated by the Ministry of Industry of Thailand.

3.2 Materials Equipment and Chemical reagents

3.2.1 Materials

1. Sugar cane bagasse
2. Acrylic column number 503, 100 cm length
3. Synthetic silk dyestuff
4. Actual silk dyeing wastewater

3.2.2 Equipment

1. Glassware
2. pH meter
3. Hot - air oven
4. Analytical balance

5. Desiccator
6. Spectrophotometer
7. Peristaltic Pump
8. Digestion vessels
9. Erlenmyer flask

3.2.3 Chemical reagents

1. Ag_2SO_4
2. $K_2Cr_2O_7$
3. Conc. H_2SO_4
4. $HgSO_4$
5. Distilled water
6. $Fe(NH_4)_2(SO_4)_2.6H_2O$
7. Ferroin indicator
8. Potassium Hydrogen Phthalate (KHP)

3.3 Experimental Setup

3.3.1 Synthetic silk dyeing wastewater

A synthetic silk dyestuff is trade name Singtho Tee Klong number 15 (dark red). It was prepared by mixing a dried dyestuff with distilled water. Characteristics of synthetic silk dyeing wastewater prepared by control range of color intensity in 767-778 SU. Range of color intensity was determined by the color intensity of actual wastewater which collected from the Ban Nhongtakai female silk weavers cooperative society in Buriram province.

Characteristics of actual silk dyeing wastewater were varies and depend on production processes. Thus the sampled wastewater might have specific characteristics at only period of sampling and source. The characteristics of pre-test actual silk dyeing wastewater (Singtho Tee Klong number 15) that use to determine color intensity range are shown in the table 3-1. Synthetic silk dyeing wastewater was prepared several batches. Thus it might have specifics characteristics at each batch. The characteristics of synthetic silk dyeing wastewater are shown in the table 3-2.

Table 3-1 Characteristics of pre-test actual silk dyeing wastewater

Parameters	Industrial Effluent Standard*	Actual silk dyeing wastewater
Color (Space Unit)	Not Obnoxious	772.49 (765.51-778.44)
pH	5.5-9	7.09
COD (mg/L)	<400	857.04
SS (mg/L)	<50	509.34
TDS (mg/L)	<3,000	8,537.00

* Source: Ministry of Science, Technology and Environment (1996).

Table 3-2 Characteristics of synthetic silk dyeing wastewater

Parameters	Industrial Effluent Standard*	Synthetic silk dyeing wastewater (Mean ± S.D.)
Color (Space Unit)	Not Obnoxious	772.49 ± 3.07
pH	5.5-9	7.14 ± 0.21
COD (mg/L)	<400	392.56 ± 67.73
SS (mg/L)	<50	68.74 ± 32.54

* Source: Ministry of Science, Technology and Environment (1996).

3.3.2 Actual silk dyeing wastewater

Silk dyeing wastewater was collected from the Ban Nhongtakai female silk weavers cooperative society in Buriram province by grab sampling technique. The sample of actual silk dyeing wastewater was collected from one batch of dyeing process to used for all replicates in the experiment part 2. It was separated from the bleaching process and had dark red color due to high concentration of dark red synthetic silk dyestuff (trade name Singtho Tee Klong number 15). Silk dyeing wastewater was kept in polyethylene. After that the characteristics of silk dyeing wastewater were analyzed. The characteristics of actual silk dyeing wastewater are shown in Table 3-3.

Table 3-3 Characteristics of actual silk dyeing wastewater

Parameters	Industrial Effluent Standard*	Actual silk dyeing wastewater (Mean ± S.D.)
Color (Space Unit)	Not Obnoxious	853.20 ± 12.94
pH	5.5-9	7.52 ± 0.02
COD (mg/L)	<400	571.11 ± 21.27
SS (mg/L)	<50	100.00 ± 9.18
TDS (mg/L)	<3,000	4,199.04 ± 61.27

*Source: Ministry of Science, Technology and Environment (1996)

3.3.3 Sugar cane bagasse preparation

3.3.3.1 Chemical preparation

Sugar cane bagasse was collected from a market as solid waste, cut into 0.5, 1, 2 cm and soak with 0.1 N H_2SO_4 for 1 hour and replaced with new solution every hour until no color is leaching. Then, the sugar cane bagasse was washed out by distilled water until pH was consistent at 6.5-7.5. It was dried in oven at 65 °C for 72 hours or until the weight was constant. It was then packed into a sealing plastic bag.

3.3.3.2 Simple preparation

Dry with sunlight

Sugar cane bagasse was collected from a market as solid waste and cut into 0.5, 1, 2 cm. It was soaked with distilled water for 1 hour and replaced with new distilled water every hour until the soaked distilled water was colorless. It was dry by exposed to the sun for 3 days or until the weight was constant and then packed into a sealing plastic bag.

Dry with oven

Sugar cane bagasse was collected from a market as solid waste and cut into 0.5, 1, 2 cm. It was soaked with distilled water for 1 hour and replaced with new distilled water every hour until the soaked distilled water was colorless. It was dry in oven at 65 °C for 72 hours or until the weight was constant and then packed into a sealing plastic bag.

3.3.4 Column preparation

Column experiments were conducted using acrylic column number 503 that internal diameter of 4.4 cm and height of 100 cm. It was packed with sugar cane bagasse. All acrylic columns uses in all experiments were cleaned with tap water and detergent, wash with tap water and then rinse thoroughly with distilled water, respectively before being use in further experiment. Column packing was controlled by bulk density. Every sugar cane bagasse depth of 2 cm use 3 gram sugar cane bagasse.

3.4 Procedure and Analytical Methods

3.4.1 Experimental Procedure

Part 1

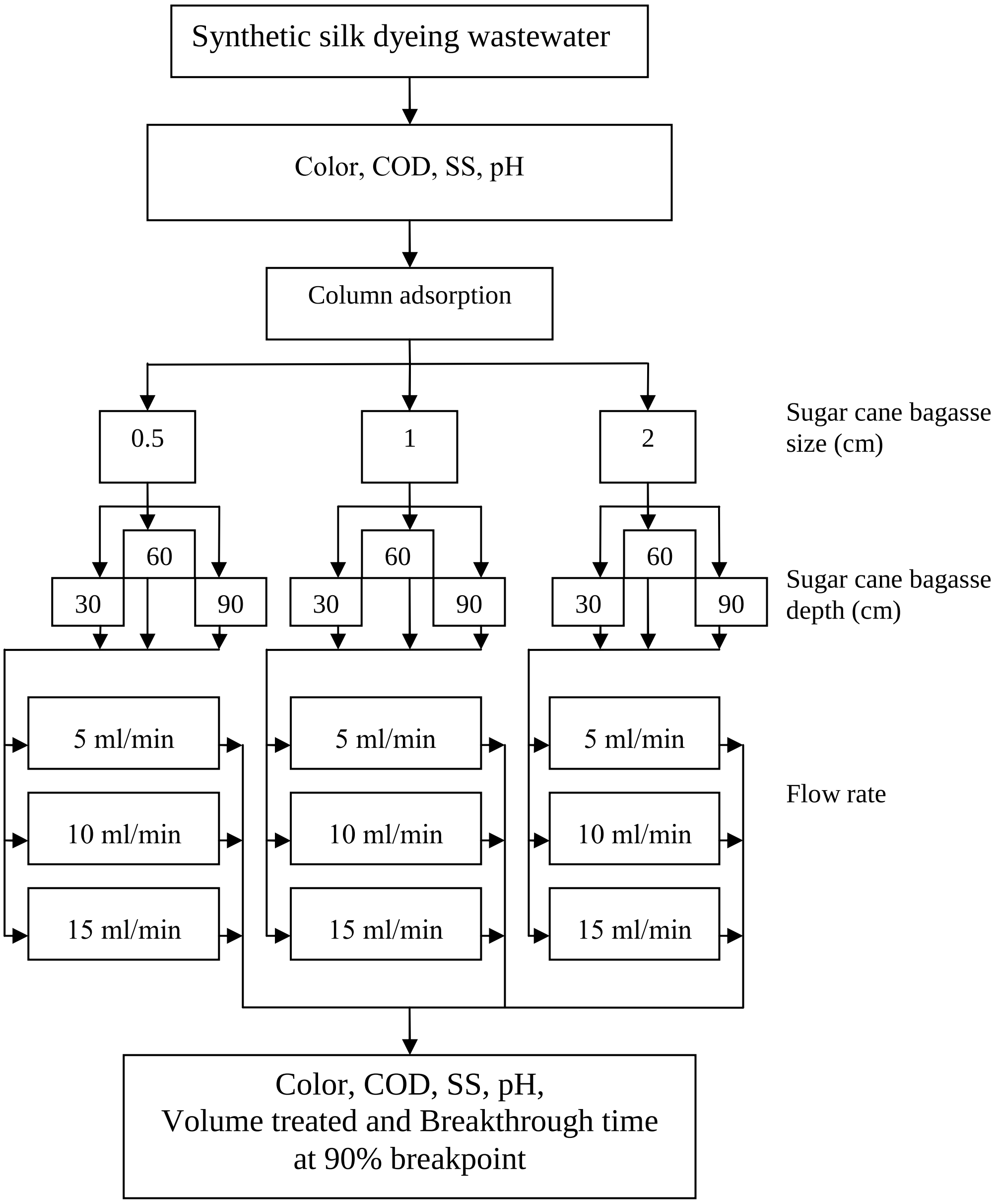
Each particle size ranges of chemical prepared sugar cane bagasse (0.5, 1, 2 cm.) was packed in 30, 60 and 90 cm sugar cane bagasse depths. Synthetic silk dyeing wastewater was fed through the column by a peristaltic pump with three flow rates of 5, 10 and 15 ml/min and no pH adjustment. Effluent samples were collected and analyzed for color intensity in the visible wavelengths of 400 to 700 nm (every 50 nm) by a spectrophotometer and reported as Space Unit (SU). COD, SS and pH in the influent and effluent were also monitored.

Part 2

The optimum operating condition from Part 1 was used for studying the color removal efficiency of actual silk dyeing wastewater by using chemical prepared sugar cane bagasse and simple prepared sugar cane bagasse. The operation followed the procedure described in Part 1.

3.4.2 Experimental frameworks

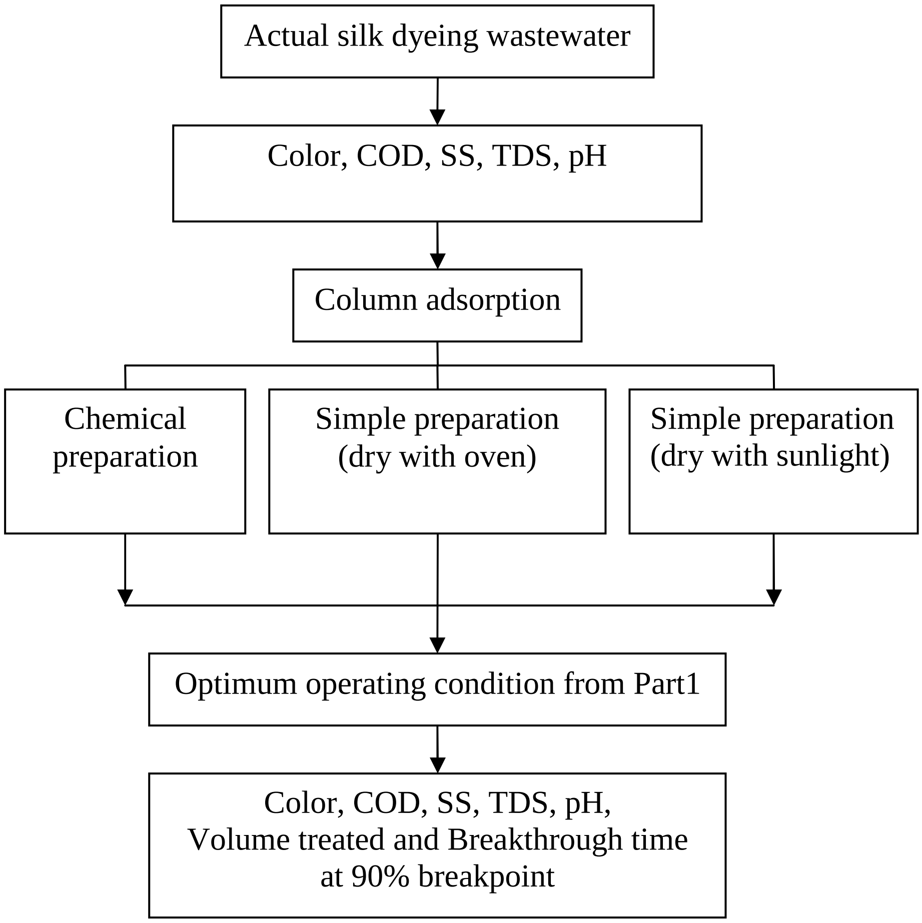
The diagram of experiment framework Part 1 was shown in Figure 3-1.



Measuring: Color, COD, SS, pH, volume treated and breakthrough time (3 replicates).

Figure 3-1 Chart of experimental framework Part 1

The diagram of experiment framework Part 2 was shown in Figure 3-2.



Measuring: Color, COD, SS, TDS, pH, volume treated and breakthrough time (3 replicates).

Figure 3-2 Chart of experimental framework Part 2

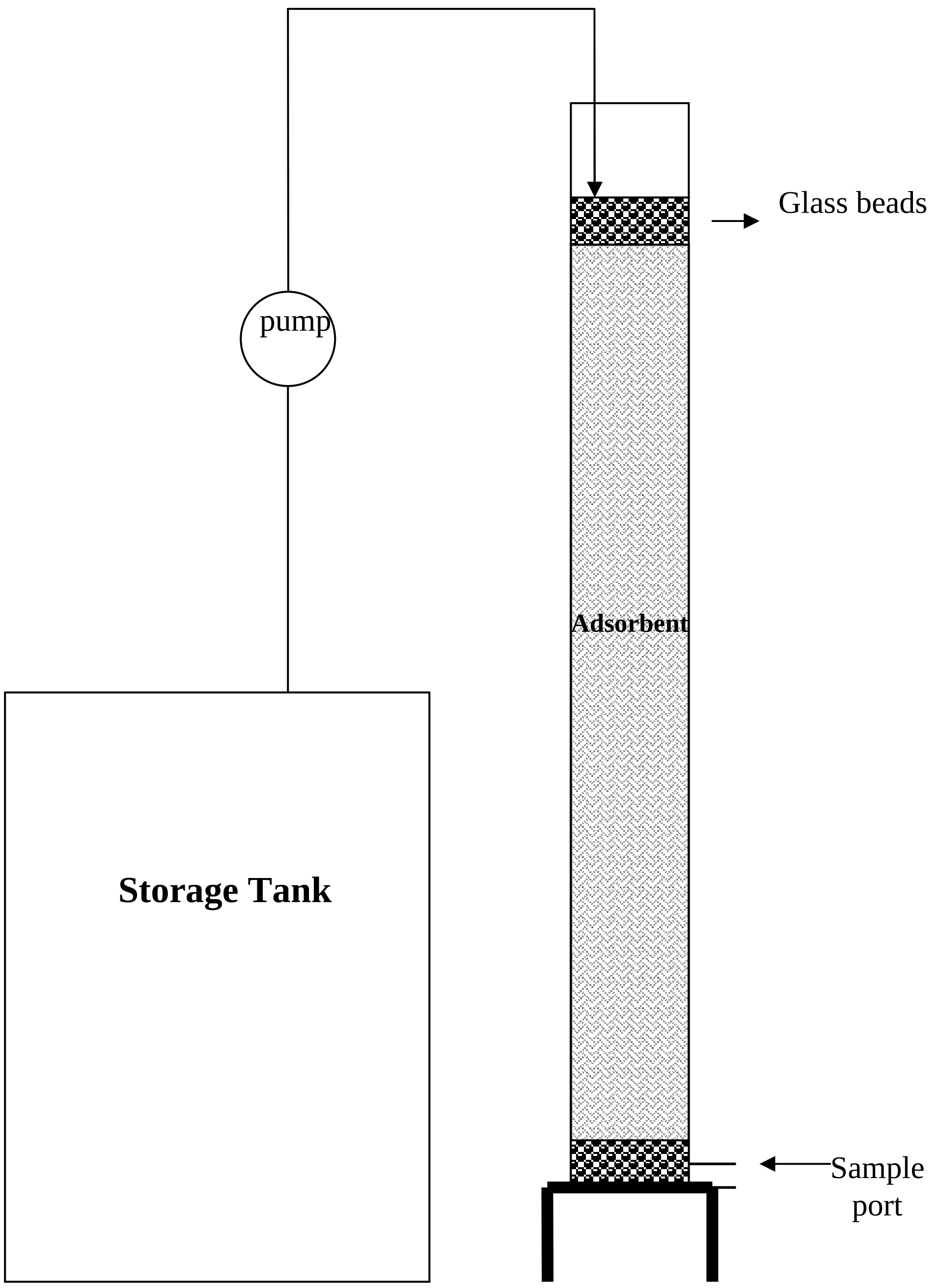


Figure 3-3 Schematic diagram of experiment

3.4.3 Analytical Methods

The routine parameters for analysis of the experimental system performance were color, COD, SS, TDS and pH. All analysis for COD, SS, TDS and pH were based on the Standard Methods for the Examination of Water and Wastewater. The color was analyzed using spectrophotometric method by measuring absorbance at the 400-700 nm, using a spectrophotometer. The detail of parameters and analytical methods were shown in Table 3-4.

Table 3-4 Parameters and analytical methods

Parameter	Unit	Method
pH	-	Glass electrode instrument
COD	mg/L	Closed Reflux method
Color	Space Unit	Spectrophotometric method
SS	mg/L	GF/C filtration method
TDS	mg/L	Dry at 103-105 °C

3.5 Statistical Analysis

Descriptive Analysis: the volume treated, breakthrough time and the removal efficiency of color, COD, concentrations of suspended solids and total dissolved solid were described as Mean, Minimum, Maximum values and Standard Deviation (S.D.). The One-way Analysis of Variance test (ANOVA) and the General Linear Model (ANOVA Model) were used for comparing the color removal efficiency of system in which parameters were different (sugar cane bagasse sizes, sugar cane bagasse depths, flow rates and types of sugar cane bagasse preparation). The significant difference of variables was determined at the α level of 0.05.

CHAPTER IV
RESULTS

4.1 Experimental Part 1

4.1.1 Effect of sugar bagasse sizes on the treatment efficiency of synthetic silk dyeing wastewater

The treatment efficiency of synthetic silk dyeing wastewater by using various sugar cane bagasse sizes at constant sugar cane bagasse depths of 30, 60 and 90 cm and constant flow rates of 5, 10 and 15 ml/min are shown in Figure 4-1.

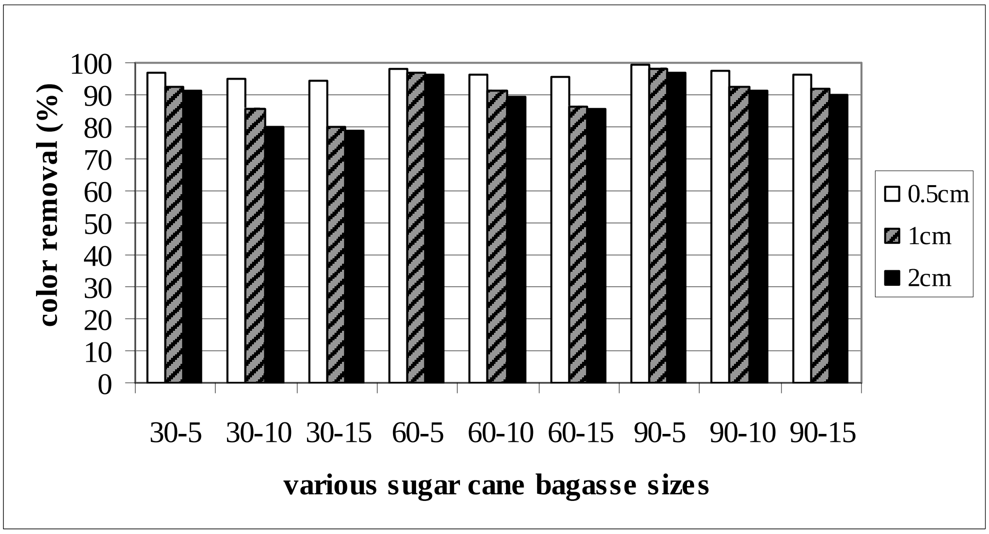


Figure 4-1 The color removal efficiency of various sugar cane bagasse sizes at constant sugar cane bagasse depths and constant flow rates

Three different sugar cane bagasse sizes of 0.5, 1 and 2 cm at all conditions had a similar trend of adsorption of synthetic silk dyeing wastewater. The color removal efficiency at the smaller size was more efficient than the larger size. The color removal efficiency, volume treated and breakthrough time at 90% breakpoint, COD, SS, pH are shown in Table 4-1 and 4-2, respectively.

Table 4-1 The color removal efficiency, volume treated and breakthrough time at 90% breakpoint for various sugar cane bagasse sizes at constant sugar cane bagasse depths and constant flow rates

Depth (cm)	Flow rate (ml/min)	Size (cm)	Color removal (%)		Volume Treated (ml)		Break through Time (min)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
30	5	0.5	96.78	0.07	121.40	6.78	24.28	1.36
		1	92.20	1.01	62.59	6.46	12.52	1.29
		2	91.37	0.14	16.16	0.69	3.23	0.14
	10	0.5	95.09	0.30	88.58	18.04	8.86	1.80
		1	85.91	0.33	-	-	-	-
		2	79.88	0.50	-	-	-	-
	15	0.5	94.24	1.01	74.52	8.85	4.97	0.59
		1	79.94	1.04	-	-	-	-
		2	78.88	0.12	-	-	-	-
60	5	0.5	97.86	0.71	388.30	11.71	77.66	2.34
		1	96.88	0.44	304.43	15.86	60.89	3.17
		2	96.05	0.95	190.95	2.38	38.19	0.48
	10	0.5	96.16	0.57	348.80	28.08	34.88	2.81
		1	91.37	0.37	104.45	6.98	10.45	0.70
		2	89.18	0.51	-	-	-	-
	15	0.5	95.52	0.10	188.75	20.21	12.58	1.35
		1	86.42	0.16	-	-	-	-
		2	85.72	0.34	-	-	-	-
90	5	0.5	99.13	0.29	491.07	3.28	98.21	0.66
		1	98.09	0.18	539.47	5.56	107.89	1.11
		2	96.84	0.16	474.52	31.85	94.90	6.37
	10	0.5	97.30	1.33	577.57	59.65	57.76	5.97
		1	92.41	1.01	143.60	27.52	14.36	2.75
		2	91.00	0.55	120.00	4.68	12.00	0.47
	15	0.5	96.13	0.15	308.57	10.71	20.57	0.71
		1	92.04	0.90	141.35	7.22	9.42	0.48
		2	90.20	0.71	25.29	2.50	1.69	0.17

Remark: dash (-) refer to color removal efficiency is less than 90% breakpoint

Table 4-2 COD, SS, pH of effluent for various sugar cane bagasse sizes at constant sugar cane bagasse depths and constant flow rates

Depth (cm)	Flow rate (ml/min)	Size (cm)	COD (mg/L)		SS (mg/L)		pH	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
30	5	0.5	1,974.53	63.69	23.40	1.47	5.41	0.04
		1	1,685.82	109.47	10.07	2.33	5.57	0.02
		2	1,465.63	213.52	20.11	5.53	5.53	0.17
	10	0.5	1,627.78	50.00	10.60	0.00	5.39	0.01
		1	1,413.10	46.32	22.92	0.61	5.25	0.03
		2	1,305.02	203.58	4.16	1.07	5.17	0.05
	15	0.5	1,330.44	111.68	30.20	0.87	5.55	0.03
		1	1,238.26	66.33	15.47	0.07	6.49	0.42
		2	819.22	30.94	21.35	3.08	5.55	0.04
60	5	0.5	3,013.19	215.23	49.54	6.73	5.13	0.01
		1	2,574.32	104.32	75.67	9.20	4.96	0.00
		2	2,271.29	198.52	12.80	0.64	5.28	0.12
	10	0.5	2,691.26	146.81	23.10	2.90	5.49	0.01
		1	2,475.52	179.15	24.80	2.13	5.36	0.00
		2	2,022.22	226.25	10.33	2.10	5.28	0.37
	15	0.5	1,882.02	176.99	31.33	2.80	5.46	0.01
		1	1,868.44	77.39	17.90	0.37	5.70	0.02
		2	1,754.90	149.49	24.08	4.27	5.48	0.46
90	5	0.5	3,747.35	74.31	29.43	2.10	5.27	0.02
		1	2,889.99	87.58	11.87	1.20	5.27	0.03
		2	2,388.00	127.55	7.20	0.84	5.26	0.06
	10	0.5	2,780.41	93.16	31.43	4.10	5.50	0.02
		1	2,748.26	193.24	11.99	5.29	5.27	0.15
		2	2,380.00	43.47	6.23	1.55	4.96	0.00
	15	0.5	2,673.03	81.38	37.33	1.80	5.33	0.04
		1	2,418.46	78.83	45.33	0.57	5.46	0.01
		2	2,183.80	56.48	27.11	1.25	5.29	0.57
Before Treatment			392.56	67.73	68.74	32.54	7.14	0.21

Increasing sugar cane bagasse size resulted in the decrease of the color removal efficiency, and COD at all conditions. Volume treated and breakthrough time at 90% breakpoint decreased with increasing sugar cane bagasse size except sugar cane bagasse depth of 90 cm and flow rate of 5 ml/min. However, the SS and pH value were not related with sugar cane bagasse sizes.

a) Sugar cane bagasse depth of 30 cm

- At sugar cane bagasse depth of 30 cm and flow rate of 5 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 96.78% to 91.37 %. Volume treated and breakthrough time at 90% breakpoint decreased from 121.40 to 16.16 ml and 24.28 to 3.23 minutes, respectively. The COD values decreased from 1,974.53 to 1,465.63 mg/L. The maximum and minimum of the SS and pH value were 23.40 and 10.07 mg/L and 5.57 and 5.41, respectively.
- At sugar cane bagasse depth of 30 cm and flow rate of 10 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 95.09 % to 79.88 %. The COD values decreased from 1,627.78 to 1,305.02 mg/L. Volume treated and breakthrough time at 90% breakpoint for sugar cane bagasse sizes of 1 and 2 cm were non-detected. The maximum and minimum of the SS and pH value were 22.92 and 4.16 mg/L and 5.39 and 5.17, respectively.
- Concerning the flow rate of 15 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 94.24 % to 78.88 %. The COD values decreased from 1,330.44 to 819.22 mg/L. Volume treated and breakthrough time at 90% breakpoint for sugar cane bagasse sizes of 1 and 2 cm were non-detected. The maximum and minimum of the SS and pH value were 30.20 and 15.47 mg/L and 6.49 and 5.55, respectively.

b) Sugar cane bagasse depth of 60 cm

- At sugar cane bagasse depth of 60 cm and flow rate of 5 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 97.86 % to 96.05 %. Volume treated and breakthrough time at 90% breakpoint decreased from 388.30 to 190.95 ml and 77.66 to 38.19 minutes, respectively. The

COD values decreased from 3,013.19 to 2,271.29 mg/L. The maximum and minimum of the SS and pH value were 75.67 and 12.80 mg/L and 5.28 and 4.96, respectively.

- Regarding an sugar cane bagasse depth of 60 cm and flow rate of 10 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 96.16 % to 89.18 %. The COD values decreased from 2,691.26 to 2,022.22 mg/L. Volume treated and breakthrough time at 90% breakpoint at sugar cane bagasse size of 2 cm was non-detected. However, volume treated and breakthrough time at 90% breakpoint for sugar cane bagasse size of 0.5 to 1 cm decreased from 348.80 to 104.45 ml and 34.88 to 10.45 minutes, respectively. The maximum and minimum of the SS and pH value were 24.80 and 10.33 mg/L and 5.49 and 5.28, respectively.
- At sugar cane bagasse depth of 60 cm and flow rate of 15 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 95.52 % to 85.72 %. The COD values decreased from 1,882.02 to 1,754.90. Volume treated and breakthrough time at 90 % breakpoint for sugar cane bagasse sizes of 1 and 2 cm were non-detected. The maximum and minimum of the SS and pH value were 31.33 and 17.90 mg/L and 5.70 and 5.46, respectively.

c) Sugar cane bagasse depth of 90 cm

- At sugar cane bagasse depth of 90 cm and flow rate of 5 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 99.13% to 96.84%. The COD values decreased from 3,747.35 to 2,388.00 mg/L. The maximum and minimum of the SS and pH value were 29.43 and 7.20 mg/L and 5.27and 5.26, respectively. The maximum volume treated and breakthrough time at 90% breakpoint were 539.47 ml and 107.89 minutes, respectively at sugar cane bagasse sizes of 1 cm. The minimum volume treated and breakthrough time at 90% breakpoint were 474.52 ml and 94.90 minutes, respectively at sugar cane bagasse sizes of 2 cm.
- At sugar cane bagasse depth of 90 cm and flow rate of 10 ml/min for sugar cane bagasse sizes of 0.5 to 2 cm, the color removal efficiency decreased from 97.30% to 91.00%. Volume treated and breakthrough time at 90% breakpoint decreased from 577.57 to 120.00 ml and 57.76 to 12.00 minutes, respectively. The

COD values decreased from 2,780.41 to 2,380.00 mg/L. The maximum and minimum of the SS and pH value were 31.43 and 6.23 mg/L and 5.50 and 4.96, respectively.

- At sugar cane bagasse depth of 90 cm and flow rate of 15 ml/min the color removal efficiency decreased from 96.13% to 90.20% for sugar cane bagasse sizes of 0.5 to 2 cm. Volume treated and breakthrough time at 90% breakpoint decreased from 308.57 to 25.29 ml and 20.57 to 1.69 minutes, respectively. The COD values decreased from 2,673.03 to 2,183.80 mg/L. The maximum and minimum of the SS and pH value were 45.33 and 27.11 mg/L and 5.46 and 5.29, respectively.

The color removal efficiency at various sizes of sugar cane bagasse was statistical analyzed by using one-way ANOVA at 0.05 level of significance. It was found that using sugar cane bagasse size of 0.5 cm was significantly higher than sugar cane bagasse sizes of 1 and 2 cm (p-value = 0.000). It also was revealed that the color removal efficiency of sugar cane bagasse sizes of 1 and 2 was not different (p-value = 0.174).

4.1.2 Effect of sugar cane bagasse depths on the treatment efficiency of synthetic silk dyeing wastewater

The color removal efficiency of synthetic silk dyeing wastewater by using various sugar cane bagasse depths at constant sugar cane bagasse sizes of 0.5, 1 and 2 cm and constant flow rates of 5, 10 and 15 ml/min are shown in Figure 4-2.

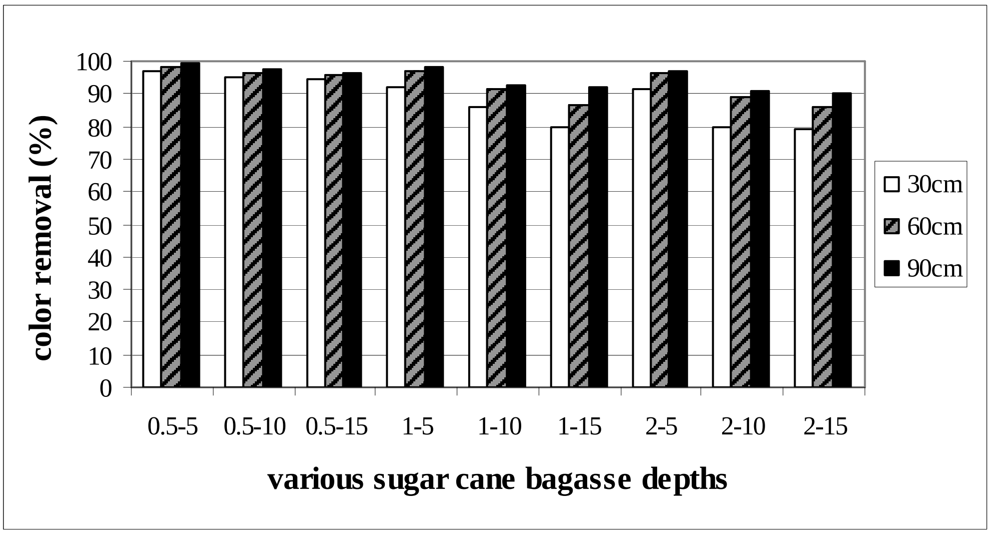


Figure 4-2 The color removal efficiency of various sugar cane bagasse depths at constant sugar cane bagasse sizes and constant flow rates

Three different sugar cane bagasse depths of 30, 60 and 90 cm at all conditions had a similar trend of adsorption of synthetic silk dyeing wastewater. The color removal efficiency at the higher sugar cane bagasse depth was more efficient than the shorter sugar cane bagasse depth. The color removal efficiency, volume treated and breakthrough time at 90% breakpoint, COD, SS, pH are displayed in Table 4-3 and 4-4, respectively.

Table 4-3 The color removal efficiency, volume treated and breakthrough time at 90% breakpoint for various sugar cane bagasse depths at constant sugar cane bagasse sizes and constant flow rates

Size (cm)	Flow rate (ml/min)	Depth (cm)	Color removal (%)		VolumeTreated (ml)		Break through Time (min)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
0.5	5	30	96.78	0.07	121.40	6.78	24.28	1.36
		60	97.86	0.71	388.30	11.71	77.66	2.34
		90	99.13	0.29	491.07	3.28	98.21	0.66
	10	30	95.09	0.30	88.58	18.04	8.86	1.80
		60	96.16	0.57	348.80	28.08	34.88	2.81
		90	97.30	1.33	577.57	59.65	57.76	5.97
	15	30	94.24	1.01	74.52	8.85	4.97	0.59
		60	95.52	0.10	188.75	20.21	12.58	1.35
		90	96.13	0.15	308.57	10.71	20.57	0.71
1	5	30	92.20	1.01	62.59	6.46	12.52	1.29
		60	96.88	0.44	304.43	15.86	60.89	3.17
		90	98.09	0.18	539.47	5.56	107.89	1.11
	10	30	85.91	0.33	-	-	-	-
		60	91.37	0.37	104.45	6.98	10.45	0.70
		90	92.41	1.01	143.60	27.52	14.36	2.75
	15	30	79.94	1.04	-	-	-	-
		60	86.42	0.16	-	-	-	-
		90	92.04	0.90	141.35	7.22	9.42	0.48
2	5	30	91.37	0.14	16.16	0.69	3.23	0.14
		60	96.05	0.95	190.95	2.38	38.19	0.48
		90	96.84	0.16	474.52	31.85	94.90	6.37
	10	30	79.88	0.50	-	-	-	-
		60	89.18	0.51	-	-	-	-
		90	91.00	0.55	120.00	4.68	12.00	0.47
	15	30	78.88	0.12	-	-	-	-
		60	85.72	0.34	-	-	-	-
		90	90.20	0.71	25.29	2.50	1.69	0.17

Remark: dash (-) refer to color removal efficiency is less than 90% breakpoint

Table 4-4 COD, SS, pH of effluent for various sugar cane bagasse depths at constant sugar cane bagasse sizes and constant flow rates

Size (cm)	Flow rate (ml/min)	Depth (cm)	COD (mg/L)		SS (mg/L)		pH	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
0.5	5	30	1,974.53	63.69	23.40	1.47	5.41	0.04
		60	3,013.19	215.23	49.54	6.73	5.13	0.01
		90	3,747.35	74.31	29.43	2.10	5.27	0.02
	10	30	1,627.78	50.00	10.60	0.00	5.39	0.01
		60	2,691.26	146.81	23.10	2.90	5.49	0.01
		90	2,780.41	93.16	31.43	4.10	5.50	0.02
	15	30	1,330.44	111.68	30.20	0.87	5.55	0.03
		60	1,882.02	176.99	31.33	2.80	5.46	0.01
		90	2,673.03	81.38	37.33	1.80	5.33	0.04
1	5	30	1,685.82	109.47	10.07	2.33	5.57	0.02
		60	2,574.32	104.32	75.67	9.20	4.96	0.00
		90	2,889.99	87.58	11.87	1.20	5.27	0.03
	10	30	1,413.10	46.32	22.92	0.61	5.25	0.03
		60	2,475.52	179.15	24.80	2.13	5.36	0.00
		90	2,748.26	193.24	11.99	5.29	5.27	0.15
	15	30	1,238.26	66.33	15.47	0.07	6.49	0.42
		60	1,868.44	77.39	17.90	0.37	5.70	0.02
		90	2,418.46	78.83	45.33	0.57	5.46	0.01
2	5	30	1,465.63	213.52	20.11	5.53	5.53	0.17
		60	2,271.29	198.52	12.80	0.64	5.28	0.12
		90	2,388.00	127.55	7.20	0.84	5.26	0.06
	10	30	1,305.02	203.58	4.16	1.07	5.17	0.05
		60	2,022.22	226.25	10.33	2.10	5.28	0.37
		90	2,380.00	43.47	6.23	1.55	4.96	0.00
	15	30	819.22	30.94	21.35	3.08	5.55	0.04
		60	1,754.90	149.49	24.08	4.27	5.48	0.46
		90	2,183.80	56.48	27.11	1.25	5.29	0.57
Before Treatment			392.56	67.73	68.74	32.54	7.14	0.21

Increasing sugar cane bagasse depth resulted in increase of the color removal efficiency, COD, the volume treated and breakthrough time at 90% breakpoint at all conditions. However, the SS and pH values were not related with sugar cane bagasse depths.

a) Sugar cane bagasse size of 0.5 cm

- At sugar cane bagasse size of 0.5 cm and flow rate of 5 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 96.78% to 99.13%. Volume treated and breakthrough time at 90% breakpoint increased from 121.40 to 491.07 ml and 24.28 to 98.21 minutes, respectively. The COD values increased from 1,974.53 to 3,747.35 mg/L. The maximum and minimum of the SS and pH value were 49.54 and 23.40 mg/L and 5.41 and 5.13, respectively.
- At sugar cane bagasse size of 0.5 cm and flow rate of 10 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 95.09% to 97.30%. Volume treated and breakthrough time at 90% breakpoint increased from 88.58 to 577.57ml and 8.86 to 57.76 minutes, respectively. The COD values increased from 1,627.78 to 2,780.41 mg/L. The maximum and minimum of the SS and pH value were 31.43 and 10.60 mg/L and 5.50 and 5.39, respectively.
- At sugar cane bagasse size of 0.5 cm and flow rate of 15 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 94.24% to 96.13%. Volume treated and breakthrough time at 90% breakpoint increased from 74.52 to 308.57 ml and 4.97 to 20.57 minutes, respectively. The COD values increased from 1,330.44 to 2,673.03 mg/L. The maximum and minimum of the SS and pH value were 37.33 and 30.20 mg/L and 5.55 and 5.33, respectively.

b) Sugar cane bagasse size of 1 cm

- At sugar cane bagasse size of 1 cm and flow rate of 5 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 92.20% to 98.09%. Volume treated and breakthrough time at 90% breakpoint increased from 62.59to 539.47ml and 12.52 to 107.89 minutes, respectively. The COD values increased from 1,685.82 to 2,889.99 mg/L. The maximum and minimum of the SS and pH value were 75.67 and 10.07 mg/L and 5.57 and 4.96, respectively.

- At sugar cane bagasse size of 1 cm and flow rate of 10 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 85.91% to 92.41%. The COD values increased from 1,413.10 to 2,748.26 mg/L. Volume treated and breakthrough time at 90% breakpoint at sugar cane bagasse depths of 30 was non-detected. However, Volume treated and breakthrough time at 90% breakpoint for sugar cane bagasse depths of 60 to 90 cm increased from 104.45 to 143.60 ml and 10.45 to 14.36 minutes, respectively. The maximum and minimum of the SS and pH value were 24.80 and 11.99 mg/L and 5.36 and 5.25, respectively.
- At sugar cane bagasse size of 1 cm and flow rate of 15 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 79.94% to 92.04%. The COD values increased from 1,238.26 to 2,418.46 mg/L. Volume treated and breakthrough time at 90% breakpoint for sugar cane bagasse depths of 30 and 60 cm were non-detected. The maximum and minimum of the SS and pH value were 45.33 and 15.47 mg/L and 6.49 and 5.46, respectively.

c) Sugar cane bagasse size of 2 cm

- At sugar cane bagasse size of 2 cm and flow rate of 5 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 91.37% to 96.84%. Volume treated and breakthrough time at 90% breakpoint increased from 16.16 to 474.52 ml and 3.23 to 94.90 minutes, respectively. The COD values increased from 1,465.63 to 2,388.00 mg/L. The maximum and minimum of the SS and pH value were 20.11 and 7.20 mg/L and 5.53 and 5.26, respectively.
- At sugar cane bagasse size of 2 cm and flow rate of 10 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 79.88% to 91.00%. The COD values increased from 1,305.02 to 2,380.00 mg/L. Volume treated and breakthrough time at 90% breakpoint at sugar cane bagasse depths of 30 and 60 cm were non-detected. The maximum and minimum of the SS and pH value were 10.33 and 4.16 mg/L and 5.28 and 4.96, respectively.
- At sugar cane bagasse size of 2 cm and flow rate of 15 ml/min for sugar cane bagasse depths of 30 to 90 cm, the color removal efficiency increased from 78.88% to 90.20%. The COD values increased from 819.22 to 2,183.80 mg/L. Volume treated and breakthrough time at 90% breakpoint for sugar cane bagasse depths of 30

and 60 cm were non-detected. The maximum and minimum of the SS and pH value were 27.11 and 21.35 mg/L and 5.55 and 5.29, respectively.

The color removal efficiency at various sugar cane bagasse depths was statistical analyzed by using one-way ANOVA at 0.05 level of significance. It was found that using sugar cane bagasse depth of 30 cm was significantly lower than sugar cane bagasse depths of 60 cm (p-value = 0.002) and 90 cm (p-value = 0.000). Whereas the color removal efficiency at 60 and 90 cm of sugar cane bagasse depths were not significant different (p-value = 0.158).

4.1.3 Effect of flow rates on the treatment efficiency of synthetic silk dyeing wastewater

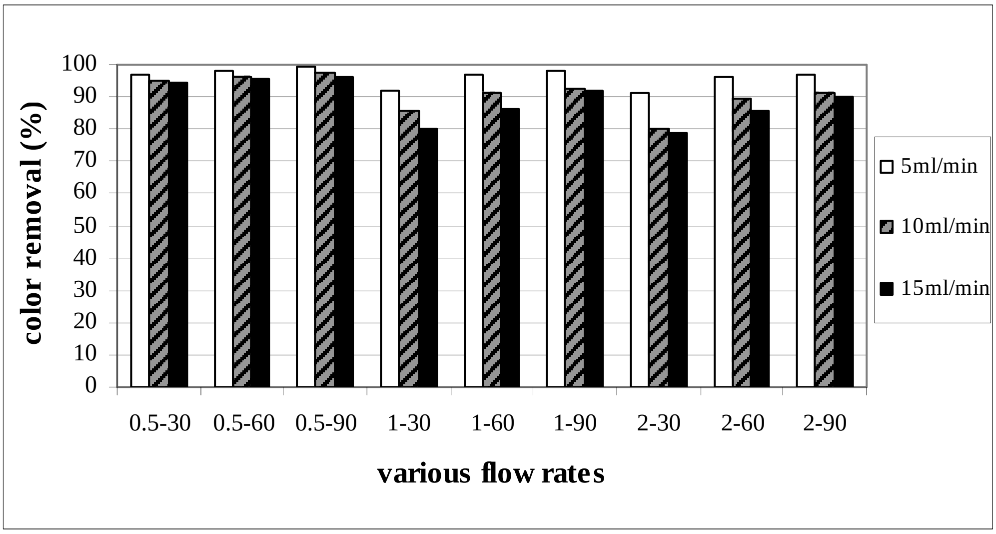


Figure 4-3 The color removal efficiency of various flow rates at constant sugar cane bagasse sizes and constant sugar cane bagasse depths

Figure 4-3 presents the color removal efficiency of synthetic silk dyeing wastewater of various flow rates at constant sugar cane bagasse sizes of 0.5, 1 and 2 cm and constant sugar cane bagasse depths of 30, 60 and 90 cm. The trend of three different flow rates of 5, 10 and 15 ml/min at all conditions were not different. The color removal efficiency at the lower flow rate was more efficient than the higher flow rate. The color removal efficiency, volume treated and breakthrough time at 90% breakpoint, COD, SS, pH for various flow rates at sugar cane bagasse sizes of 0.5, 1 and 2 cm. and constant sugar cane bagasse depths of 30, 60 and 90 cm are displayed in Table 4-5 and 4-6, respectively.

Table 4-5 The color removal efficiency, volume treated and breakthrough time at 90% breakpoint for various flow rates at constant sugar cane bagasse sizes and constant sugar cane bagasse depths

Size (cm)	Depth (cm)	Flow rate (ml/min)	Color removal (%)		VolumeTreated (ml)		Break through Time (min)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
0.5	30	5	96.78	0.07	121.40	6.78	24.28	1.36
		10	95.09	0.30	88.58	18.04	8.86	1.80
		15	94.24	1.01	74.52	8.85	4.97	0.59
	60	5	97.86	0.71	388.30	11.71	77.66	2.34
		10	96.16	0.57	348.80	28.08	34.88	2.81
		15	95.52	0.10	188.75	20.21	12.58	1.35
	90	5	99.13	0.29	491.07	3.28	98.21	0.66
		10	97.30	1.33	577.57	59.65	57.76	5.97
		15	96.13	0.15	308.57	10.71	20.57	0.71
1	30	5	92.20	1.01	62.59	6.46	12.52	1.29
		10	85.91	0.33	-	-	-	-
		15	79.94	1.04	-	-	-	-
	60	5	96.88	0.44	304.43	15.86	60.89	3.17
		10	91.37	0.37	104.45	6.98	10.45	0.70
		15	86.42	0.16	-	-	-	-
	90	5	98.09	0.18	539.47	5.56	107.89	1.11
		10	92.41	1.01	143.60	27.52	14.36	2.75
		15	92.04	0.90	141.35	7.22	9.42	0.48
2	30	5	91.37	0.14	16.16	0.69	3.23	0.14
		10	79.88	0.50	-	-	-	-
		15	78.88	0.12	-	-	-	-
	60	5	96.05	0.95	190.95	2.38	38.19	0.48
		10	89.18	0.51	-	-	-	-
		15	85.72	0.34	-	-	-	-
	90	5	96.84	0.16	474.52	31.85	94.90	6.37
		10	91.00	0.55	120.00	4.68	12.00	0.47
		15	90.20	0.71	25.29	2.50	1.69	0.17

Remark: dash (-) refer to color removal efficiency is less than 90% breakpoint

Table 4-6 COD, SS, pH of effluent for various flow rates at constant sugar cane bagasse sizes and constant sugar cane bagasse depths

Size (cm)	Depth (cm)	Flow rate (ml/min)	COD (mg/L)		SS (mg/L)		pH	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
0.5	30	5	1,974.53	63.69	23.40	1.47	5.41	0.04
		10	1,627.78	50.00	10.60	0.00	5.39	0.01
		15	1,330.44	111.68	30.20	0.87	5.55	0.03
	60	5	3,013.19	215.23	49.54	6.73	5.13	0.01
		10	2,691.26	146.81	23.10	2.90	5.49	0.01
		15	1,882.02	176.99	31.33	2.80	5.46	0.01
	90	5	3,747.35	74.31	29.43	2.10	5.27	0.02
		10	2,780.41	93.16	31.43	4.10	5.50	0.02
		15	2,673.03	81.38	37.33	1.80	5.33	0.04
1	30	5	1,685.82	109.47	10.07	2.33	5.57	0.02
		10	1,413.10	46.32	22.92	0.61	5.25	0.03
		15	1,238.26	66.33	15.47	0.07	6.49	0.42
	60	5	2,574.32	104.32	75.67	9.20	4.96	0.00
		10	2,475.52	179.15	24.80	2.13	5.36	0.00
		15	1,868.44	77.39	17.90	0.37	5.70	0.02
	90	5	2,889.99	87.58	11.87	1.20	5.27	0.03
		10	2,748.26	193.24	11.99	5.29	5.27	0.15
		15	2,418.46	78.83	45.33	0.57	5.46	0.01
2	30	5	1,465.63	213.52	20.11	5.53	5.53	0.17
		10	1,305.02	203.58	4.16	1.07	5.17	0.05
		15	819.22	30.94	21.35	3.08	5.55	0.04
	60	5	2,271.29	198.52	12.80	0.64	5.28	0.12
		10	2,022.22	226.25	10.33	2.10	5.28	0.37
		15	1,754.90	149.49	24.08	4.27	5.48	0.46
	90	5	2,388.00	127.55	7.20	0.84	5.26	0.06
		10	2,380.00	43.47	6.23	1.55	4.96	0.00
		15	2,183.80	56.48	27.11	1.25	5.29	0.57
Before Treatment			392.56	67.73	68.74	32.54	7.14	0.21

It was observed that the increasing of flow rate caused the decreasing of the color removal efficiency, and COD for three sugar cane bagasse sizes and three sugar cane bagasse depths. Volume treated and breakthrough time at 90% breakpoint decreased with increasing flow rate except sugar cane bagasse size of 0.5 cm and sugar cane bagasse depth of 90 cm. However, the SS and pH value were not related with sugar cane bagasse sizes

a) Sugar cane bagasse size of 0.5 cm

- At sugar cane bagasse size of 0.5 cm and sugar cane bagasse depth of 30 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 96.78% to 94.24%. Volume treated and breakthrough time at 90% breakpoint decreased from 121.40 to 74.52 ml and 24.28 to 4.97 minutes, respectively. The COD values decreased from 1,974.53 to 1,330.44 mg/L. The maximum and minimum of the SS and pH value were 30.20 and 10.60 mg/L and 5.55 and 5.39, respectively.
- At sugar cane bagasse size of 0.5 cm and sugar cane bagasse depth of 60 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 97.86% to 95.52%. Volume treated and breakthrough time at 90% breakpoint decreased from 388.30 to 188.75 ml and 77.66 to 12.58 minutes, respectively. The COD values decreased from 3,013.19 to 1,882.02 mg/L. The maximum and minimum of the SS and pH value were 49.54 and 23.10 mg/L and 5.49 and 5.13, respectively.
- At sugar cane bagasse size of 0.5 cm and sugar cane bagasse depth of 90 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 99.13% to 96.13%. The COD values decreased from 3,747.35 to 2,673.03 mg/L. The maximum and minimum of the SS and pH value were 37.33 and 29.43 mg/L and 5.50 and 5.27, respectively. The maximum volume treated and breakthrough time at 90% breakpoint were 577.57 ml and 57.76 minutes, respectively at flow rate of 10 ml/min. The minimum volume treated and breakthrough time at 90% breakpoint were 308.57 ml and 20.57 minutes, respectively at flow rate of 15 ml/min.

b) Sugar cane bagasse size of 1 cm

- At sugar cane bagasse size of 1 cm and sugar cane bagasse depth of 30 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 92.20% to 79.94%. The COD values decreased from 1,685.82 to 1,238.26 mg/L. Volume treated and breakthrough time at 90% breakpoint for flow rates of 10 and 15 cm were non-detected. The maximum and minimum of the SS and pH value were 22.92 and 10.07 mg/L and 6.49 and 5.25, respectively.
- At sugar cane bagasse size of 1 cm and sugar cane bagasse depth of 60 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 96.88% to 86.42%. The COD values decreased from 2,574.32 to 1,868.44 mg/L. Volume treated and breakthrough time at 90% breakpoint at flow rate of 15 ml/min was non-detected. However, volume treated and breakthrough time at 90% breakpoint for flow rate of 5 to 10 ml/min increased from 304.43 to 104.45 ml and 60.89 to 10.45 minutes, respectively. The maximum and minimum of the SS and pH value were 75.67 and 17.90 mg/L and 5.70 and 4.96, respectively.
- At sugar cane bagasse size of 1 cm and sugar cane bagasse depth of 90 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 98.09% to 92.04%. Volume treated and breakthrough time at 90% breakpoint decreased from 539.47 to 141.35 ml and 107.89 to 9.42 minutes, respectively. The COD values decreased from 2,889.99 to 2,418.46 mg/L. The maximum and minimum of the SS and pH value were 45.33 and 11.87 mg/L and 5.46 and 5.27, respectively.

c) Sugar cane bagasse size of 2 cm

- At sugar cane bagasse size of 2 cm and sugar cane bagasse depth of 30 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 91.37% to 78.88%. The COD values decreased from 1,465.63 to 819.22 mg/L. Volume treated and breakthrough time at 90% breakpoint for flow rates of 10 and 15 cm were non-detected. The maximum and minimum of the SS and pH value were 21.35 and 4.16 mg/L and 5.55 and 5.17, respectively.
- At sugar cane bagasse size of 2 cm and sugar cane bagasse depth of 60 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 96.05% to 85.72%. The COD values decreased from 2,271.29 to 1,754.90 mg/L.

Volume treated and breakthrough time at 90% breakpoint at flow rate of 10 and 15 ml/min were non-detected. The maximum and minimum of the SS and pH values were 24.08 and 10.33 mg/L and 5.48 and 5.28, respectively.

- At sugar cane bagasse size of 2 cm and sugar cane bagasse depth of 90 cm for flow rates of 5 to 15 ml/min, the color removal efficiency decreased from 96.84% to 90.20%. Volume treated and breakthrough time at 90% breakpoint decreased from 474.52 to 25.29 ml and 94.90 to 1.69 minutes, respectively. The COD values decreased from 2,388.00 to 2,183.80 mg/L. The maximum and minimum of the SS and pH value were 27.11 and 6.23 mg/L and 5.29 and 4.96, respectively.

The color removal efficiency at various flow rates of sugar cane bagasse was statistical analyzed by using one-way ANOVA at 0.05 level of significance. It was found that color removal efficiency at flow rate of 5 ml/min was significantly higher than flow rate of 10 and 15 ml/min (p-value = 0.000). It was revealed that color removal efficiency 10 and 15 ml/min of flow rate were not significant different (p-value = 0.116).

From the data in Tables 4-1, 4-3 and 4-5, the highest color removal efficiency was 99.13% at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth of 90 cm and flow rate of 5 ml/min. The lowest color removal efficiency was 78.88% at sugar cane bagasse size of 2 cm sugar cane bagasse depth of 30 cm and flow rate of 15 ml/min. The General Linear Model (ANOVA Model) at the 0.05 level of significance was used to analyze for the color removal efficiencies under three factors namely; sugar cane bagasse sizes, depths of adsorption and flow rates. The results implied that using different sugar cane bagasse sizes, depths of adsorption or flow rates could affect on significant different color removal efficiencies (p-value = 0.000). In addition, there could affect on significant different color removal efficiencies when using different sugar cane bagasse sizes and depths of adsorption (p-value = 0.000), sugar cane bagasse sizes and flow rates (p-value = 0.000), depths of adsorption and flow rates (p-value = 0.000) or sugar cane bagasse sizes, depths of adsorption and flow rates(p-value = 0.000).

The highest value of volume treated at 90% breakpoint was 577.57 ml at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth of 90 cm and flow rate of 10 ml/min. The lowest value of volume treated at 90% breakpoint was 16.16 ml at sugar cane bagasse size of 2 cm sugar cane bagasse depth of 30 cm and flow rate of 5ml/min. The optimum operating condition was selected by considering highest value of volume treated at 90% breakpoint. Therefore sugar cane bagasse size of 0.5 cm, sugar cane bagasse depth of 90 cm and flow rate of 10 ml/min was selected for experiment Part 2.

4.2 Experimental Part 2

4.2.1 Effect of type of sugar cane bagasse preparation at optimum operating condition

From experimental part 1, the optimum operating condition was determined. From those results, the optimum operating conditions used for studying the treatment efficiency of actual silk dyeing wastewater in this part were 0.5 cm of sugar cane bagasse size, 90 cm of sugar cane bagasse depth and 10 ml/min of flow rate.

Three different types of sugar cane bagasse preparation, chemical prepared sugar cane bagasse, simple prepared sugar cane bagasse (dry with hot air oven) and simple prepared sugar cane bagasse (dry with sunlight) were packed into three identical columns. The results of the color removal efficiency, COD, SS, TDS and pH are shown in table 4-7

Table 4-7 The results of the color removal efficiency, COD, SS, TDS and pH

Types of sugar cane bagasse preparation	**Color (SU)**	**%Color removal**	**COD (mg/L)**	**SS (mg/L)**	**TDS (mg/L)**	**pH**
Chemical preparation	88.86 (1.85)	89.59 (0.06)	2,559.41 (51.76)	80.93 (5.08)	6,002.18 (46.21)	5.49 (0.20)
Simple preparation (dry with oven)	59.67 (1.89)	93.01 (0.33)	2,996.44 (146.02)	69.93 (5.41)	6,200.46 (69.75)	5.23 (0.15)
Simple preparation (dry with sunlight)	185.79 (1.50)	78.22 (0.51)	1,747.21 (3.76)	127.60 (3.70)	5,352.30 (35.74)	5.75 (0.11)
Industrial Effluent Standard*	Not Obnoxious	-	400	<50	<3,000	5.5-9
Before Treatment	853.20 (12.94)	-	571.11 (21.27)	100.00 (9.18)	4,199.04 (61.27)	7.52 (0.02)

*Source: Ministry of Science, Technology and Environment (1996).
Remark: The Standard Deviation is showed in the parenthesis.

Three different types of sugar cane bagasse preparation were used to adsorb actual silk dyeing wastewater could decrease color intensity from 853.20 SU to 88.86, 59.67 and 185.79 SU for chemical preparation, simple preparation (dry with oven) and simple preparation (dry with sunlight), respectively. The highest color removal efficiency was simple preparation (dry with oven) at 93.01%. Volume treated and breakthrough time at 90% breakpoint of simple preparation (dry with oven) were 59.78 ml (S.D. = 8.27) and 5.98 minutes (S.D. = 0.83), respectively. The color removal efficiency of chemical preparation and simple preparation (dry with sunlight) were lower than 90%, and therefore their volume treated and breakthrough time at 90% breakpoint could not detect.

The removal efficiency of color at various types of sugar cane bagasse preparation was statistical analyzed by using one-way ANOVA at 0.05 level of significance. The result showed that the color removal efficiency of simple preparation (dry with sunlight) was significantly lower than chemical preparation and simple preparation (dry with oven) (p-value = 0.000). It was revealed that the color removal efficiency of chemical preparation was significantly lower than simple preparation (dry with oven) (p-value = 0.002).

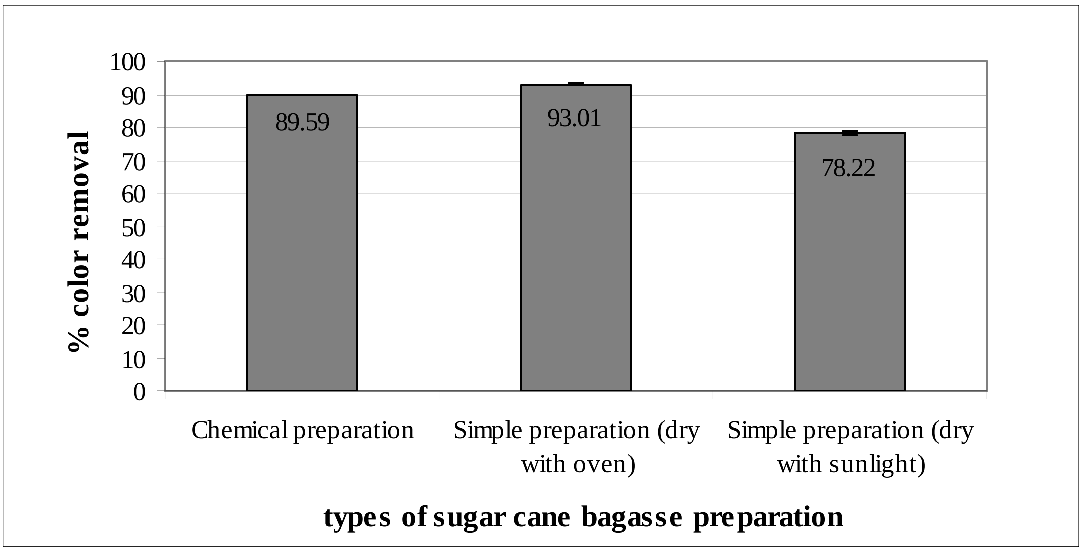


Figure 4-4 The color removal efficiency of different types of sugar cane bagasse preparation

After treating actual silk dyeing wastewater with different types of sugar cane bagasse preparation, it was observed that COD and TDS apparently increased. The highest COD and TDS were simple preparation (dry with oven) and the lowest COD and TDS were simple preparation (dry with sunlight). Nevertheless, the simple preparation (dry with oven) presented lowest SS and pH and the simple preparation (dry with sunlight) presented highest SS and pH. The whole SS and pH of all sugar cane bagasse preparation types excepting SS of simple preparation (dry with sunlight) decreased.

The COD, SS and TDS of all sugar cane bagasse preparation types exceeded those of the required effluent standards stipulated by the Ministry of Industry of Thailand. Considering pH value, it shows that only simple preparation (dry with sunlight) can be in the range of the required effluent standards stipulated by the Ministry of Industry of Thailand.

CHAPTER V
DISCUSSION

5.1 Experimental Part 1

5.1.1 Effect of sugar cane bagasse sizes

Three different sugar cane bagasse sizes of 0.5, 1 and 2 cm at all conditions had a similar trend of graph as the adsorption of synthetic silk dyeing wastewater. The color removal efficiency at the sugar cane bagasse size of 0.5 cm was significantly higher than sugar cane bagasse sizes of 1 and 2 cm. This result corresponded to the first hypothesis, which stated that the color removal efficiency at the smaller size is more efficient than the larger size. This result was in agreement with the study of Mokhtar A. et al (50), Walker G. M. and Weatherley L.R. (51), Dimitrova S.V. (52) and Tipprasertsin K. (33), who found that the removal efficiency of adsorbent which increased size of adsorbent resulted in the higher removal efficiency than those of smaller size of adsorbent. It indicated that the removal efficiency change if the size of adsorbent changed.

The volume treated and breakthrough time at 90% breakpoint increased as the sugar cane bagasse size decreased. It means that the breakthrough concentration of larger sugar cane bagasse size was saturated quicker than the smaller sugar cane bagasse size. This is due to the smaller particle sizes had specific surface area more than the larger particle size (51). There were many reports indicated that the volume treated at breakpoint increased with decreasing particle size of adsorbent, for example, the results reported by Tipprasertsin K. (33) for the adsorption of synthetic reactive dye solution by using treated flute reed as an adsorbent. The volume treated and breakthrough time at 90% breakpoint and exhaustion point increased from 70 to 242 ml and 340 to 427 ml, respectively and the breakthrough time at 90% breakpoint and exhaustion point increased from 1.94 to 6.72 hours and 9.44 to 11.86 hours respectively with decreasing in the particle size from 420-1190 to 2000-2800 μm.

5.1.2 Effect of sugar cane bagasse depths

Increasing sugar cane bagasse depth resulted in increase in the color removal efficiency, the volume treated and breakthrough time at 90% breakpoint at all conditions. The result was in agreement with the second hypothesis which stated that the color removal efficiency at the higher sugar cane bagasse depth is more efficient than the lower sugar cane bagasse depth.

The color removal efficiency increased when the depth of adsorbent increased. This phenomenon could be explained that the increase of the depth of adsorbent will increase the larger surface and longer detention time, thus result in a longer contact time of the wastewater with the adsorbent. This result was agreement with the study of Nhoochana Y. (53), who reported that color removal efficiency increased from 49.35 to 73.50% and 18.91 to 23.06% when increasing the sugar cane bagasse depth from 20 to 30 cm for the removal of green and blue synthetic dyeing wastewater, respectively.

The volume treated and breakthrough time at 90% breakpoint increased as the depth of adsorbent increased. Tipprasertsin K. (33) studied the removal of color from synthetic reactive dye solution by using treated flute reed in a fixed bed column and found that the volume treated at adsorbent depth of 45 cm was more than at adsorbent depth of 15 and 30 cm and the volume treated at adsorbent depth of 30 cm was higher than at adsorbent depth of 15 cm. In addition, Kumar U. and Bandyopadhyay M. (54), who observed that time to achieve breakthrough was increased with the increase of adsorbent depths.

5.1.3 Effect of flow rates

The trend of three different flow rates of 5, 10 and 15 ml/min at all conditions were not different. It was found that using flow rate of 5 ml/min was significantly higher than flow rate of 10 and 15 ml/min. This result is consistent with the third hypothesis, which stated that the color removal efficiency at the lower flow rate is more efficient than the higher flow rate. This result is similar to the studies of Kongdang P. (4), Aungudornpukdee J. (55), Pomsuwan D. (56), Pibul P. (57) who noted that removal efficiency decrease as an increase of flow rates.

It could be explained that when dyeing wastewater pass through the column, the upper portion of sugar cane bagasse becomes saturated with color molecules and the mass transfer zone moves down the column. The mass transfer zone characterizes the slow change in the concentration of color molecules on the sugar cane bagasse during the continuous adsorption until it reaches the outlet. When synthetic dyeing wastewater flow through the adsorbent at high flow rates, the molecules of color passes through sugar cane bagasse absorbent at high flow rates. This causes an insufficient contract time for permitting color molecules being diffused too all adsorbing site of adsorbent. Hence, the color removal efficiency was decreased.

When consider the result of the volume treated and breakthrough time at 90% breakpoint, it can be found that increasing of flow rate result in decreasing of the volume treated and breakthrough time. It could be explained that as the flow rate increased the speed of the adsorption zone or mass transfer zone through the adsorbent bed also increased (58). As time passes, this zone approaches the bottom of column and all active sites of adsorbent were decreased. This phenomenon leads to the decreasing amount of color molecules adsorbed. In addition, the result of breakthrough time from this study was in agreement with, Pibul P. (57) studied the removal of chromium from electroplating wastewater using peat moss as a tertiary treatment and found that increasing of overflow rate result in decreasing of breakthrough time. In addition, Robinson *et al* (42) found that the adsorption of reactive dyes onto the barley husks was dependent on the flow rate. The barley husks could remove reactive dyes only 44.8 mg/L at the flow rate of 1.77 ml/min while it could remove 80 mg/L of reactive dyes at the flow rate of 0.51 ml/min.

5.1.4 Effect of sugar cane bagasse sizes, sugar cane bagasse depths and flow rates on COD SS and pH

Synthetic silk dyeing wastewater was prepared by controlling range of color intensity. The synthetic silk dyeing wastewater was prepared by several batches. Therefore, these batches could have little different characteristics. In this study, COD, SS and pH values were different in each replicate; however, TDS value was not analyzed in this part because an equipment obstruction was occurred.

From the result in Chapter IV, COD value at all condition increase with decreasing sugar cane bagasse size and flow rate and increasing sugar cane bagasse depth. The COD value of effluent is more than the COD value of influent that may be the leaching of organics from the sugar cane bagasse. Increasing of influent SS value resulted in increase of effluent SS value. Therefore, the SS values of effluent for each condition can not be compared. However, The SS value of effluent was less than those of influent.

These findings were similar to the study of Tipprasertsin K. (33) stated that the treated flute reed could remove the color and SS but increased the COD value. This might be the leaching of other organics except the color from the treated flute reed during experiment resulted in increasing COD value. Nevertheless, the results were inconsistent with the studies of Supawimol P. (59) which used palm oil shell ash and Mahaphrom N. (60) which used granular activated carbon as adsorbent. The results of two studies found that increasing of adsorbent depth resulted in decrease in the COD and SS value, whereas increasing of flow rate resulted in increase in the COD and SS value. Kongdang P. (4) determined the efficiency of color and COD removal from dyeing wastewater using sugar cane bagasse ash as an adsorbent. Results indicated that the color and COD removal efficiencies of low overflow rates were significantly higher than higher than high overflow rates. In the high adsorbent depth, the color and COD removal efficiencies were significantly higher than low adsorbent depth. The ranges of removal efficiency of color and COD were about 62.95-80.01% and 34.00-52.72%, respectively. The physical adsorption was the one technique for removal COD from dyeing wastewater, but it can not remove completely.

Although dried organic adsorbents increased COD value, adsorbents in the form of ash and activated carbon could decrease COD values. It infers that organic compound in organic adsorbent could be eliminated by heat in incinerating process. Moreover, the pore structure of ash and activated carbon enlarge the surface area which results in an increasing of the adsorptive capacity. Considering only removing the undesired color in wastewater, dried sugar cane bagasse is an effective color removal. It is because dried sugar cane bagasse has a great ability to remove the undesired color in wastewater without transforming itself to the form of ash and activated carbon.

Considering the pH, the pH of the effluent from the packing column are slightly decreased and not related with sugar cane bagasse sizes, depths of adsorbent and flow rate. This may be the sugar cane bagasse was soaked with 0.1 N H_2SO_4

which increased the positive charge (H^+) on the surface of sugar cane bagasse. Rinsing with distilled water may be not thoroughly rinse out of 0.1 N H_2SO_4. During the column operation, the H^+ was removed from the surface by the wastewater flow. Therefore, the effluent had lower pH when it flows through the sugar cane bagasse in the packing column. The pH value of effluent is slightly increased when the volume treated increased and breakthrough time. In addition, Nhoochana Y. (53) explained that the pH of synthetic dyeing effluent which is treated by sugar cane bagasse adsorption is lower than those of influent that might be due to chemical structure and characteristics of dye. The dye was used in the study that is organic compound and high water solubility. When the column operation, negative charge was released and may be ion-exchange resulted pH is changed.

5.2 Experimental Part 2

5.2.1 Characteristics of actual silk dyeing wastewater

Characteristics of actual silk dyeing wastewater were varies and depend on production processes. Thus the sampled wastewater might have specific characteristics at only period of sampling and source. In the experiment Part2, the sample of actual silk dyeing wastewater was collected from one batch of dyeing process from the Ban Nhongtakai female silk weavers cooperative society in Buriram province to use for all replicates. Wastewater from dyeing process was separated from the bleaching process. It had dark red color due to high concentration of dark red synthetic silk dyestuff (trade name Singtho Tee Klong number 15) and had several chemical compounds. Before it was used in this study, it was filtered pass two layers of gauze to separate coarse particle. After that the characteristics of silk dyeing wastewater were analyzed.

The average characteristics of actual silk dyeing wastewater used in this study were color (853.2 SU), COD (571.11 mg/L), SS (100.00 mg/L), TDS (4,199.04 mg/L) and the pH of 7.52. Except for the pH values, all of these values exceeded those of effluent standards stipulated by the Ministry of Industry of Thailand. Comparing characteristics of actual silk dyeing wastewater with synthetic silk dyeing wastewater, it was found that color intensity, COD, SS and pH of actual silk dyeing wastewater were higher than synthetic silk dyeing wastewater. The reason might be the actual silk dyeing wastewater preparation uses more quantity of dyestuff and other chemicals. In addition, residuals silk yarn resulted in increased COD TDS and SS value. In this study, synthetic and actual silk dyeing wastewater was controlled at room temperature. In fact, Silk dyeing wastewater from dyeing process was high temperatures. At high temperatures usually provide less equilibrium adsorptive capacity. Therefore, the temperature of silk dyeing wastewater should be left for temperature reduction meet the room temperature for actual application.

5.2.2 Effect of types of sugar cane bagasse preparation at optimum operating condition

From the experiment part 1, optimum operating condition is sugar cane bagasse size of 0.5 cm, sugar cane bagasse depth of 90 cm and flow rate of 10 ml/min. This condition was selected because high color removal efficiency and highest value of volume treated at 90% breakpoint. It was used to compare treatment efficiency of actual silk dyeing wastewater by using three different types of sugar cane bagasse preparation that are chemical preparation, simple preparation (dry in oven) and simple preparation (dry with sun light)

The color removal efficiency of actual silk dyeing wastewater were 89.59%, 93.01% and 78.22% for chemical preparation, simple preparation (dry with oven) and simple preparation (dry with sunlight), respectively. Whereas the color removal efficiency of synthetic dyeing wastewater by using chemical preparation sugar cane bagasse in same condition was 97.30%.The color removal efficiency of actual silk dyeing wastewater was lower than synthetic dyeing wastewater under the same condition. It might be the cause of higher color intensity, various variation of dyes in actual dyeing wastewater and other chemical interfere. Moreover, in dyeing process might use some associated dyeing process chemical such as alkaline and salts which react with dyes structure (34). From the result, the effluent out of column of the chemical preparation and the simple preparation (dry with sunlight) had the color removal efficiency lower than 90%. This is due to the adsorbent dosage was not enough. Therefore, the breakthrough concentration was reached before desired breakpoint or 90% color removal.

The highest color removal efficiency was simple preparation (dry with oven) contradicted to the forth hypotheses, which informed that the color removal efficiency at the chemical preparation of sugar cane bagasse preparation is most efficient. The result was inconsistent with the study of Azhar S.S. *et al* (61) who investigated the potential use of sugar cane bagasse, pretreated with formaldehyde (PCSB) and sulphuric acid (PCSBC), for the removal of methyl red from simulated wastewater. As a comparison, sugar cane bagasse which undergoes the chemical treatment (sulphuric acid treatment) had shown better result in the dye adsorption compared to sugar cane bagasse treated with physical treatment (formaldehyde treatment). Singhtho S. (21) studied the decolorization of basic, direct and reactive dyes by pre-treated narrow-leaved cattail [*Typha angustifolia Lin.*]. This research showed treated narrow-leaved cattail with 37%CH_2O+0.2N H_2SO_4 (FH-NLC) had the highest efficiency for remove basic, direct and reactive dye solution at 99%, 42% and 54%, respectively. Treated narrow-leaved cattail with distilled water (DW-NLC) could remove 98%, 41% and 24%, respectively. Whereas treated narrow-leaved cattail with 0.1N NaOH (NaOH-NLC) could remove 98%, 37% and 22%, respectively. The results suggested that the efficiency for remove basic and direct dye of DW-NLC are very nearly those highest efficiency of FH-NLC.

However, the lowest color removal efficiency was simple preparation (dry with sunlight) is consistent with the forth hypotheses, which stated that the simple treatment (dry with sunlight) is least efficient. One possible explanation is that simple preparation (dry with sunlight) had more humidity than other preparation (dry with oven). Packing by control of weight and volume of sugar cane bagasse aimed to control the density. In the column of sugar cane bagasse dried with sunlight has volume of sugar cane bagasse less than the other columns which dry with oven, thus the adsorbent in the column of sugar cane bagasse which dry with sunlight is packed by looser than the other columns which dry with oven. Then, the wastewater is faster flow through the adsorbent. The little surface and shorter detention time, thus result in a shorter contact time of the wastewater with the adsorbent.

In case of COD, SS and TDS values of all sugar cane bagasse preparation types exceeded those of the required effluent standards stipulated by the Ministry of Industry of Thailand. COD and TDS values of effluent are more than those of influent due to the organic compound in sugar cane bagasse was leached out during column operating. Effluent SS value of chemical preparation and simple preparation (dry with oven) are less than those of influent but effluent SS value of simple preparation (dry with sunlight) is more than those of influent. This phenomenon may be explained that loose sugar cane bagasse packing resulted in particles of sugar cane bagasse leak out with effluent.Considering pH, it shows that pH values of effluent are less than those of influent and only simple preparation (dry with sunlight) can be in the range of the required effluent standards stipulated by the Ministry of Industry of Thailand.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study was conducted to investigate the treatment efficiency of silk dyeing wastewater by using sugar cane bagasse as adsorbent. The conclusions can be summarized below.

1. The treatment efficiency by using smaller sugar cane bagasse size was significantly higher than the larger sugar cane bagasse size.
2. The treatment efficiency at longer sugar cane bagasse depth was significantly higher than the shorter sugar cane bagasse depth.
3. The treatment efficiency at lower flow rate was significantly higher than the higher flow rate.
4. The treatment efficiency by means of the simple preparation (dry with oven) is higher than the chemical preparation and the chemical preparation is higher than the simple preparation (dry with sun light).
5. The color removal efficiency, COD value, volume treated and breakthrough time at 90% breakpoint increased with decreasing sugar cane bagasse size, flow rate and increasing sugar cane bagasse depth.
6. The sugar cane bagasse removed the color and SS from dyeing wastewater but increased the COD and TDS value.
7. The optimum operating condition of synthetic dyeing wastewater is sugar cane bagasse size of 0.5 cm, sugar cane bagasse depth of 90 cm and flow rate of 10 ml/min that resulted high color removal efficiency (97.30%) and highest value of volume treated at 90% breakpoint (577.57 ml).

6.2 Recommendation

6.2.1 Recommendation for further study

1. Only single column was used in this study. The series column should be investigated in further experiments. It may affect to treatment efficiency of adsorption systems.

2 In this study, sugar cane bagasse preparation was dry with oven and dry with sun light. Sugar cane bagasse should be prepared to sugar cane bagasse activated carbon for added porosity. The adsorption capacity might be added.

3. Each dye colors and dye types may cause different treatment efficiency. Thus, the potential of sugar cane bagasse for removal of various dye colors and dye types are needed to investigate in the further experiments.

6.2.2 Recommendations for applications

This study aim to investigate the treatment efficiency of silk dyeing wastewater by using sugar cane bagasse packed column. Sugar cane bagasse size of 0.5 cm, sugar cane bagasse depth of 90 cm and flow rate of 10 ml/min should be chosen for application because this condition caused high color removal efficiency and highest value of volume treated at 90% breakpoint. The optimum preparation type was simple preparation (dry with oven).

However, the color removal efficiency of treated sugar cane bagasse was rather small. Thus, it should be combined with the other processes such as chemical coagulation, in order to reduce partial color and other organic substances before adsorption by sugar cane bagasse. In addition, silk dyeing wastewater should be left for temperature reduction meet the room temperature before treatment.

In stead of dispose as waste, the exhausted sugar cane bagasse could be added the value by using as raw material of sugar cane bagasse products such as color paper, acoustic board, noise barrier wall etc.

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APPENDIX

APPENDIX A
DATA OF THE EXPERIMENTS PART 1

Table A-1 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 30 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	25.45	**96.71**	24.33	**96.84**	24.78	**96.80**
100.00	20.00	73.01	90.56	68.84	91.06	69.29	91.05
200.00	40.00	104.80	86.45	100.02	87.01	102.58	86.75
300.00	60.00	128.49	83.39	131.56	82.91	139.73	81.95
400.00	80.00	143.69	81.42	151.36	80.34	156.28	79.81
700.00	140.00	190.28	75.40	215.67	71.99	219.76	71.62
1000.00	200.00	249.52	67.74	271.03	64.80	280.50	63.77
1600.00	320.00	376.85	51.28	408.08	47.00	406.69	47.47
2200.00	440.00	467.27	39.59	465.36	39.56	455.15	41.21
2800.00	560.00	521.15	32.62	513.14	33.36	517.82	33.12
inf		773.44	-	769.99	-	774.22	-

Table A-2 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 30 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	35.67	**95.38**	40.23	**94.79**	37.76	**95.11**
100.00	10.00	75.90	90.17	93.97	87.83	80.23	89.61
200.00	20.00	107.95	86.02	124.18	83.92	120.35	84.41
500.00	50.00	272.45	64.71	281.38	63.56	277.08	64.12
800.00	80.00	455.20	41.05	464.53	39.84	460.79	40.32
1100.00	110.00	526.00	31.88	534.61	30.76	536.87	30.47
1400.00	140.00	579.30	24.97	589.16	23.70	584.46	24.31
1700.00	170.00	585.80	24.13	591.13	23.44	597.48	22.62
2000.00	200.00	605.90	21.53	611.37	20.82	610.78	20.90
2300.00	230.00	626.63	18.85	635.62	17.68	637.05	17.50
2600.00	260.00	637.58	17.43	647.63	16.13	643.05	16.72
3200.00	320.00	649.35	15.90	651.14	15.67	650.71	15.73
3800.00	380.00	671.23	13.07	680.03	11.93	682.58	11.60
4400.00	440.00	678.08	12.18	682.35	11.63	683.87	11.43
5000.00	500.00	685.88	11.17	694.09	10.11	687.78	10.93
inf		772.14	-	772.14	-	772.14	-

Table A-3 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 30 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	52.28	**93.23**	36.71	**95.24**	44.27	**94.26**
100.00	100.00	89.73	88.38	84.77	89.01	89.39	88.41
200.00	200.00	128.46	83.37	112.66	85.39	118.48	84.64
500.00	500.00	196.46	74.56	188.04	75.62	192.89	74.99
800.00	800.00	247.87	67.90	252.85	67.22	256.39	66.76
1100.00	1100.00	308.17	60.09	309.46	59.88	316.82	58.92
1400.00	1400.00	396.25	48.69	392.96	49.05	402.22	47.85
1700.00	1700.00	442.59	42.69	440.16	42.93	446.85	42.07
2000.00	2000.00	491.28	36.38	481.47	37.58	486.89	36.87
2600.00	2600.00	550.16	28.76	542.87	29.62	547.59	29.01
3200.00	3200.00	571.29	26.02	562.26	27.10	570.10	26.09
3800.00	3800.00	586.48	24.05	580.72	24.71	589.38	23.59
4400.00	4400.00	600.98	22.18	597.65	22.51	603.01	21.82
5000.00	5000.00	601.08	22.16	597.45	22.54	601.87	21.97
inf		772.24	-	771.31	-	771.31	-

Table A-4 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 60 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	24.81	96.79	16.71	**97.83**	10.94	**98.58**
100.00	20.00	21.98	**97.16**	25.09	96.74	17.58	97.72
200.00	40.00	29.88	96.14	30.97	95.98	29.07	96.23
300.00	60.00	54.34	92.98	54.23	92.96	51.07	93.37
400.00	80.00	83.22	89.25	81.57	89.41	76.79	90.03
700.00	140.00	120.15	84.48	119.50	84.48	115.55	85.00
1000.00	200.00	148.43	80.82	136.08	82.33	132.12	82.85
1600.00	320.00	180.75	76.65	168.25	78.16	170.73	77.83
2200.00	440.00	203.58	73.70	187.28	75.69	191.47	75.14
2800.00	560.00	229.40	70.36	222.75	71.08	228.16	70.38
inf		774.02	-	770.22	-	770.22	-

Table A-5 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 60 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	33.89	**95.59**	25.44	**96.72**	29.48	**96.18**
100.00	10.00	41.31	94.63	33.84	95.64	35.15	95.44
200.00	20.00	61.41	92.01	60.87	92.15	62.56	91.89
300.00	30.00	-	-	66.32	91.45	67.75	91.22
400.00	40.00	-	-	81.37	89.51	85.69	88.90
500.00	50.00	-	-	95.13	87.74	112.24	85.45
600.00	60.00	-	-	107.93	86.09	119.56	84.51
800.00	80.00	139.27	81.88	-	-	-	-
1100.00	110.00	197.55	74.30	-	-	-	-
1200.00	120.00	-	-	203.23	73.80	215.26	72.10
1400.00	140.00	232.68	69.73	-	-	-	-
1800.00	180.00	-	-	363.16	53.18	372.16	51.77
2000.00	200.00	390.88	49.14	-	-	-	-
2400.00	240.00	-	-	483.30	37.69	492.67	36.15
2600.00	260.00	517.95	32.61	-	-	-	-
3000.00	300.00	-	-	547.10	29.47	558.95	27.56
3200.00	320.00	576.10	25.04	-	-	-	-
3800.00	380.00	606.60	21.08	-	-	-	-
4400.00	440.00	659.43	14.20	-	-	-	-
inf		768.58	-	775.67	-	771.62	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-6 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 60 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	35.50	**95.42**	33.95	**95.62**	34.72	**95.52**
100.00	100.00	66.27	91.45	62.06	91.99	66.60	91.41
200.00	200.00	82.85	89.31	76.58	90.12	78.67	89.85
300.00	300.00	96.13	87.60	88.05	88.64	95.02	87.74
400.00	400.00	110.23	85.78	108.55	86.00	111.45	85.62
500.00	500.00	121.15	84.37	114.09	85.28	115.03	85.16
600.00	600.00	131.00	83.10	125.01	83.87	121.86	84.28
1200.00	1200.00	162.03	79.10	157.82	79.64	164.10	78.83
1800.00	1800.00	183.68	76.30	179.75	76.81	185.46	76.07
2400.00	2400.00	211.98	72.65	210.04	72.90	215.46	72.20
3000.00	3000.00	253.65	67.27	252.36	67.44	255.05	67.09
3600.00	3600.00	288.48	62.78	280.46	63.81	284.59	63.28
4200.00	4200.00	306.70	60.43	304.68	60.69	308.19	60.24
4800.00	4800.00	338.05	56.38	338.56	56.32	341.83	55.90
inf		775.06	-	775.06	-	775.06	-

Table A-7 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 90 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	20.53	97.35	21.98	97.15	21.05	97.28
100.00	20.00	4.64	**99.40**	9.09	**98.82**	6.43	**99.17**
200.00	40.00	8.00	98.97	14.35	98.14	12.62	98.37
300.00	60.00	25.43	96.71	30.28	96.07	28.62	96.30
400.00	80.00	51.16	93.39	55.63	92.78	49.72	93.58
500.00	100.00	80.90	89.54	79.15	89.72	80.29	89.63
600.00	120.00	101.98	86.82	92.53	87.98	96.06	87.59
700.00	140.00	117.13	84.86	104.48	86.43	110.51	85.73
1000.00	200.00	139.70	81.94	118.98	84.55	129.59	83.26
1600.00	320.00	149.95	80.61	135.68	82.38	142.68	81.57
2200.00	440.00	157.90	79.58	150.45	80.46	153.02	80.24
inf		773.44	-	769.99	-	774.22	-

Table A-8 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 90 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	43.53	94.34	10.72	**98.62**	20.68	**97.32**
100.00	10.00	30.97	**95.97**	11.20	98.56	30.80	96.01
200.00	20.00	39.47	94.86	25.88	96.67	41.01	94.69
300.00	30.00	50.55	93.42	40.53	94.78	49.76	93.55
400.00	40.00	59.13	92.31	59.31	92.36	57.79	92.51
500.00	50.00	-	-	75.81	90.24	68.83	91.08
700.00	70.00	-	-	103.55	86.67	87.81	88.62
800.00	80.00	-	-	109.95	85.84	93.17	87.93
1000.00	100.00	105.06	86.33	-	-	115.78	85.00
1100.00	110.00	-	-	-	-	-	-
1400.00	140.00	-	-	144.88	81.35	130.29	83.11
1600.00	160.00	134.08	82.56	-	-	-	-
2000.00	200.00	-	-	181.98	76.57	174.56	77.38
2200.00	220.00	139.18	81.89	-	-	-	-
2600.00	260.00	-	-	256.28	67.01	250.74	67.51
2800.00	280.00	144.60	81.19	-	-	-	-
3200.00	320.00	-	-	339.15	56.34	355.49	53.93
3400.00	340.00	161.58	78.98	-	-	-	-
4000.00	400.00	187.78	75.57	-	-	-	-
inf		768.58	-	776.72	-	771.62	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-9 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm sugar cane bagasse depth at 90 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	30.89	**96.00**	28.62	**96.29**	30.08	**96.10**
100.00	6.67	47.51	93.85	44.76	94.20	46.27	94.00
200.00	13.33	61.13	92.08	59.78	92.25	60.15	92.20
300.00	20.00	76.72	90.07	75.51	90.21	76.82	90.04
400.00	26.67	91.62	88.14	83.27	89.20	98.11	87.28
500.00	33.33	97.45	87.38	88.05	88.59	102.17	86.75
600.00	40.00	105.78	86.30	98.73	87.20	106.46	86.20
700.00	46.67	116.40	84.93	104.09	86.51	111.83	85.50
800.00	53.33	123.29	84.03	112.71	85.39	117.81	84.73
1400.00	93.33	148.38	80.79	146.72	80.98	153.26	80.13
2000.00	133.33	150.73	80.48	159.12	79.37	168.84	78.11
2600.00	173.33	154.92	79.94	162.72	78.90	169.18	78.07
3200.00	213.33	157.70	79.58	169.91	77.97	172.06	77.69
inf		772.24	-	771.31	-	771.31	-

Table A-10 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 30 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	52.47	**93.21**	68.08	**91.19**	60.35	**92.19**
100.00	20.00	89.64	88.40	84.77	89.03	86.01	88.87
200.00	40.00	135.73	82.44	142.45	81.57	137.58	82.20
300.00	60.00	185.65	75.98	194.65	74.81	185.93	75.94
400.00	80.00	229.23	70.34	236.40	69.41	221.83	71.29
1000.00	200.00	415.33	46.25	416.53	46.10	414.63	46.34
1600.00	320.00	508.65	34.18	518.53	32.90	517.83	32.99
2200.00	440.00	536.03	30.63	542.00	29.86	540.00	30.12
2800.00	560.00	553.68	28.35	557.28	27.89	555.48	28.12
inf		772.76	-	772.76	-	772.76	-

Table A-11 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 30 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	106.25	**86.23**	111.26	**85.58**	108.56	**85.93**
100.00	10.00	183.71	76.19	183.59	76.21	183.47	76.22
200.00	20.00	251.85	67.36	255.05	66.94	254.39	67.03
500.00	50.00	419.23	45.67	429.18	44.38	423.46	45.12
800.00	80.00	516.88	33.01	537.83	30.30	526.84	31.72
1100.00	110.00	570.60	26.05	579.88	24.85	577.50	25.15
1400.00	140.00	596.23	22.73	607.78	21.23	596.96	22.63
1700.00	170.00	626.33	18.83	632.00	18.09	627.74	18.64
2000.00	200.00	649.50	15.82	655.53	15.04	652.79	15.40
2300.00	230.00	663.03	14.07	656.35	14.94	658.45	14.66
2600.00	260.00	660.73	14.37	656.53	14.91	657.32	14.81
2900.00	290.00	671.53	12.97	668.25	13.39	664.53	13.88
3200.00	320.00	679.43	11.94	673.08	12.77	679.44	11.94
3500.00	350.00	692.25	10.28	662.35	14.16	683.30	11.44
3800.00	380.00	697.23	9.64	678.38	12.08	692.38	10.27
inf		771.59	-	771.59	-	771.59	-

Table A-12 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 30 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	146.39	**80.98**	162.34	**78.91**	154.55	**79.92**
100.00	6.67	219.31	71.51	234.43	69.54	226.35	70.59
200.00	13.33	309.61	59.77	320.85	58.31	316.65	58.86
500.00	33.33	490.74	36.24	496.15	35.54	497.78	35.32
800.00	53.33	572.34	25.64	578.13	24.88	579.38	24.72
1100.00	73.33	617.54	19.76	614.85	20.11	624.58	18.85
1400.00	93.33	643.49	16.39	639.90	16.86	650.53	15.48
1700.00	113.33	656.01	14.77	654.28	14.99	663.05	13.85
2000.00	133.33	671.19	12.79	661.80	14.01	676.23	12.14
2600.00	173.33	682.34	11.34	682.43	11.33	687.38	10.69
3200.00	213.33	682.54	11.32	688.93	10.49	687.58	10.66
3800.00	253.33	693.57	9.88	696.21	9.54	698.61	9.23
inf		769.65	-	769.65	-	769.65	-

Table A-13 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 60 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	20.82	**97.31**	27.55	**96.44**	23.99	**96.90**
100.00	20.00	36.33	95.31	32.85	95.76	31.64	95.91
200.00	40.00	55.09	92.88	40.01	94.83	39.28	94.92
300.00	60.00	72.21	90.67	83.12	89.26	75.46	90.25
400.00	80.00	102.16	86.80	97.43	87.41	96.35	87.55
700.00	140.00	127.18	83.57	130.13	83.19	127.98	83.46
1000.00	200.00	182.45	76.43	155.78	79.87	151.55	80.42
1600.00	320.00	197.53	74.48	185.20	76.07	184.36	76.18
2200.00	440.00	240.53	68.92	218.53	71.76	220.29	71.54
2800.00	560.00	306.05	60.46	289.50	62.59	288.93	62.67
inf		773.93	-	773.93	-	773.93	-

Table A-14 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 60 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	64.23	**91.72**	69.98	**90.99**	66.87	**91.40**
20.00	2.00	65.34	91.58	71.52	90.79	69.37	91.08
40.00	4.00	66.48	91.43	73.94	90.48	71.74	90.77
100.00	10.00	76.09	90.19	77.91	89.97	76.12	90.21
200.00	20.00	91.76	88.17	98.88	87.27	98.13	87.38
500.00	50.00	153.75	80.18	157.06	79.78	155.35	80.02
800.00	80.00	202.98	73.83	235.30	69.71	231.79	70.19
1100.00	110.00	265.85	65.73	324.08	58.28	317.64	59.15
1400.00	140.00	329.90	57.47	395.15	49.13	391.00	49.71
2000.00	200.00	440.83	43.17	480.55	38.13	474.09	39.03
inf		775.67	-	776.72	-	777.55	-

Table A-15 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 60 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	103.30	**86.57**	105.69	**86.26**	104.34	**86.44**
100.00	6.67	126.92	83.50	128.00	83.36	128.20	83.33
200.00	13.33	155.15	79.83	165.25	78.52	156.43	79.66
500.00	33.33	241.37	68.62	244.70	68.19	242.65	68.45
800.00	53.33	327.90	57.37	330.25	57.06	329.18	57.20
1100.00	73.33	402.97	47.61	399.45	48.07	404.25	47.44
1400.00	93.33	460.62	40.12	468.83	39.05	461.90	39.95
1700.00	113.33	503.77	34.51	509.95	33.70	505.05	34.34
2000.00	133.33	537.22	30.16	546.05	29.01	538.50	29.99
2600.00	173.33	584.17	24.05	588.75	23.46	585.45	23.89
3200.00	213.33	608.80	20.85	619.95	19.40	610.08	20.69
3800.00	253.33	632.77	17.73	637.65	17.10	634.05	17.57
4400.00	293.33	636.97	17.19	639.13	16.91	638.25	17.02
5000.00	333.33	646.72	15.92	650.05	15.49	648.00	15.75
5600.00	373.33	655.00	14.85	658.75	14.36	656.28	14.68
6200.00	413.33	658.50	14.39	662.00	13.93	659.78	14.22
6800.00	453.33	661.77	13.96	669.63	12.94	663.05	13.80
7400.00	493.33	665.22	13.52	673.45	12.45	666.50	13.35
8000.00	533.33	669.42	12.97	671.65	12.68	670.70	12.80
8600.00	573.33	671.75	12.67	678.13	11.84	673.03	12.50
9200.00	613.33	673.95	12.38	677.83	11.88	675.23	12.21
9800.00	653.33	-	-	687.73	10.59	0.00	100.00
10400.00	693.33	686.22	10.79	-	-	687.50	10.62
11100.00	740.00	673.22	12.48	677.15	11.96	674.50	12.31
inf		769.18	-	769.18	-	769.18	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-16 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 90 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	13.44	**98.27**	16.16	**97.92**	14.99	**98.07**
100.00	20.00	20.43	97.37	17.53	97.74	16.65	97.86
200.00	40.00	35.83	95.39	23.93	96.92	23.27	97.00
300.00	60.00	43.08	94.46	40.98	94.72	40.18	94.83
400.00	80.00	56.63	92.71	55.88	92.81	55.47	92.86
500.00	100.00	69.76	91.02	71.01	90.86	70.39	90.94
600.00	120.00	87.63	88.72	90.97	88.29	88.33	88.63
1200.00	240.00	130.48	83.21	138.85	82.13	135.45	82.56
1800.00	360.00	158.03	79.66	166.10	78.62	165.84	78.65
2400.00	480.00	184.58	76.24	186.35	76.01	186.23	76.03
inf		776.88	-	776.88	-	776.88	-

Table A-17 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 90 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	50.69	**93.43**	66.45	**91.41**	58.87	**92.39**
60.00	6.00	56.07	92.73	68.07	91.20	-	-
80.00	8.00	61.83	91.99	69.93	90.96	-	-
100.00	10.00	63.35	91.79	70.16	90.93	66.14	91.45
140.00	14.00	-	-	-	-	78.44	89.86
160.00	16.00	-	-	-	-	80.54	89.59
200.00	20.00	82.02	89.37	105.52	86.36	89.01	88.49
800.00	80.00	152.71	80.21	167.03	78.41	168.88	78.17
1400.00	140.00	202.76	73.72	218.00	71.82	216.83	71.97
2000.00	200.00	271.06	64.87	286.30	62.99	279.28	63.90
2600.00	260.00	344.21	55.39	359.45	53.53	348.50	54.95
3200.00	320.00	410.06	46.86	425.30	45.02	417.20	46.07
3800.00	380.00	452.91	41.30	468.15	39.48	457.30	40.89
5000.00	500.00	528.76	31.47	544.00	29.68	516.53	33.23
inf		771.59	-	773.58	-	773.58	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-18 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm sugar cane bagasse depth at 90 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	68.08	**91.14**	54.30	**92.93**	60.94	**92.07**
100.00	6.67	68.80	91.04	58.90	92.33	67.20	91.25
200.00	13.33	92.77	87.92	97.46	87.31	89.39	88.36
500.00	33.33	128.82	83.23	122.03	84.11	128.98	83.21
800.00	53.33	153.39	80.03	146.60	80.91	153.55	80.01
1100.00	73.33	170.09	77.85	163.30	78.74	170.25	77.83
1400.00	93.33	188.09	75.51	181.30	76.39	188.25	75.49
2000.00	133.33	211.77	72.43	204.98	73.31	211.93	72.40
2600.00	173.33	243.09	68.35	236.30	69.23	243.25	68.33
3200.00	213.33	266.34	65.32	259.55	66.20	266.50	65.30
3800.00	253.33	301.82	60.70	295.03	61.58	301.98	60.68
4400.00	293.33	333.47	56.58	326.68	57.46	333.63	56.56
5000.00	333.33	357.24	53.48	350.45	54.37	357.40	53.46
5600.00	373.33	367.27	52.18	360.48	53.06	367.43	52.16
6200.00	413.33	384.54	49.93	377.75	50.81	384.70	49.91
inf		767.97	-	767.97	-	767.97	-

Table A-19 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 30 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	68.06	**91.24**	65.94	**91.51**	67.18	**91.35**
20.00	4.00	-	-	79.92	89.71	80.15	89.68
80.00	16.00	117.87	84.82	-	-	-	-
100.00	20.00	128.59	83.44	-	-	125.04	83.90
200.00	40.00	166.22	78.59	173.39	77.67	167.50	78.43
500.00	100.00	230.57	70.31	-	-	-	-
800.00	160.00	341.35	56.04	389.96	49.79	384.83	50.45
1100.00	220.00	422.37	45.61	-	-	-	-
1400.00	280.00	463.19	40.35	523.32	32.62	538.18	30.71
1700.00	340.00	636.06	18.09	-	-	-	-
2000.00	400.00	-	-	599.01	22.87	600.37	22.70
inf		776.49	-	776.66	-	776.66	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-20 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 30 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	154.37	**79.93**	158.76	**79.36**	151.14	**80.35**
200.00	20.00	364.05	52.67	372.37	51.59	360.75	53.10
500.00	50.00	511.35	33.52	-	-	508.25	33.92
800.00	80.00	581.10	24.45	589.23	23.39	577.50	24.92
1120.00	112.00	624.33	18.83	-	-	620.73	19.30
1400.00	140.00	632.05	17.83	659.23	14.29	628.45	18.30
1700.00	170.00	659.25	14.29	-	-	655.65	14.76
2000.00	200.00	665.28	13.51	675.70	12.15	661.68	13.98
2320.00	232.00	669.23	12.99	-	-	665.63	13.46
2600.00	260.00	-	-	686.26	10.78	-	-
2620.00	262.00	675.30	12.20	-	-	671.70	12.67
2900.00	290.00	681.53	11.39	-	-	677.93	11.86
3220.00	322.00	678.43	11.80	-	-	674.83	12.27
3240.00	324.00	-	-	697.62	9.30	-	-
3500.00	350.00	685.52	10.88	-	-	681.92	11.34
3800.00	380.00	691.09	10.15	710.03	7.69	687.49	10.62
4100.00	410.00	690.51	10.23	-	-	686.91	10.69
4400.00	440.00	695.51	9.58	706.65	8.13	691.91	10.04
5000.00	500.00	702.35	8.69	698.53	9.18	698.75	9.16
inf		769.17	-	769.17	-	769.17	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-21 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 30 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	161.21	**78.99**	165.12	**78.76**	163.95	**78.91**
100.00	6.67	-	-	-	-	309.19	60.22
200.00	13.33	312.57	59.26	322.94	58.45	316.03	59.34
800.00	53.33	530.13	30.91	535.03	31.16	538.19	30.75
1400.00	93.33	625.85	18.43	615.48	20.81	613.02	21.13
2000.00	133.33	651.66	15.07	643.17	17.25	638.17	17.89
2400.00	160.00	-	-	656.21	15.57	-	-
2600.00	173.33	665.60	13.25	659.45	15.15	659.15	15.19
3200.00	213.33	-	-	669.72	13.83	667.47	14.12
3600.00	240.00	-	-	663.64	14.61	673.93	13.29
inf		767.30	-	777.21	-	777.21	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-22 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 60 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	23.41	**96.99**	38.10	**95.10**	30.45	**96.08**
20.00	4.00	26.75	96.56	-	-	-	-
40.00	8.00	34.21	95.59	-	-	-	-
60.00	12.00	40.72	94.76	-	-	-	-
100.00	20.00	51.33	93.39	-	-	-	-
180.00	36.00	-	-	75.57	90.27	72.54	90.66
200.00	40.00	79.63	89.75	80.62	89.62	81.47	89.51
300.00	60.00	83.33	89.27	-	-	-	-
400.00	80.00	111.43	85.65	116.94	84.94	114.73	85.23
600.00	120.00	121.26	84.38	-	-	-	-
800.00	160.00	141.97	81.72	-	-	-	-
1000.00	200.00	173.45	77.66	-	-	181.38	76.65
1020.00	204.00	-	-	191.31	75.37	-	-
1600.00	320.00	238.87	69.24	280.66	63.86	271.18	65.08
1900.00	380.00	-	-	329.25	57.61	315.53	59.37
2200.00	440.00	359.51	53.70	-	-	-	-
inf		776.49	-	776.66	-	776.66	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-23 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 60 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	83.14	**89.16**	79.00	**89.70**	86.75	**88.69**
40.00	4.00	-	-	94.28	87.71	-	-
60.00	6.00	-	-	100.05	86.96	-	-
100.00	10.00	100.72	86.87	118.35	84.57	117.13	84.73
200.00	20.00	125.86	83.59	133.28	82.62	140.53	81.68
500.00	50.00	182.88	76.16	182.25	76.24	198.03	74.18
800.00	80.00	257.45	66.43	247.68	67.71	266.48	65.26
1400.00	140.00	383.63	49.98	365.05	52.41	385.45	49.75
1700.00	170.00	444.68	42.02	430.85	43.83	440.48	42.57
2000.00	200.00	473.28	38.30	409.25	46.64	470.78	38.62
2300.00	230.00	493.28	35.69	456.93	40.43	498.23	35.04
2600.00	260.00	538.35	29.81	517.73	32.50	534.90	30.26
3200.00	320.00	546.80	28.71	528.55	31.09	556.33	27.47
3800.00	380.00	568.00	25.95	559.15	27.10	577.53	24.70
4400.00	440.00	583.90	23.87	571.90	25.44	586.23	23.57
5000.00	500.00	595.85	22.32	583.58	23.92	598.80	21.93
5600.00	560.00	597.88	22.05	591.73	22.85	603.55	21.31
inf		767.01	-	767.01	-	767.01	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-24 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 60 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	113.77	**85.35**	110.36	**85.79**	107.27	**86.02**
100.00	6.67	-	-	-	-	131.65	82.84
200.00	13.33	199.53	74.31	220.79	71.57	178.69	76.71
400.00	26.67	-	-	-	-	255.84	66.66
500.00	33.33	332.77	57.15	358.81	53.80	-	-
700.00	46.67	-	-	-	-	377.51	50.80
800.00	53.33	430.70	44.54	463.92	40.26	-	-
1000.00	66.67	-	-	-	-	456.67	40.48
1100.00	73.33	498.65	35.79	527.65	32.06	-	-
1300.00	86.67	-	-	-	-	516.21	32.72
1400.00	93.33	-	-	570.36	26.56	-	-
1420.00	94.67	548.58	29.36	-	-	-	-
1600.00	106.67	-	-	-	-	561.36	26.84
1700.00	113.33	578.82	25.47	611.74	21.23	-	-
1900.00	126.67	-	-	-	-	599.16	21.91
2000.00	133.33	608.58	21.64	-	-	-	-
2020.00	134.67	-	-	639.67	17.63	-	-
2200.00	146.67	-	-	-	-	623.45	18.75
2300.00	153.33	628.09	19.12	658.72	15.18	-	-
2600.00	173.33	638.03	17.84	674.13	13.20	-	-
2800.00	186.67	-	-	-	-	652.81	14.92
2900.00	193.33	654.70	15.70	686.94	11.55	-	-
3100.00	206.67	-	-	-	-	668.44	12.88
3200.00	213.33	660.20	14.99	691.25	10.99	-	-
3400.00	226.67	-	-	-	-	675.48	11.97
3500.00	233.33	677.25	12.80	704.54	9.28	-	-
3700.00	246.67	-	-	-	-	681.08	11.24
3800.00	253.33	677.75	12.73	-	-	-	-
inf		776.62	-	776.62	-	767.30	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-25 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 90 cm and flow rate of 5 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	23.07	**97.01**	25.51	**96.70**	24.66	**96.81**
20.00	4.00	-	-	25.96	96.64	24.78	96.79
80.00	16.00	29.54	96.17	-	-	-	-
200.00	40.00	43.07	94.42	51.38	93.35	40.64	94.74
400.00	80.00	-	-	70.65	90.86	67.72	91.24
420.00	84.00	-	-	-	-	69.59	91.00
440.00	88.00	-	-	-	-	69.65	90.99
460.00	92.00	74.98	90.28	-	-	77.53	89.97
500.00	100.00	-	-	83.17	89.24	-	-
520.00	104.00	-	-	86.02	88.87	-	-
600.00	120.00	80.93	89.51	93.21	87.94	89.41	88.43
800.00	160.00	-	-	105.98	86.29	104.54	86.48
1300.00	260.00	129.14	83.26	-	-	-	-
1400.00	280.00	-	-	146.88	81.00	140.93	81.77
2000.00	400.00	168.95	78.10	-	-	-	-
inf		771.50	-	773.00	-	773.00	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-26 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 90 cm and flow rate of 10 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	73.93	**90.45**	65.49	**91.54**	69.56	**91.02**
20.00	2.00	-	-	67.79	91.24	70.09	90.95
40.00	4.00	74.05	90.43	-	-	-	-
80.00	8.00	75.03	90.31	71.01	90.83	72.11	90.69
100.00	10.00	75.56	90.24	72.60	90.62	72.77	90.60
120.00	12.00	-	-	73.70	90.48	77.65	89.97
140.00	14.00	-	-	88.33	88.59	88.98	88.51
160.00	16.00	-	-	92.16	88.10	94.58	87.78
200.00	20.00	87.25	88.73	121.75	84.27	126.68	83.64
400.00	40.00	127.28	83.56	162.64	78.99	163.53	78.88
700.00	70.00	164.05	78.81	199.46	74.24	201.28	74.00
1000.00	100.00	226.00	70.81	236.94	69.39	236.35	69.47
1300.00	130.00	272.45	64.81	292.27	62.25	292.33	62.24
1600.00	160.00	297.48	61.57	322.38	58.36	322.60	58.33
1900.00	190.00	353.50	54.34	357.06	53.88	357.18	53.86
2200.00	220.00	390.05	49.62	398.96	48.47	399.23	48.43
2800.00	280.00	467.03	39.67	477.12	38.37	479.65	38.04
3400.00	340.00	512.68	33.78	525.39	32.14	522.58	32.50
4000.00	400.00	553.25	28.54	-	-	-	-
inf		774.17	-	774.17	-	774.17	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-27 Color removal efficiency of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm sugar cane bagasse depth at 90 cm and flow rate of 15 ml/min

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2		Rep3	
		SU (mean)	%color removal	SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	75.27	**90.19**	81.23	**89.49**	70.26	**90.91**
20.00	1.33	-	-	-	-	74.78	90.33
40.00	2.67	-	-	-	-	81.93	89.40
100.00	6.67	81.49	89.38	94.94	87.72	90.49	88.29
120.00	8.00	82.03	89.31	-	-	-	-
200.00	13.33	102.04	86.70	115.11	85.11	118.78	84.63
300.00	20.00	-	-	131.77	82.95	137.00	82.27
400.00	26.67	136.97	82.15	150.38	80.54	158.33	79.52
700.00	46.67	-	-	203.49	73.67	-	-
980.00	65.33	-	-	-	-	250.25	67.62
1000.00	66.67	257.08	66.50	252.97	67.27	-	-
1580.00	105.33	-	-	-	-	343.95	55.50
1600.00	106.67	355.19	53.71	341.62	55.80	-	-
2180.00	145.33	-	-	422.59	45.32	443.70	42.59
2200.00	146.67	435.36	43.26	-	-	-	-
2800.00	186.67	502.10	34.56	479.83	37.92	492.40	36.29
3400.00	226.67	545.15	28.95	-	-	535.70	30.69
4000.00	266.67	573.13	25.31	542.20	29.85	557.75	27.84
inf		767.30	-	772.91	-	772.91	-

Remark: Dash (-) refer to sample was not color intensity analyzed.

Table A-28 Influent and effluent COD of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
0.5	5	30	1	320.06	2044.04	**1974.53**	**63.69**
			2	366.24	1918.97		
			3	343.15	1960.57		
		60	1	408.93	3184.87	**3013.19**	**215.23**
			2	484.26	2771.73		
			3	484.26	3082.96		
		90	1	320.06	3690.61	**3747.35**	**74.31**
			2	366.24	3831.46		
			3	343.15	3719.98		
	10	30	1	533.33	1671.97	**1627.78**	**50.00**
			2	533.33	1573.51		
			3	533.33	1637.88		
		60	1	488.89	2594.01	**2691.26**	**146.81**
			2	360.19	2860.14		
			3	424.54	2619.63		
		90	1	488.89	2765.41	**2780.41**	**93.16**
			2	382.31	2880.16		
			3	424.54	2695.67		
	15	30	1	377.46	1230.77	**1330.44**	**111.68**
			2	379.74	1451.14		
			3	379.74	1309.42		
		60	1	375.50	1782.02	**1882.02**	**176.99**
			2	375.50	1777.67		
			3	375.50	2086.37		
		90	1	377.46	2759.86	**2673.03**	**81.38**
			2	379.74	2598.51		
			3	379.74	2660.73		

Table A-29 Influent and effluent COD of synthetic dyeing wastewater at sugar cane bagasse size of 1cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
1	5	30	1	284.62	1811.13	**1685.82**	**109.47**
			2	284.62	1608.83		
			3	284.62	1637.49		
		60	1	408.93	2679.36	**2574.32**	**104.32**
			2	408.93	2470.72		
			3	408.93	2572.89		
		90	1	306.51	2988.88	**2889.98**	**87.58**
			2	306.51	2822.23		
			3	306.51	2858.85		
	10	30	1	343.53	1460.34	**1413.10**	**46.32**
			2	343.53	1367.75		
			3	343.53	1411.20		
		60	1	360.19	2298.42	**2475.52**	**179.15**
			2	382.31	2656.66		
			3	371.25	2471.47		
		90	1	343.53	2946.36	**2748.26**	**193.24**
			2	334.53	2560.29		
			3	334.53	2738.13		
	15	30	1	398.01	1294.23	**1238.26**	**66.33**
			2	398.01	1165.00		
			3	398.01	1255.55		
		60	1	331.67	1936.49	**1868.44**	**77.39**
			2	331.67	1784.25		
			3	331.67	1884.57		
		90	1	375.50	2328.66	**2418.46**	**78.83**
			2	375.50	2476.21		
			3	375.50	2450.52		

Table A-30 Influent and effluent COD of synthetic dyeing wastewater at sugar cane bagasse size of 2cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
2	5	30	1	297.43	1235.97	**1465.63**	**213.52**
			2	444.40	1658.13		
			3	444.40	1502.80		
		60	1	297.43	2042.43	**2271.29**	**198.52**
			2	444.40	2397.07		
			3	444.40	2374.38		
		90	1	367.27	2241.27	**2388.00**	**127.55**
			2	277.18	2450.36		
			3	277.18	2472.38		
	10	30	1	511.07	1511.07	**1305.02**	**203.58**
			2	511.07	1300.00		
			3	511.07	1104.00		
		60	1	426.67	2252.00	**2022.22**	**226.25**
			2	426.67	2015.00		
			3	426.67	1799.67		
		90	1	456.00	2334.67	**2380.00**	**43.47**
			2	456.00	2384.00		
			3	456.00	2421.34		
	15	30	1	506.98	793.60	**819.22**	**30.94**
			2	369.28	853.60		
			3	369.28	810.46		
		60	1	440.00	1628.71	**1754.90**	**149.49**
			2	440.00	1716.00		
			3	506.98	1920.00		
		90	1	506.98	2234.05	**2183.80**	**56.48**
			2	352.00	2194.67		
			3	352.00	2122.67		

Table A-31 Influent and effluent SS of synthetic dyeing wastewater at sugar cane bagasse size of 0.5cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
0.5	5	30	1	66.40	23.57	**23.40**	**1.47**
			2	91.53	24.77		
			3	78.97	21.85		
		60	1	108.20	56.97	**49.54**	**6.73**
			2	111.67	43.87		
			3	111.67	47.77		
		90	1	66.40	31.56	**29.43**	**2.10**
			2	91.53	27.36		
			3	78.97	29.37		
	10	30	1	72.40	10.60	**10.60**	**0.00**
			2	72.40	10.60		
			3	72.40	10.60		
		60	1	85.73	26.20	**23.10**	**2.90**
			2	75.53	20.45		
			3	80.63	22.65		
		90	1	85.73	27.03	**31.43**	**4.10**
			2	103.33	35.13		
			3	80.63	32.13		
	15	30	1	117.57	31.05	**30.20**	**0.87**
			2	125.07	29.31		
			3	125.07	30.25		
		60	1	112.27	34.07	**31.33**	**2.80**
			2	112.27	28.47		
			3	112.27	31.44		
		90	1	117.57	39.43	**37.33**	**1.80**
			2	125.07	36.23		
			3	125.07	36.33		

Table A-32 Influent and effluent SS of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
1	5	30	1	70.93	7.50	**10.07**	**2.34**
			2	70.93	12.06		
			3	70.93	10.65		
		60	1	111.67	83.77	**75.67**	**9.20**
			2	111.67	65.67		
			3	111.67	77.57		
		90	1	71.73	13.17	**11.87**	**1.20**
			2	71.73	10.80		
			3	71.73	11.63		
	10	30	1	59.07	22.93	**22.92**	**0.61**
			2	59.07	23.53		
			3	59.07	22.31		
		60	1	103.33	26.90	**24.80**	**2.13**
			2	75.53	22.63		
			3	89.43	24.87		
		90	1	59.07	6.77	**11.99**	**5.29**
			2	58.00	17.34		
			3	58.00	11.87		
	15	30	1	58.40	15.54	**15.47**	**0.07**
			2	58.40	15.41		
			3	58.40	15.46		
		60	1	50.67	17.50	**17.90**	**0.37**
			2	50.67	18.23		
			3	50.67	17.97		
		90	1	112.27	45.58	**45.33**	**0.57**
			2	112.27	45.73		
			3	112.27	44.67		

Table A-33 Influent and effluent SS of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
2	5	30	1	29.27	15.27	**20.11**	**5.53**
			2	52.00	26.13		
			3	52.00	18.93		
		60	1	29.27	13.47	**12.80**	**0.64**
			2	52.00	12.20		
			3	52.00	12.73		
		90	1	36.27	7.27	**7.20**	**0.84**
			2	14.27	6.33		
			3	14.27	8.00		
	10	30	1	18.47	4.87	**4.16**	**1.07**
			2	18.47	4.67		
			3	18.47	2.93		
		60	1	44.47	9.60	**10.33**	**2.10**
			2	44.47	8.70		
			3	44.47	12.70		
		90	1	36.87	5.10	**6.23**	**1.55**
			2	36.87	5.60		
			3	36.87	8.00		
	15	30	1	12.87	20.06	**21.35**	**3.08**
			2	48.67	19.13		
			3	48.67	24.87		
		60	1	29.70	23.26	**24.08**	**4.27**
			2	29.70	28.70		
			3	12.87	20.27		
		90	1	12.87	28.47	**27.11**	**1.25**
			2	44.00	26.00		
			3	44.00	26.87		

Table A-34 Influent and effluent pH of synthetic dyeing wastewater at sugar cane bagasse size of 0.5 cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
0.5	5	30	1	7.15	5.37	**5.41**	**0.04**
			2	7.27	5.45		
			3	7.21	5.42		
		60	1	7.13	5.12	**5.13**	**0.01**
			2	7.12	5.13		
			3	7.12	5.13		
		90	1	7.15	5.25	**5.27**	**0.02**
			2	7.27	5.29		
			3	7.21	5.27		
	10	30	1	7.10	5.38	**5.39**	**0.01**
			2	7.10	5.40		
			3	7.10	5.38		
		60	1	7.38	5.50	**5.49**	**0.01**
			2	7.37	5.48		
			3	7.39	5.49		
		90	1	7.38	5.51	**5.50**	**0.02**
			2	7.52	5.48		
			3	7.39	5.50		
	15	30	1	7.24	5.58	**5.55**	**0.03**
			2	7.21	5.53		
			3	7.21	5.54		
		60	1	7.19	5.44	**5.46**	**0.01**
			2	7.19	5.47		
			3	7.19	5.46		
		90	1	7.24	5.29	**5.33**	**0.04**
			2	7.21	5.36		
			3	7.21	5.34		

Table A-35 Influent and effluent pH of synthetic dyeing wastewater at sugar cane bagasse size of 1 cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
1	5	30	1	7.09	5.59	**5.57**	**0.02**
			2	7.09	5.55		
			3	7.09	5.56		
		60	1	7.12	4.96	**4.96**	**0.00**
			2	7.12	4.96		
			3	7.12	4.96		
		90	1	7.06	5.24	**5.27**	**0.03**
			2	7.06	5.30		
			3	7.06	5.26		
	10	30	1	7.21	5.22	**5.25**	**0.02**
			2	7.21	5.27		
			3	7.21	5.25		
		60	1	7.38	5.36	**5.36**	**0.00**
			2	7.52	5.35		
			3	7.45	5.36		
		90	1	7.21	5.13	**5.27**	**0.14**
			2	7.20	5.42		
			3	7.20	5.25		
	15	30	1	7.35	6.08	**6.49**	**0.42**
			2	7.35	6.91		
			3	7.35	6.47		
		60	1	7.24	5.72	**5.70**	**0.02**
			2	7.24	5.68		
			3	7.24	5.69		
		90	1	7.19	5.46	**5.46**	**0.01**
			2	7.19	5.47		
			3	7.19	5.45		

Table A-36 Influent and effluent pH of synthetic dyeing wastewater at sugar cane bagasse size of 2 cm

Sizes (cm)	Flow rates (ml/min)	Depth (cm)	Rep.	Inf. (mg/L)	Eff. (mg/L)	Mean (mg/L)	S.D.
2	5	30	1	6.71	5.71	**5.53**	**0.17**
			2	6.79	5.39		
			3	6.79	5.48		
		60	1	6.71	5.42	**5.28**	**0.12**
			2	6.79	5.24		
			3	6.79	5.18		
		90	1	6.57	5.31	**5.26**	**0.06**
			2	6.66	5.29		
			3	6.66	5.19		
	10	30	1	7.24	5.21	**5.17**	**0.05**
			2	7.24	5.12		
			3	7.24	5.18		
		60	1	7.46	5.02	**5.28**	**0.37**
			2	7.46	5.71		
			3	7.46	5.12		
		90	1	7.17	4.96	**4.96**	**0.00**
			2	7.17	4.96		
			3	7.17	4.96		
	15	30	1	6.90	5.60	**5.55**	**0.04**
			2	6.98	5.52		
			3	6.98	5.54		
		60	1	6.79	5.95	**5.48**	**0.46**
			2	6.79	5.47		
			3	6.90	5.03		
		90	1	6.90	5.95	**5.29**	**0.57**
			2	6.89	4.93		
			3	6.89	5.00		

APPENDIX B
DATA OF THE EXPERIMENTSPART 2

Table B-1 Color removal efficiency of actual dyeing wastewater of chemical preparation

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2	
		SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	90.17	**89.54**	87.55	**89.63**
100.00	10.00	130.37	84.88	124.13	85.29
200.00	20.00	185.90	78.44	171.98	79.63
300.00	30.00	240.63	72.10	230.83	72.65
400.00	40.00	281.14	67.40	271.45	67.84
500.00	50.00	316.83	63.26	316.63	62.49
600.00	60.00	348.56	59.58	343.15	59.34
700.00	70.00	-	-	369.38	56.24
800.00	80.00	392.47	54.49	387.38	54.11
900.00	90.00	-	-	402.70	52.29
1000.00	100.00	422.06	51.06	417.18	50.57
1100.00	110.00	-	-	426.93	49.42
1200.00	120.00	2626.35	-204.56	437.58	48.16
1300.00	130.00	-	-	448.08	46.91
1400.00	140.00	460.15	46.64	455.83	46.00
1500.00	150.00	-	-	463.38	45.10
1600.00	160.00	475.49	44.86	471.00	44.20
1700.00	170.00	-	-	478.05	43.36
1800.00	180.00	488.28	43.38	484.25	42.63
1900.00	190.00	-	-	490.60	41.88
2000.00	200.00	498.05	42.25	497.23	41.09
2200.00	220.00	507.05	41.20	-	-
2300.00	230.00	-	-	512.43	39.29
2400.00	240.00	518.20	39.91	-	-
2600.00	260.00	526.15	38.99	526.05	37.68
2900.00	290.00	-	-	535.75	36.53
3200.00	320.00	-	-	546.43	35.26
inf		862.35	-	844.05	-

Remark: Dash (-) refer to that volume treated was not sampling.

Table B-2 Color removal efficiency of actual dyeing wastewater of simple preparation (dry with oven)

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2	
		SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	58.33	93.24	61.00	92.77
20.00	2.00	-	-	62.78	92.56
40.00	4.00	-	-	70.92	91.60
60.00	6.00	-	-	81.48	90.35
80.00	8.00	-	-	92.02	89.10
100.00	10.00	109.68	87.28	103.08	87.79
200.00	20.00	169.96	80.29	160.73	80.96
300.00	30.00	229.86	73.35	231.30	72.60
400.00	40.00	280.35	67.49	283.20	66.45
500.00	50.00	318.80	63.03	325.20	61.47
600.00	60.00	347.79	59.67	354.63	57.99
700.00	70.00	-	-	380.85	54.88
800.00	80.00	390.53	54.71	398.03	52.84
900.00	90.00	-	-	413.00	51.07
1000.00	100.00	420.04	51.29	426.40	49.48
1100.00	110.00	-	-	435.20	48.44
1200.00	120.00	439.20	49.07	446.00	47.16
1300.00	130.00	-	-	454.73	46.13
1400.00	140.00	461.35	46.50	463.33	45.11
1500.00	150.00	-	-	471.68	44.12
1600.00	160.00	477.25	44.66	478.53	43.31
1700.00	170.00	-	-	485.08	42.53
1800.00	180.00	488.91	43.30	491.80	41.73
1900.00	190.00	-	-	498.55	40.93
2000.00	200.00	500.01	42.02	504.33	40.25
2200.00	220.00	510.38	40.82	-	-
2300.00	230.00	-	-	519.75	38.42
2400.00	240.00	520.83	39.60	-	-
2600.00	260.00	530.89	38.44	534.90	36.63
3200.00	320.00	-	-	554.08	34.36
3500.00	350.00	-	-	564.75	33.09
3800.00	380.00	-	-	574.60	31.92
4100.00	410.00	-	-	583.00	30.93
4400.00	440.00	-	-	591.25	29.95
5000.00	500.00	-	-	604.78	28.35
inf		862.35	-	844.05	-

Remark: Dash (-) refer to that volume treated was not sampling.

Table B-3 Color removal efficiency of actual dyeing wastewater of simple preparation (dry with sunlight)

Volume treated (ml)	Breakthrough Time (min)	Rep1		Rep2	
		SU (mean)	%color removal	SU (mean)	%color removal
0.00	0.00	184.73	78.58	193.30	77.10
20.00	2.00	-	-	186.85	77.86
40.00	4.00	-	-	196.23	76.75
60.00	6.00	-	-	211.12	74.99
80.00	8.00	-	-	222.74	73.61
100.00	10.00	231.08	73.20	234.48	72.22
200.00	20.00	279.33	67.61	285.44	66.18
300.00	30.00	319.18	62.99	324.12	61.60
400.00	40.00	355.29	58.80	359.73	57.38
500.00	50.00	384.15	55.45	389.13	53.90
600.00	60.00	408.60	52.62	412.50	51.13
700.00	70.00	-	-	432.15	48.80
800.00	80.00	440.86	48.88	448.33	46.88
900.00	90.00	-	-	460.88	45.40
1000.00	100.00	467.53	45.78	472.08	44.07
1100.00	110.00	-	-	481.90	42.91
1200.00	120.00	487.35	43.49	491.10	41.82
1300.00	130.00	-	-	499.38	40.84
1400.00	140.00	506.93	41.21	506.33	40.01
1500.00	150.00	-	-	513.10	39.21
1600.00	160.00	518.95	39.82	517.23	38.72
1700.00	170.00	-	-	523.43	37.99
1800.00	180.00	533.01	38.19	528.93	37.33
1900.00	190.00	-	-	533.53	36.79
2000.00	200.00	540.38	37.34	539.10	36.13
2200.00	220.00	554.18	35.74	-	-
2300.00	230.00	-	-	552.85	34.50
2400.00	240.00	564.01	34.60	-	-
2600.00	260.00	573.83	33.46	566.15	32.92
3200.00	320.00	-	-	585.93	30.58
3500.00	350.00	-	-	595.13	29.49
3800.00	380.00	-	-	603.20	28.54
4100.00	410.00	-	-	612.55	27.43
4400.00	440.00	-	-	621.53	26.36
5000.00	500.00	-	-	639.78	24.20
inf		862.35	-	844.05	-

Remark: Dash (-) refer to that volume treated was not sampling.

Table B-4 Influent and effluent COD of actual dyeing wastewater

Treatment	Rep	Inf. (mg/L)	Mean (mg/L)	S.D.	Eff. (mg/L)	Mean (mg/L)	S.D.
Chemical preparation	1	586.15	571.11	21.27	2522.81	2559.41	51.76
	2	556.08			2596.18		
Simple Preparation (dry with oven)	1	586.15	571.11	21.27	2893.18	2996.44	146.02
	2	556.08			3099.69		
Simple Preparation (dry with sunlight)	1	586.15	571.11	21.27	1749.87	1747.21	3.76
	2	556.08			1744.55		

Table B-5 Influent and effluent SS of actual dyeing wastewater

Treatment	Rep	Inf. (mg/L)	Mean (mg/L)	S.D.	Eff. (mg/L)	Mean (mg/L)	S.D.
Chemical preparation	1	94.80	100.00	9.18	78.00	80.93	5.08
	2	110.60			78.00		
	3	94.60			86.80		
Simple Preparation (dry with oven)	1	94.80	100.00	9.18	64.00	69.93	5.41
	2	110.60			74.60		
	3	94.60			71.2		
Simple Preparation (dry with sunlight)	1	94.80	100.00	9.18	124.00	127.6	3.70
	2	110.60			127.4		
	3	94.60			131.4		

Table B-6 Influent and effluent TDS of actual dyeing wastewater

Treatment	Rep	Inf. (mg/L)	Mean (mg/L)	S.D.	Eff. (mg/L)	Mean (mg/L)	S.D.
Chemical preparation	1	4155.71	4199.04	61.27	6034.86	6002.18	46.21
	2	4242.36			5969.50		
Simple Preparation (dry with oven)	1	4155.71	4199.04	61.27	6249.79	6200.46	69.75
	2	4242.36			6151.14		
Simple Preparation (dry with sunlight)	1	4155.71	4199.04	61.27	5327.02	5352.30	35.74
	2	4242.36			5377.57		

Table B-7 Influent and effluent pH of actual dyeing wastewater

Treatment	Rep	Inf. (mg/L)	Mean (mg/L)	S.D.	Eff. (mg/L)	Mean (mg/L)	S.D.
Chemical preparation	1	7.53	7.52	0.02	5.63	5.49	0.20
	2	7.50			5.35		
Simple Preparation (dry with oven)	1	7.53	7.52	0.02	5.33	5.23	0.15
	2	7.50			5.12		
Simple Preparation (dry with sunlight)	1	7.53	7.52	0.02	5.67	5.75	0.11
	2	7.50			5.83		

APPENDIX C
STATISTICAL ANALYSIS

Table C-1 Percentage of color removal of synthetic dyeing wastewater at various sugar cane bagasse size, flow rates and sugar cane bagasse depths

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
C0.5_5_30	3	96.710	96.840	96.78333	.066583
C0.5_5_60	3	97.160	98.580	97.85667	.710375
C0.5_5_90	3	98.820	99.400	99.13000	.292062
c0.5_10_30	3	94.790	95.380	95.09333	.295353
c0.5_10_60	3	95.590	96.720	96.16333	.565184
c0.5_10_90	3	95.970	98.620	97.30333	1.325079
c0.5_15_30	3	93.230	95.240	94.24333	1.005104
c0.5_15_60	3	95.420	95.620	95.52000	.100000
c0.5_15_90	3	96.000	96.290	96.13000	.147309
c1_5_30	3	91.190	93.210	92.19667	1.010017
c1_5_60	3	96.440	97.310	96.88333	.435239
c1_5_90	3	97.920	98.270	98.08667	.175594
c1_10_30	3	85.580	86.230	85.91333	.325320
c1_10_60	3	90.990	91.720	91.37000	.365923
c1_10_90	3	91.410	93.430	92.41000	1.010149
c1_15_30	3	78.910	80.980	79.93667	1.035101
c1_15_60	3	86.260	86.570	86.42333	.155671
c1_15_90	3	91.140	92.930	92.04667	.895228
c2_5_30	3	91.240	91.510	91.36667	.135769
c2_5_60	3	95.100	96.990	96.05667	.945216
c2_5_90	3	96.700	97.010	96.84000	.157162
c2_10_30	3	79.360	80.350	79.88000	.496890
c2_10_60	3	88.690	89.700	89.18333	.505404
c2_10_90	3	90.450	91.540	91.00333	.545191
c2_15_30	3	78.760	78.990	78.88667	.116762
c2_15_60	3	85.350	86.020	85.72000	.340441
c2_15_90	3	89.490	90.910	90.19667	.710023
Valid N (listwise)	3				

Table C-2 Comparison of color removal efficiencies of synthetic dyeing wastewater at various sugar cane bagasse sizes

Oneway

Descriptives

Sugar cane bagasse size	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
.5	27	96.4693	1.53005	.29446	93.23	99.40
1.0	27	90.5852	5.47815	1.05427	78.91	98.27
2.0	27	88.7926	6.07404	1.16895	78.76	97.01
Total	81	91.9490	5.77849	.64205	78.76	99.40

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	870.902	2	435.451	18.866	.000
Within Groups	1800.371	78	23.082		
Total	2671.274	80			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: color_removal

LSD

(I) size	(J) size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.5	1.0	5.88407*	1.30758	.000	3.2809	8.4873
	2.0	7.67667*	1.30758	.000	5.0735	10.2798
1.0	.5	-5.88407*	1.30758	.000	-8.4873	-3.2809
	2.0	1.79259	1.30758	.174	-.8106	4.3958
2.0	.5	-7.67667*	1.30758	.000	-10.2798	-5.0735
	1.0	-1.79259	1.30758	.174	-4.3958	.8106

*. The mean difference is significant at the .05 level.

Table C-3 Comparison of color removal efficiencies of synthetic dyeing wastewater at various sugar cane bagasse depths

Oneway

Descriptives

Sugar cane bagasse depth	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
30	27	88.2556	6.92441	1.33260	78.76	96.84
60	27	92.7974	4.54597	.87487	85.35	98.58
90	27	94.7941	3.28763	.63271	89.49	99.40
Total	81	91.9490	5.77849	.64205	78.76	99.40

ANOVA

color_removal

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	606.306	2	303.153	11.451	.000
Within Groups	2064.968	78	26.474		
Total	2671.274	80			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: color_removal
LSD

(I) depth	(J) depth	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
30	60	-4.54185*	1.40037	.002	-7.3298	-1.7539
	90	-6.53852*	1.40037	.000	-9.3264	-3.7506
60	30	4.54185*	1.40037	.002	1.7539	7.3298
	90	-1.99667	1.40037	.158	-4.7846	.7913
90	30	6.53852*	1.40037	.000	3.7506	9.3264
	60	1.99667	1.40037	.158	-.7913	4.7846

*. The mean difference is significant at the .05 level.

Table C-4 Comparison of color removal efficiencies of synthetic dyeing wastewater at various flow rates

Oneway

Descriptives

Flow rate	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
5	27	96.1333	2.57178	.49494	91.19	99.40
10	27	90.9244	5.27182	1.01456	79.36	98.62
15	27	88.7893	6.22054	1.19714	78.76	96.29
Total	81	91.9490	5.77849	.64205	78.76	99.40

ANOVA

color_removal

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	770.643	2	385.321	15.813	.000
Within Groups	1900.631	78	24.367		
Total	2671.274	80			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: color_removal
LSD

(I) flowrate	(J) flowrate	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
5	10	5.20889*	1.34349	.000	2.5342	7.8836
	15	7.34407*	1.34349	.000	4.6694	10.0188
10	5	-5.20889*	1.34349	.000	-7.8836	-2.5342
	15	2.13519	1.34349	.116	-.5395	4.8099
15	5	-7.34407*	1.34349	.000	-10.0188	-4.6694
	10	-2.13519	1.34349	.116	-4.8099	.5395

*. The mean difference is significant at the .05 level.

Table C-5 Comparison of color removal efficiencies of synthetic dyeing wastewater by General Linear Model

Univariate Analysis of Variance

Tests of Between-Subjects Effects

Between-Subjects Factors

		N
size	.5	27
	1.0	27
	2.0	27
depth	30	27
	60	27
	90	27
flowrate	5	27
	10	27
	15	27

Tests of Between-Subjects Effects

Dependent Variable: color_removal

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2650.141[a]	26	101.929	260.459	.000
Intercept	684824.291	1	684824.291	1749938	.000
size	870.902	2	435.451	1112.713	.000
depth	606.306	2	303.153	774.650	.000
flowrate	770.643	2	385.321	984.615	.000
size * depth	148.207	4	37.052	94.679	.000
size * flowrate	175.095	4	43.774	111.856	.000
depth * flowrate	38.963	4	9.741	24.891	.000
size * depth * flowrate	40.025	8	5.003	12.784	.000
Error	21.132	54	.391		
Total	687495.564	81			
Corrected Total	2671.274	80			

a. R Squared = .992 (Adjusted R Squared = .988)

Table C-6 Comparison of color removal efficiencies of actual dyeing wastewater at various types of preparation

Oneway

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
DWsun	2	77.86	78.58	78.2200	.50912
H2SO4	2	89.54	89.63	89.5850	.06364
DWoven	2	92.77	93.24	93.0050	.33234
Valid N (listwise)	2				

ANOVA

percent_color_removal

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	239.637	2	119.819	961.883	.000
Within Groups	.374	3	.125		
Total	240.011	5			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: percent_color_removal

LSD

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.DWsun	2.H2SO4	-11.36500(*)	.35294	.000	-12.4882	-10.2418
	3.DWoven	-14.78500(*)	.35294	.000	-15.9082	-13.6618
2.H2SO4	1.DWsun	11.36500(*)	.35294	.000	10.2418	12.4882
	3.DWoven	-3.42000(*)	.35294	.002	-4.5432	-2.2968
3.DWoven	1.DWsun	14.78500(*)	.35294	.000	13.6618	15.9082
	2.H2SO4	3.42000(*)	.35294	.002	2.2968	4.5432

* The mean difference is significant at the .05 level.

APPENDIX D
PICTURS OF THE EXPERIMENT

Figure D-1 The experimental apparatus

Figure D-2 Chemical treated sugar cane bagasse of 0.5 cm

Figure D-3 Chemical treated sugar cane bagasse of 1 cm

Figure D-4 Chemical treated sugar cane bagasse of 2 cm

Figure D-5 A spectrophotometer was used in this study

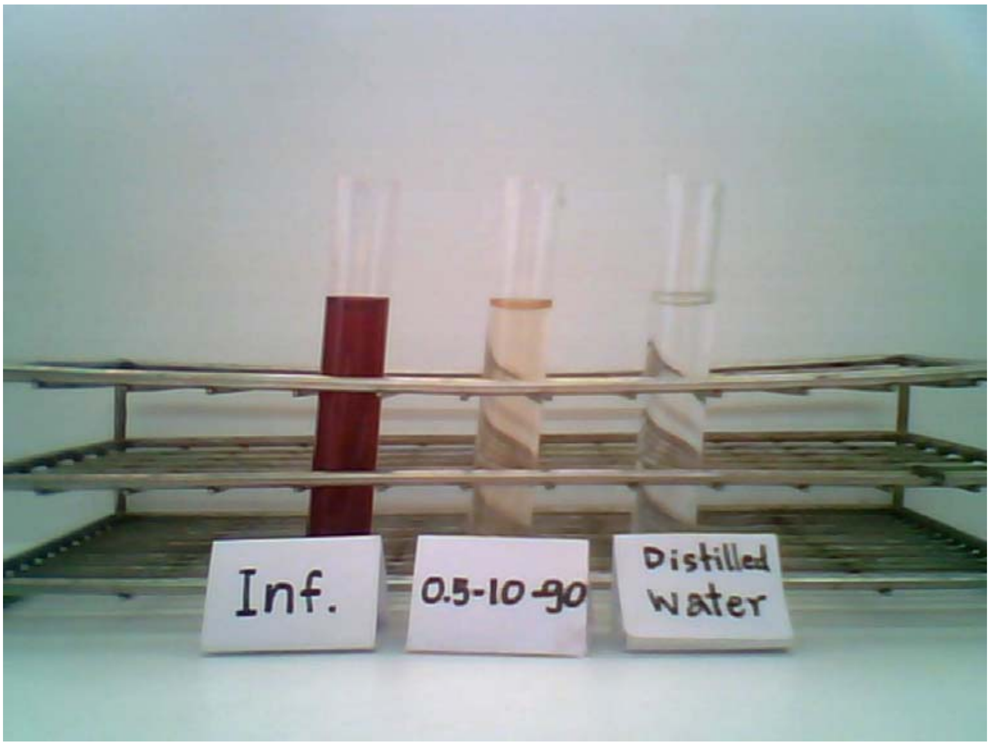

Figure D-6 The comparison of color intensity of synthetic dyeing wastewater at optimum operating condition

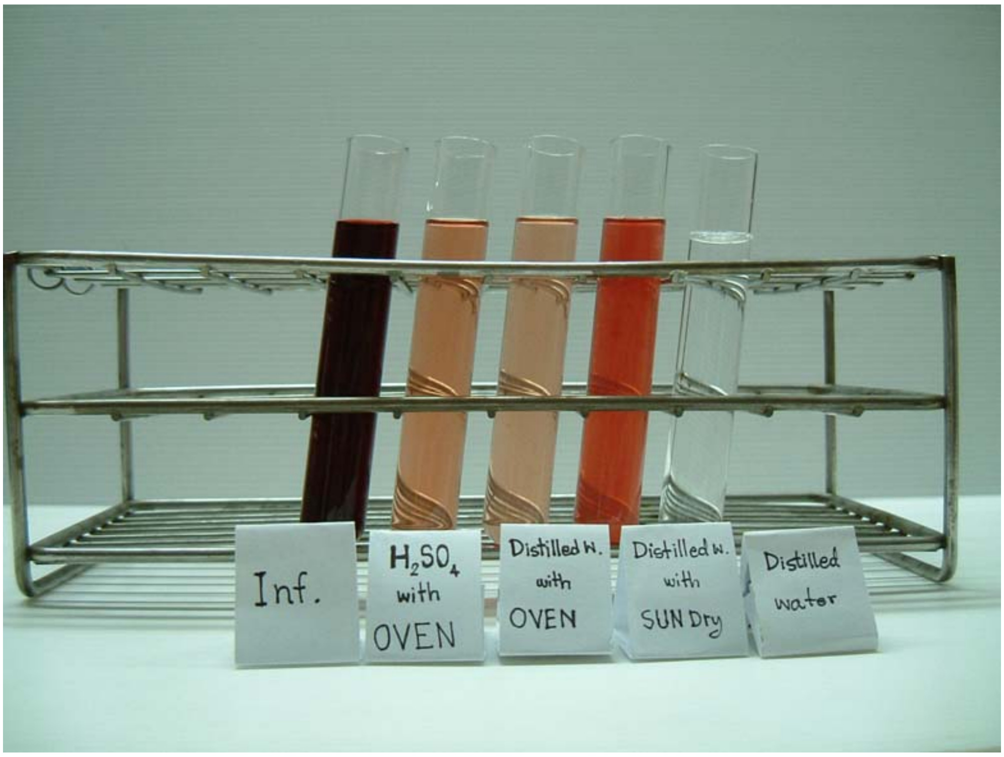

Figure D-7 The comparison of color intensity of actual dyeing wastewater for various types of sugar cane bagasse preparation at optimum operating condition

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