COLOR REMOVAL OF TEXTILE WASTEWATER BY COAGULATION-FLOCULATION USING ALUM AND TAMARIND-KERNEL POWDER

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ABSTRACT

The research objective was to study and compare color removal efficiency from dyeing factory wastewater using chemical coagulation by the jar test method using alum and alum with tamarind-kernel powder (polyelectrolyte) respectively. There were two water samples. One sample comprised dye synthetic water (the dyes were: Dystar Indigo Gvan; Sulphur Black BR 200; Direct Kayarus Blue BRL 200; and Reactive Cibacorn Blue CR). The second sample comprised wastewater from the storage pond of a cotton dyeing factory. The experiment was divided into two parts. In the first part, the pH was studied to ascertain the level at which color residue could be most efficiently coagulated using alum only. In the second part, removal efficiency was studied using alum and tamarind-kernel powder to coagulate color residues.

With regard to the first part, residues from Dystar Indigo Gvan were most efficiently coagulated by 150 mg/l of alum at pH 8. Color, COD and SS were reduced by 71.72%, 86.78% and 75.98% respectively. Residues from Sulphur Black BR 200 were most efficiently coagulated by 250 mg/l of alum at pH 7. Color, COD and SS were reduced by 99.95%, 88.44% and 41.67% respectively. Residues from Direct Kayarus blue BRL 200 were most efficiently coagulated by 100 mg/l of alum at pH 8. Color, COD and SS were reduced by 97.55%, 94.38% and 70.00% respectively. Residues from Reactive Cibacorn Blue CR were most efficiently coagulated by 200 mg/l of alum at pH 8. Color and COD were reduced by 50.96% and 42.63% respectively, but SS increased. Residues from wastewater were most efficiently coagulated by 1200 mg/l of alum at pH 8. Color, COD and SS were reduced by 88.24%, 93.78% and 91.76% respectively.

The results in the second part showed that when using suspension from tamarind-kernel powder with alum, removal efficiency was similar even if alum was reduced by 50%. With regard to Dystar Indigo Gvan, when 1mg/l of suspension from tamarind-kernel powder was used, color, COD and SS were reduced by 71.79%, 86.92% and 60.96% respectively. With regard to Sulphur Black BR 200, when 5 mg/l of suspension from tamarind-kernel powder were used, color, COD and SS were reduced by 99.95%, 89.93% and 75.00% respectively. With regard to Direct Kayarus Blue BRL 200, when 1 mg/l of suspension from tamarind-kernel powder was used, color, COD, and SS were reduced by 96.91%, 90.43% and 65.00% respectively. With regard to Reactive Cibacorn Blue CR BRL 200, when 1 mg/l of suspension from tamarind-kernel powder was used, color and COD were reduced by 53.44% and 61.52% respectively but SS increased. With regard to wastewater, when 3 mg/l of suspension from tamarind-kernel powder were used, color, COD and SS were reduced by 73.11%, 91.70% and 92.94% respectively.

From these results, it can be concluded that the amount of alum can be reduced by 50% by using suspension from tamarind-kernel powder with alum as a coagulant.

KEY WORDS : COLOR REMOVAL/ TAMARIND-KERNEL POWDER/ TEXTILE WASTEWATER/ COAGULATION-FLOCULATION

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การศึกษาการกำจัดสีย้อมสิ่งทอโดยสารส้มและผงเมล็ดมะขามโดยกระบวนการสร้างและรวมตะกอน
(COLOR REMOVAL OF TEXTILE WASTEWATER BY COAGULATION-FLOCULATION USING ALUM AND TAMARIND-KERNEL POWDER)

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วท.ม. (เทคโนโลยีที่เหมาะสมเพื่อการพัฒนาทรัพยากรและสิ่งแวดล้อม)

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาเปรียบเทียบประสิทธิภาพในการกำจัดสีย้อมสิ่งทอจากโรงงานย้อมฝ้ายในกรณีที่ใช้สารส้มเป็นสารสร้างตะกอนเพียงอย่างเดียว และในกรณีที่ใช้สารแขวนลอยเมล็ดมะขามซึ่งมีสมบัติเป็นสารโพลีอิเลคโตรไลต์เป็นสารช่วยสร้างตะกอนร่วมกับสารส้ม โดยการตกตะกอนทางเคมีด้วยวิธีจาร์เทสต์ ในการทดลองน้ำตัวอย่างถูกแบ่งออกเป็นสองกลุ่ม คือ กลุ่มน้ำสังเคราะห์โดยใช้สีย้อมสิ่งทอที่ใช้ในโรงงานย้อมฝ้าย (ได้แก่ 1. Dystar Indigo Gvan 2. Sulphur Black BR 200 3. Direct Kayarus Blue BRL 200 และ 4. Reactive Cibacorn Blue CR) และน้ำเสียจากบ่อรวมก่อนเข้าสู่ระบบบำบัดของโรงงานย้อมฝ้าย การศึกษามีสองส่วน คือ การศึกษาเพื่อหาพีเอชที่เหมาะสมและปริมาณสารส้มที่มีประสิทธิภาพในการตกตะกอนสูงที่สุด และการศึกษาเพื่อหาปริมาณสารส้มและสารแขวนลอยเมล็ดมะขามที่เหมาะสมที่จะใช้เป็นสารตกตะกอนร่วมกันที่มีประสิทธิภาพในการตกตะกอนสูงสุด

จากการศึกษาส่วนแรกพบว่า การตกตะกอนสีย้อม Dystar Indigo Gvan มีประสิทธิภาพสูงสุดที่ pH 8 และใช้สารส้ม 150 มก./ล. สามารถลดสี COD และ SS ได้ 71.72%, 86.78% และ 75.98% ตามลำดับ การตกตะกอนสีย้อม Sulphur Black BR 200 มีประสิทธิภาพสูงสุดที่ pH 7 และใช้สารส้ม 250 มก./ล. สามารถลดสี COD และ SS ได้ 99.95%, 88.44% และ 41.67% ตามลำดับ การตกตะกอนสีย้อม Direct Kayarus Blue BRL 200 มีประสิทธิภาพสูงสุดที่ pH 8 และใช้สารส้ม 100 มก./ล. สามารถลดสี COD และ SS ได้ 97.55%, 94.38% และ 70.00% ตามลำดับ การตกตะกอนสีย้อม Reactive Cibacorn Blue CR มีประสิทธิภาพสูงสุดที่ pH 8 และใช้สารส้ม 200 มก./ล. สามารถลดสี และ COD ได้ 50.96% และ 42.63% ตามลำดับ แต่ค่า SS เพิ่มขึ้น การตกตะกอนน้ำเสียจากโรงงานย้อมฝ้าย มีประสิทธิภาพสูงสุดที่ pH 8 และใช้สารส้ม 1,200 มก./ล. สามารถลดสี COD และ SS ได้ 88.24%, 93.78% และ 91.76% ตามลำดับ

จากการศึกษาการตกตะกอนน้ำตัวอย่างด้วยสารส้มร่วมกับสารแขวนลอยเมล็ดมะขามพบว่า ทุกกลุ่มตัวอย่างสามารถลดปริมาณสารส้มลงได้ถึง 50% โดยที่ประสิทธิภาพในการบำบัดใกล้เคียงกับการศึกษาส่วนแรก โดย สีย้อม Dystar Indigo Gvan เมื่อใช้สารแขวนลอยเมล็ดมะขาม 1 มก./ล. สามารถลดสี COD และ SS ได้ 71.79%, 86.92%และ 60.96% ตามลำดับ สีย้อม Sulphur Black BR 200 เมื่อใช้สารแขวนลอยเมล็ดมะขาม 5 มก./ล. สามารถลดสี COD และ SS ได้ 99.95%, 89.93%และ 75.00% ตามลำดับ สีย้อม Direct Kayarus Blue BRL 200 เมื่อใช้สารแขวนลอยเมล็ดมะขาม 1 มก./ล สามารถลดสี COD และ SS ได้ 96.91%, 90.43%และ 65.00% ตามลำดับ สีย้อม Reactive Cibacorn Blue CR เมื่อใช้สารแขวนลอยเมล็ดมะขาม 1 มก./ล. สามารถลดสี และ COD ได้ 53.44%,และ 61.52% ตามลำดับ แต่ค่า SS เพิ่มขึ้น และในส่วนของน้ำเสียจากโรงงานย้อมฝ้าย เมื่อใช้สารแขวนลอยเมล็ดมะขาม 3 มก./ล. สามารถลดสี COD และ SS ได้ 73.11%, 91.70%และ 92.94% ตามลำดับ

ผลการศึกษาชี้ให้เห็นว่าการใช้สารแขวนลอยเมล็ดมะขามร่วมกับสารส้มในการตกตะกอนน้ำสังเคราะห์ของสีย้อมทั้งสี่ชนิดและน้ำเสียจากโรงงานย้อมฝ้ายสามารถลดปริมาณของสารส้มได้ 50%

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CHAPTER 1
INTRODUCTION

1.1 Statement of the problem

The textile industry takes an important role in Thailand's economy. The value of export for textile industry was 220,877.8 million baht in 2002.(1).

The textile industry consists of fiber process, spinning-weaving process, dyeing-printing-finishing process and clothing process. (2) Wastewater, which was differed widely, was released from textile industry production. The most serious pollution problem of textile wastewater was dye, which is complex substance and difficult to remove (3)

In general, treatment operations were divided into three basic groups such as physical, chemical and biological treatments. (4) Chemical coagulation is the technology that can treat dyes problem from wastewater. There were well-known chemical coagulants for instant, alum, ferrous sulfate and ferrous chloride. The residue of these chemical coagulants was high and the residue would also impact on the environment. (5)

At present, several natural materials were used to be coagulant for turbid water coagulation. Tamarind kernel was the one of all natural materials, which was the appropriate coagulant when used with alum because tamarind seed contained non-ionic polysaccharides. When tamarind-kernel powder was dissolved in water, it becomes suspension that was anion, transparent and high viscous. These characteristics make higher efficiency of coagulation and reduce the amount of alum in the process when used with tamarind kernel. (6)

The development of natural material, tamarind seed as a substitute for chemical coagulant in textile wastewater treatment, has been proposed in this study. If tamarind seed can be able to be coagulant, the use of chemical coagulant is not only

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reduced but tamarind seed that is about 50,000 tons per year can be more valuable as well.(8)

1.2 Hypothesis

Efficiency of textile color removal by coagulation using alum with suspension from tamarind-kernel powder was higher than using only alum.

1.3 Objective

To study the efficiency of textile color removal by coagulation using only alum compared to alum with suspension from tamarind-kernel powder in different ratio.

1.4 Scope of the study

There were two groups of sample. The first group was synthesized from four types of dyes that were used in the textile industry such as Dystar Indigo Gvan (Vat dyes), Sulphur Black BR 200 (Sulphur dyes), Direct Kayarus Blue BRL 200 (Direct dyes), and Reactive Cibracron Blue CR (Reactive dyes). The second group was wastewater that was sampling from storage pond of cotton dyeing factory.

The first part: two groups of samples were determined the optimum conditions for coagulation with alum by jar test that was equipped the difference of pH and alum dose and the efficiency of coagulation was evaluated by the quantity of color, COD and SS.

The second part: two groups of samples were determined the optimum condition for coagulation using alum with suspension of tamarind-kernel powder in difference ratio. Alum dose and pH were chosen from the first part that given the optimum condition for coagulation and the efficiency of coagulation was evaluated from the quantity of color, COD and SS.

1.5 Expected Results

The efficiency of textile color removal by coagulation using alum and suspension from tamarind-kernel powder.

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1.6 Conceptual framework

To approach the subject as mentioned in the hypothesis, the conceptual framework has carried out in follow.

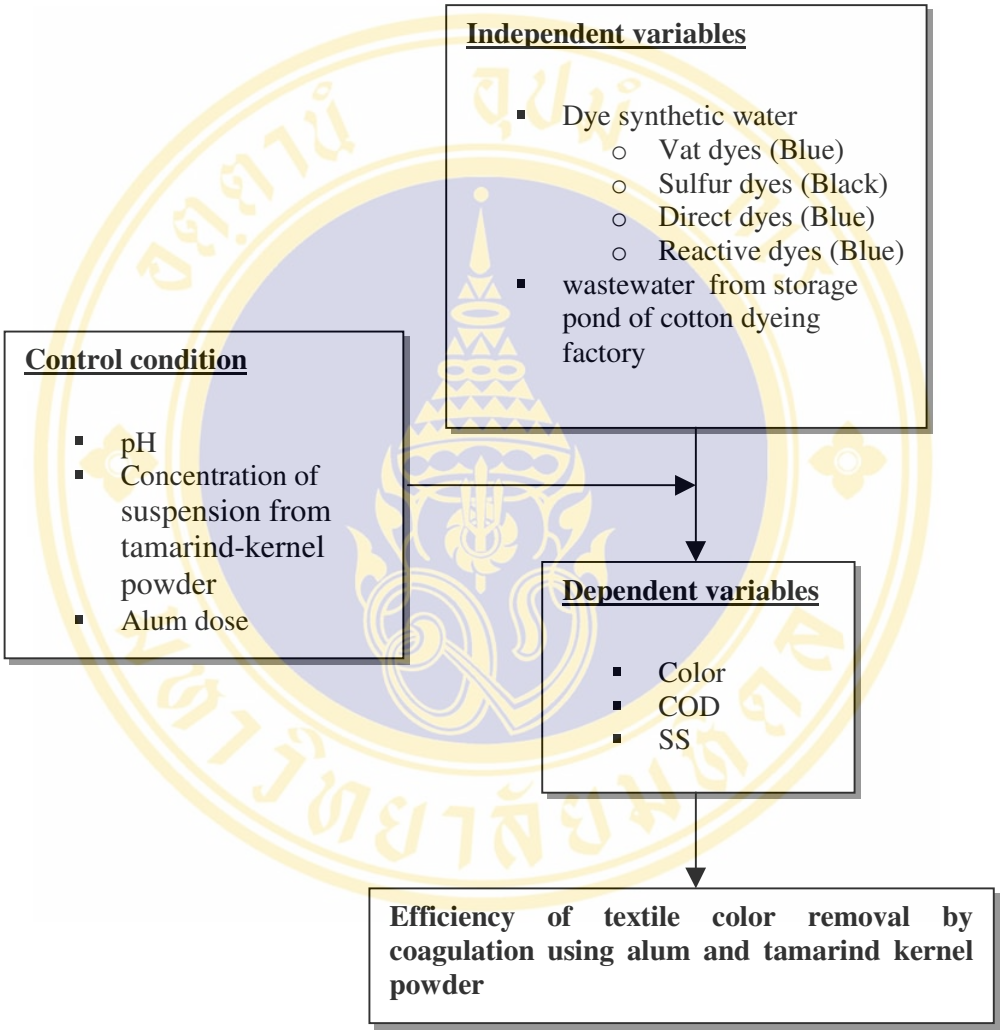

Figure 1-1 Conceptual framework for the study

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CHAPTER 2
LITERATURE REVIEWS

2.1 Textile industry

Textiles are any products derived from the weaving of fibers that are natural or man-made fibers into fabric. In the process, the fibers or the fabric receive function to impart particular qualities of appearance, touch, and durability.

There are two groups of fibers in the textile industry. First group is natural fibers such as wool and cotton. Second group is man-made fibers such as rayon, nylon, and polyester.

The mainly process of textile industry are,

2.1.1 spinning process

This process is spinning shot fibers or threads into long fibers. The fibers are twisted for tight.

2.1.2 weaving process

The process are weaving the set of threads lying lengthwise (warp) with the set of threads lying crosswise (weft) for the product that is fabric.

2.1.3 dyeing and finishing process

Dyeing process is used to add color and intricacy to textiles and increase product value. Finishing process encompassed chemical or mechanical treatment performed on fibers or fabric to improve appearance, texture, or performance. This process is divided as follows,

1) Fabric preparation (pretreatment), the fabric is removed impurities or processing chemicals that interfere with dyeing and treats the fabric to increase fibers strength and dye affinity, or ability to pick up dyes.

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2) Dyeing process is divided in two step are preparation and dyeing process. The factor that has effect to dyeing process is

- The kind of fibers, each kind of fibers has abilities to pick up dyes or reaction with dyes are differently.
- Dyes, there are many kind of dyes, each dyes are suitable with different kind of fibers.
- Additives, the chemical that add in dyeing process for increase efficiency of dyeing process.

2.2 Wastewater from textile industry

2.2.1 Source of wastewater

The sources of textile wastewater are,

1) Process water that is remain from dyeing process and wash water from preparation and continuous dyeing process.

2) Water from steam tank, in dyeing process is necessary to use steam to heat water. If steam is sent to heat water directly, the steam will increase amount of water in dyeing process.

3) Cleaning water, when the plant or factory is cleaned to cause wastewater that impurity with detergent, waste, and oil from machine.

2.2.2 The kind of pollutants in textile wastewater

Textile wastewater is composed of dyes that remain from dyeing process, additives that add to increase efficiency of dyeing process, and the remainder of fibers that are natural or man-made fibers.

2.2.3 Dyes

Dyes are classified in several ways (e.g., according to chemical constitution, application class, end-use). One well-known system of classification international used for dyes is the color index. This classifies dyes by firstly assigning each a generic name determined by its application characteristics. The classification of dyes is

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1) Disperse dyes are suspensions of finely divided organic compounds with very slight aqueous solubility. These dyes are developed to dye hydrophobic fibers such as cellulose acetate and the synthetic fibers. There are two group of disperse are azo dyes and insoluble aminoantraquinone color.

2) Acid dyes are sodium salts, usually of sulfonic acids or carboxylic acids, and are the main class of dyes used for wool dyeing and for dyeing nylon.

3) Azoic dyes are used on cellulose fibers, applied especially on cotton. Azoic dyes are made up of two chemically reactive compounds, which are applied to the fabric in two-stage process. The reaction of the two compounds in the fibers produces the colored azo chromophore. During dyeing, the azoic dyes form inside the fibers.

4) Basic dyes are usually hydrochlorides or salts of bases. The pigment is found in the cation and the dyes are often referred to as cationic dyes. They are mainly used on wool and acrylic fibers.

5) Direct dyes resemble acid dyes in that they are sodium salts of sulfonic acids and are often azo compound. They are used primarily for the dyeing of cellulose fibers.

6) Mordant dyes are used mainly in wool dyeing. In general, mordant dyes have fair to good fastness properties. These dyes usually contain a ligand functionality capable of reacting strongly with salts of aluminum, chromium, cobalt, copper, nickel, or iron to give differently colored metal complexes.

7) Sulfur dyes are complex organic compounds that contain sulfur linkages within the molecules. They are usually insoluble in water, but will form soluble components in the presence of a reducing agent such as sodium sulfide. The soluble components have an affinity for cellulose (cotton), and once on the fibers, are oxidized back to the original insoluble form. These dyes have good resistance to washing and moderate resistance to sunlight, and are not very bright.

8) Vat dyes are used mainly on cotton, linen, and rayon. They are made from indigo, anthraquinone, and carbazol. They are insoluble in water, but when treated with reducing agents, they are converted into soluble compounds in the presence of alkali. The soluble compounds have an affinity for cellulose and reoxidize to the insoluble pigment within the fibers when exposed to air.

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9) Reactive dyes are use on natural and some synthetic fibers. Most reactive dyes are used to dye cellulose. The dyes are water- soluble compounds that contain reactive groups capable of combining with the hydroxyl groups of cellulose under alkaline condition, establishing a covalent link between the dyes and the fiber.

10) Metallic dyes are inorganic compounds that insoluble in water. They are a variation on mordant dyes with the metallic oxide, again usually chrome, and already included in the formulation. They are used on cellulose fibers and there are various colors.

2.2.4 Textile wastewater treatment

Textile wastewater treatment can be any one or a combination of treatment methods. Generally, chemical coagulation or biological treatment are the main methods used to remove COD, SS and color in textile wastewater. There are well-know coagulant that used in chemical coagulation were alum, ferrous sulfate, and ferrous chloride and sometime, they are used with polymer.

2.2.5 Color and its measurement

There are two type of color in wastewater that is true color and apparent color. In textile wastewater, suspended materials cause apparent color while soluble substances create true color.

There are several techniques for measuring color such as the American Dry Manufactures institute (ADMI color unit), platinum-cobalt method and measurement by spectrophotometer. Selecting techniques for measuring color have to consider from the appropriate of equipment that is used in process. This study, measuring color use spectrophotometer find wavelength that gives highest absorbance. There is the principle that is dark color will absorb light for much or light can hard to pass. Measurement of color will show in percent of color reducing that is

$$\text{Percent of color reducing} = (A_0\text{-}A) / A_0 * 100$$

A_0 = absorbance before coagulation

A = absorbance after coagulation

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2.2.6 Synthesis of water sample

Collecting wastewater for study is difficult because

- The quality of wastewater is very much, hard to transport to laboratory.

- Production plan of the factory is not certainly.

- The study use a long time that cause wastewater will change condition.

From the reason that refers to, this study will synthesize water sample for experiment by the formula from Thongchai's research. Thongchai (1984) studied the removal of color from textile wastewater. The result showed that the additives were not effect to coagulation by alum. Then, this study will choose the formula that there are not additives. The formulas are

Direct dyes	0.0882	g/l
Reactive dyes	0.0650	g/l
Sulfur dyes	1.0000	g/l
Vat dyes	0.0460	g/l

2.2.7 Characteristic of wastewater from Jib Hua Cheang Jun (cotton dyeing factory).

Jib Hua Cheang Jun factory is cotton-dyeing factory. There are four types of dyes that use in dyeing process that are direct dyes, reactive dyes, sulfur dyes and vat dyes. In dyeing process, there are several color of direct and reactive dyes that used, only black for sulfur dyes and only blue for vat dyes.

The average characteristics of wastewater from Jib Hua Cheang Jun factory were 974.0 mg/l of BOD, 2462.0 mg/l of COD, 347.0 mg/l of SS, and pH of 9.17.

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2.3 Coagulation-Flocculation

2.3.1 Mechanism of coagulation

Coagulation/flocculation in wastewater treatment involves the addition of chemicals to alter the physical state of dissolved and suspended solids and facilitate their removal by sedimentation. In some cases the alteration is slight, and removal is effected by entrapment within a voluminous coagulate consisting primary of the coagulant itself. Another result of chemical addition is a net increase in the dissolved constituents in the wastewater.

Coagulation is used for remove waste materials in suspended or colloidal form that do not settle out on standing or settle by take along time.

There are two general types of colloidal solid particle dispersions in liquids that are hydrophobic and hydrophilic. The hydrophobic colloids possess no affinity for the liquid medium and lack stability in the presence of electrolytes. They are readily susceptible to coagulation. The hydrophilic colloids exhibit a marked affinity for water. The absorbed water retards flocculation and frequently requires special treatment to achieve effective coagulation.

Colloids possess electrical properties that create a repelling force and prevent agglomeration and settling. Stabilizing ions are strongly adsorbed to an inner fixed layer, which provides a particle charge that varies with the valence and number of adsorbed ions. Ions of an opposite charge form a diffuse outer layer, which is held near the surface by electrostatic forces. The psi potential is defined as the potential drop between the interface of the colloid and the body of solution. The zeta potential is the potential drop between the slipping plane and the body of solution and is relate to the particle charge and the thickness of the double layer. The thickness of the double layer is inversely proportional to the concentration and valence of nonspecific electrolytes, a van der waals attractive force is effective in close proximity to the colloidal particle.

The stability of a colloid is due to the repulsive electrostatic forces and in the case of hydrophilic colloids in which an envelope of water retards coagulation.

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2.3.2 Coagulation with alum

Over the years a number of different substances have been used as coagulants. The most common one is alum or aluminium sulfate. The salts of Al (III) is commonly used as coagulants in water and wastewater treatment. Al (III) is hydrolyzing metal ions, when is added to water, it will dissociate to yield trivalent Al^{3+} ions, witch hydrate to form the aquametal complexes Al $(H_2O)_6^{3+}$. These complexes then pass through a series of hydrolytic reaction in which H_2O molecules in the hydration shell are replaced by OH^- ions. This gives rise to the formation of a variety of soluble species, including mononuclear species (one aluminum ion) such as Al $(OH)^{2+}$ and $Al(OH)_2^+$, and polynuclear species (several aluminum ions) such as Al_8 $(OH)_{20}^{4+}$. Despite the fact that some of these products have only one or two positive charges, they are quite effective as coagulants because they adsorb very strongly onto the surface of most negative colloids. Hydrolysis schemes for aluminium is shown in figure 2-1

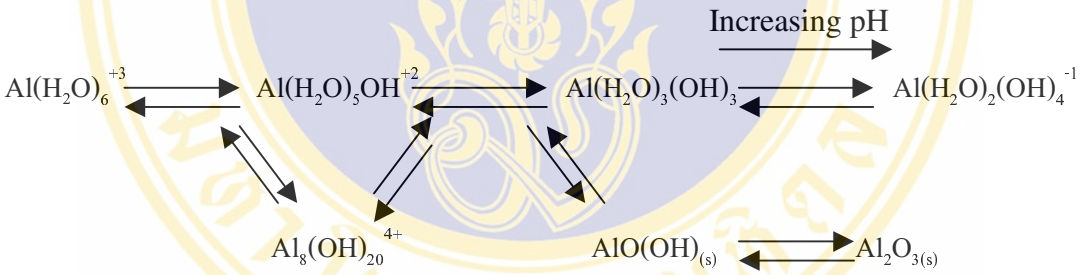

Figure 2-1 Hydrolysis schemes for aluminium (III)

There is a limited pH range in which the insoluble aluminium hydrates, such as aluminium hydroxide, will form from dilute alum solution. If the pH is too low, a soluble compound ($Al.OH.SO_4$) will form. If it is too high, the aluminium becomes complexed into soluble aluminate ions (AlO_2^-).

The optimum pH range in a particular case depends on the nature and concentration of impurities in the water. For a soft water containing a considerable amount of color, the optimum pH is likely to be in the range 5.0 to 6.3, but for a turbid water with moderate alkalinity, it is likely to be 6.0 to 7.0.

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As the pH goes above 7, the charge on colloidal aluminiium hydroxide reverses from positive to negative. The presence of positive ions of calcium can help in neutralizing this charge and achieving precipitation of aluminium at pH above 7.

When hydrolyzed, alum produces sulfuric acid as well as the hydrate; for example, when forming the simplest hydrate ($Al(OH)_3$) the hydrolysis reaction is

$$Al_2(SO_4)_3 + 6H_2O \rightleftharpoons Al(OH)_3\downarrow + 3H_2SO_4$$

It is therefore regarded as an acid salt and the water must contain enough of either natural or added alkalinity to react with the acid as it forms, thus keeping the resultant pH with in the desired range for good flocculation. Added alkalinity is usually in the form of lime (calcium hydroxide), soda ash (sodium carbonate) or caustic soda (sodium hydroxide)

It sometimes happens with water having a high alkalinity that large amounts of alum would be required to reduce the pH to that required for optimum precipitation. In such a case, economy may be obtain by the use of some sulfuric acid for pH control, in conjunction with an adequate amount of alum to form a suitable floc.

2.3.2 Controlling of coagulation by Jar Test

The efficiency of coagulation depend on many factors for example, a kind and quantity of coagulants, pH, a kind and quantity of coagulant aids, the order of chemical adding and condition controlling. The laboratory procedure that is used to control coagulation process is Jar Test. It consists of a series of six-stirring paddle, which can be rotated at a variable controlled speed to mix contents of liter beaker. This permits the simultaneous treatment and observation of six samples under identical mixing conditions in order to determine the relative merits of various chemical treatments, or to determine the optimum dosage of a particular chemical.

2.3.3 Coagulant Aids

The addition of some chemicals will enhance coagulation by promotion the growth of large, rapid-settling flocs. Polyelectrolytes are high-molecular-weight polymers, which contain absorbable groups and thus created when small dosages of polyelectrolyte (1 to 5 mg/l) are added in conjunction with alum. The polyelectrolyte is substantially unaffected by pH and can serve as a coagulant itself by reducing the

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effective charge on a colloid. There are three types of polyelectrolytes : a cationic that adsorbs on a negative colloid or floc particle, an anionic that replaces the anionic groups on a colloidal particle and permits hydrogen bonding between the colloid and the polymer, and a nonionic that adsorbs and flocculants by hydrogen bonding between the solid surfaces and the polar groups in the polymer.

2.3.4 The coagulation by polyelectrolyte

Mostly natural coagulants are organic polymers that use destabilization of colloidal particle in coagulation. The mechanism can explain by the model that is called polymer bridging (figure2-2). First step, the molecule of polymer will cling to many end-side of surface of colloidal particle (reaction 1). The next step, the colloidal particle that cling to polymer and have free end-side to cling to another colloidal particle (destabilization particle), they will be linked by polymer to cling to another particle (particle-polymer-particle-complex). The products are floc that is larger and easy to separate from water (reaction 2). The linking by polymer is occurred when the particle is cling to polymer and has free end-side to cling to another particle. If the free end-side of polymer dose not has a side of another particle to cling to, it will cling to itself that is called restabilized particle (reaction 3). If polymers are too much, many polymers will cling to one particle that makes the particle dose not has free end-side to cling to another polymer that cling to another particle (reaction 4). The product in this step is called stable particle. Not only that, strength and long of stirring will make the floc break up (reaction 5) and make the free end-side of polymer will cling to identical particle (reaction 6) that mean the colloidal particle is restabilized. The important thing in this mechanism is the size of polymer must be big and high molegular weight for wide radius of linking. The polymer bridging must be strong and is able to resist pressure between particle and turmoil from stirring.

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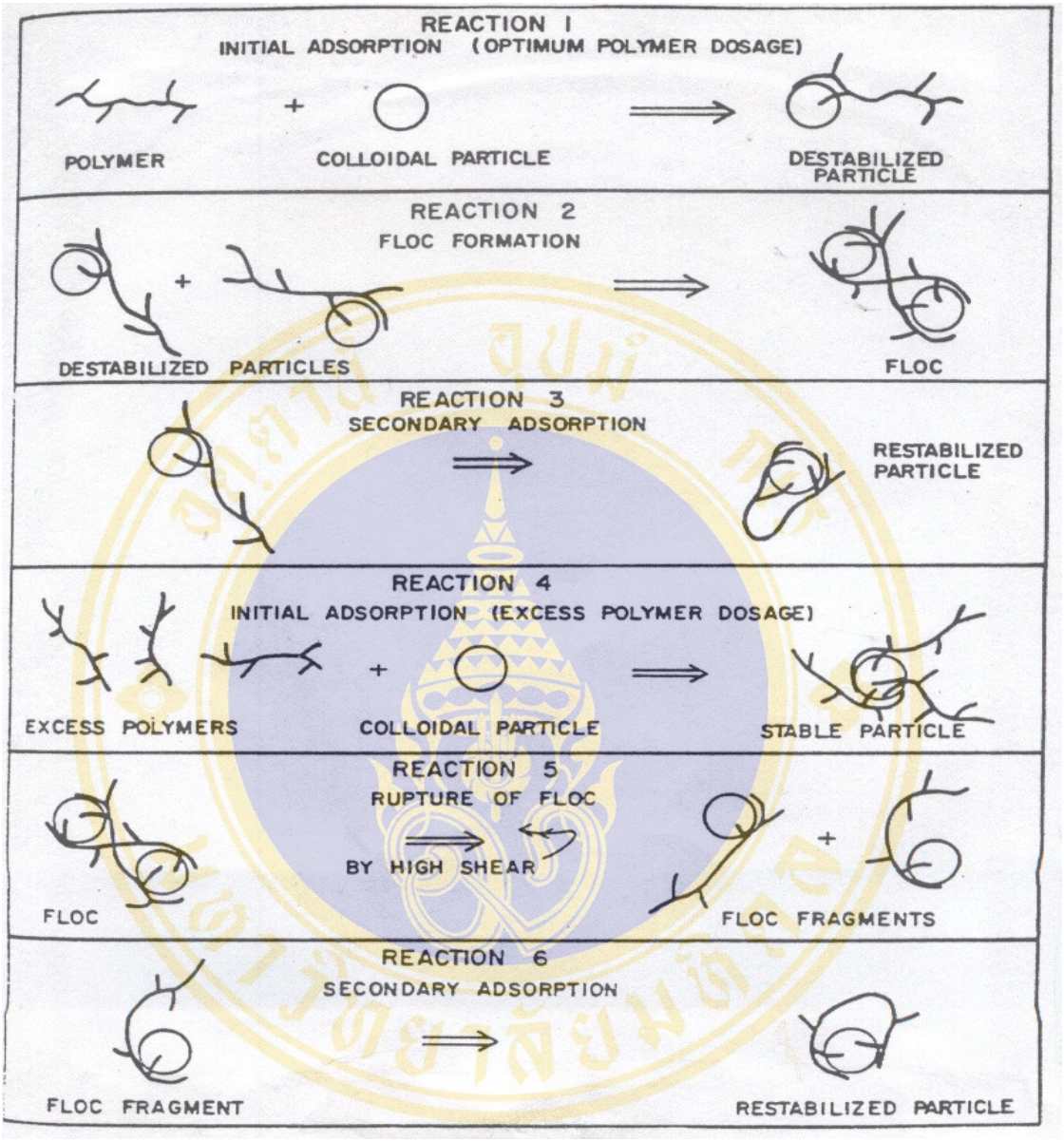

Figure2-2 The polymer bridging model

At present there are employment of natural polyelectrolytes for coagulant, for example, seed for planting that are protein and carbohydrate. They have big molecule and high molegular weight. Proteins are combined with monomer of several amino groups that are linked as same as carbohydrates are combined with small sugar molecule. Tamarind kernel is natural polyelectrolyte that is, it is possible to be coagulant in textile wastewater coagulation.

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2.4 Tamarind

Tamarind (*Tamarindus indica Linn*. Family; Ceasalpiniaceae) is a large spreading tree and evergreen. The trunk high about 6-20 m., the branch is sprawl. The leaf is compound leaf, long about 7-15 cm., consist from 10-20 pair of sub-leaf that is opposite. The fruit is the pod that high about 7.5-20 cm., wide about 2.5 cm., thick about 1 cm. One pod has 3-12 brown or black seed. It usually begins to bear fruits after 10 years and lives for 80-100 years. The fruit ripen at the winter about Decembe-February.

Tamarind is found throughout Thailand especially the north and the northeast. In Thailand, tamarind is divided to two kinds from taste that is sweet and sour. Sour-tamarind is classified by the form of pod. Mutations of sour-tamarind occur sweet-tamarind. Because of high price make breed of sweet-tamarind is developed. At present, there are over thirty species of sweet-tamarind.

2.5 Tamarind kernel

The tamarind seed is flat and irregular shape. It consists of 35% of dark reddish brown coverings called testae and 65% of white kernel (15). Association of Official Analytical Chemists (AOAC) analyze element of tamarind kernel powder (TKP) is certain: carbohydrates 67.2-68.5%, proteins 14.0-16.5%, and oil 4.8-6.7%. In Thailand there is tamarind kernel analysis by Jiraporn (2533), the result is the composition of tamarind kernel powder resemble the cereals: carbohydrates 68.5%, proteins 14.6%, and oil 7.1% that resembled Tanong's research (2525) that is carbohydrates 76.85%, proteins 16.11%, and oil 7.04%.

2.5.1 Utility of tamarind kernel

Carbohydrate and protein are the composition in tamarind-kernel, which is the polyelectrolyte. Carbohydrate in tamarind is composed of starch and nonionic polysaccharide that consist of xylose, galactose, and glucose in 1:2:3 ratio. The characteristic of polysaccharide solution is mucilaginous and become jell in

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neutral and acidic condition. Jellose is the name of polysaccharide solution and it is about 87% of total carbohydrate in tamarind-kernel. (15)

In thailand, there was 50,000 ton of tamarind by weight per year, (7) and it contain tamarind kernel about 2,000 ton by weight per year, currently there was rarely use of tamarind kernel, therefore it is interesting to study the utility of tamarind kernel.

2.5.2 Preparation of suspension from tamarind kernel powder

Tamarind seeds were dried in an oven at 105°C for 15 minutes. The testae were become brittle and were removed by light pounding and winnowing. After that, the creamy white kernel was ground coarsely in the mill to pass 0.5 mm. Sieve. Then the tamarind-kernel powder 1.0 g. were dissolved in distill water 1.0 l. Finally the product were the suspension which were transparent and high viscous.

2.6 Relevant Research

Jiraporn (5) studied about the coagulant from natural materials, which are peanut, red bean, sour-tamarind seed, horse-radish tree seed and Jamaican sorrel seed. This experiment used ground kernel of these materials to be the coagulation and coagulation aid solution testing with alum. It was found all of these natural materials could be the coagulant and sour-tamarind seed was the highest efficiency. When these natural materials and alum were used, the coagulation efficiency was higher than alum used only. Moreover, these materials did not effect to pH and alkalinity of water.

Benja (6) studied the use of tamarind seed as an coagulant and coagulant aid. The result showed that the coagulant efficiency of tamarind seed was less than coagulant aid efficiency. When the coagulant aid, tamarind seed, was used with alum, the water that was more than 100 NTU of turbidity was better coagulation than alum used without coagulant aid and the size of floc was increased also.

Chainuwat (20) studied the use of sour-tamarind and sweet-tamarind kernel powder with alum for raw water coagulation. The result showed that the sour-tamarind had higher coagulation efficiency and reduced alum using more than 50%.

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Charoensuk (21) studied coagulant aid using cation and anion polymer with alum in coagulation process at 40, 80 and 120 NTU of raw water turbidity and pH at 6.5 and 7.5. The study showed that coagulant aid, polymer, and alum reduced amount of sediment about 45 – 78 %. It was not only sediment-keeping area decreased but it reduced the use of chemical for pH controlling also.

Patcharaporn (22) studied the capability of dye removal using chemical coagulation by two types of cation polymer, Lamfloc 1525 and Zentrifloc 95, in laboratory. The appropriate cation polymer derived from the experiment was used with anion polymer, Lamfloc 7985 to remove dyes from textile wastewater and compare to alum. The study showed that Lamfloc 1525 had higher efficiency of dye removal for vat dyes and reactive dyes.

Theerawee (23) studied the COD removal efficiency of wastewater from textile industrial by coagulation and oxidation. This study used four coagulation aids that is alum, $FeSO_4$, lime. The result showed that the COD removal efficiency was 57.13-94.62%, 66.91-89.47%, 6.19-44.50% and 14.75-35.94%, respectively. Alum, at the concentration of 5000 mg/l and pH 10, had the highest COD removal efficiency about 86.47%.

Jarutus studied wastewater color coagulation by many coagulants such as ferric chloride, ferrous sulfate, alum, polyaluminium chloride and bentonite. This study used synthetic wastewater from different dyes at the concentration 100 ppm and wastewater from textile industrial. The result showed that the efficiency range of alum concentration was 200 – 1000 ppm and the disperse dyes that was insoluble was the best coagulated.

Thongchai (4) studied about color removal by three types of chemical such as alum, lime and Magnesium carbonate hydrated basic. This experiment used six different dyes that is direct dyes, vat dyes, reactive dyes, sulfer dyes, azoic dyes and metallic dyes with additives and without additives. The result showed that the color removal efficiency of alum was more than 70% except reactive dyes that was soluble color whereas the additives did not effect to the color removal efficiency.

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CHAPTER 3
MATERIALS AND METHODS

This research was studied about color removal of textile wastewater by coagulation using alum only compared to using alum with suspension from tamarind kernel powder in difference ratio. There were two groups of sample. The first group was synthesized from four types of dyes of dyes that were used in the textile industry such as Dystar Indigo Gvan (Vat dyes), Sulphur Black BR 2000 (Sulphur dyes), Direct Kayarus Blue BRL 200 (Direct dyes), and, Reactive Cibracron Blue CR (Reactive dyes). The second group was wastewater that was sampling from storage pond of cotton dyeing factory (Jib Hua Cheang Jun co.ltd). The experiment was divided into two parts. The first part was studied the appropriate pH and the highest efficiency to coagulate substance from water sample using alum only. The second part was studied the removal efficiency using alum with suspension from tamarind-kernel powder in different ratio to coagulate substance from water sample. The experimental procedure of this research was shown in Figure 3-1 as follow.

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3.1 Experimental procedure

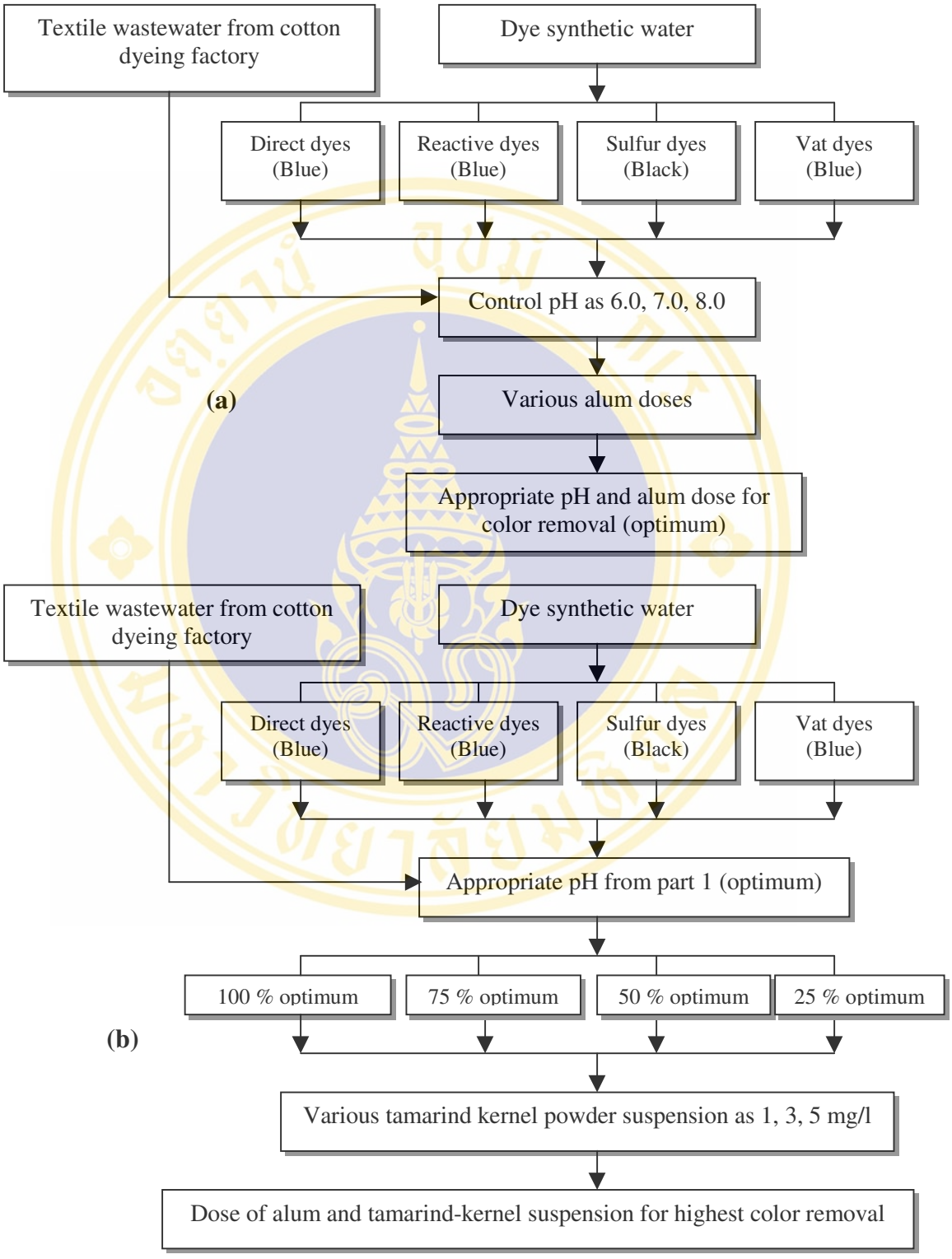

Figure 3-1 Diagram of the experimental procedure

(a) Part one; studies pH and alum dose
(b) Part two; studies coagulate substance of alum and tamarind kernel-powder suspension

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3.2 Experimental instruments

1. Hot air oven
2. Balance (Mettler Toledo model PG 2002-S)
3. Spectrophoto meter (Jasco,V-530)
4. Jar Test
5. PH meter
6. Suchtion
7. Elenmeyer flask
8. Test tube
9. Pipette
10. Burette
11. Filter paper (Whatman GF/C)

3.3 Chemical reagent

1. Alum
2. Tamarind-Kernel Powder
3. Dystar Indigo Gvan
4. Sulphur Black BR 200
5. Direct Kayarus Blue BRL 200
6. Reactive Cibracron Blue CR
7. Chemical reagent for COD analysis

3.4 Preparation of the solution

3.4.1 Preparation of suspension from tamarind kernel powder

Tamarind seeds were dried in an oven at 105°C for 15 minutes. The testae were become brittle and were removed by light pounding and winnowing. After that, the creamy white kernel was ground coarsely in the mill to pass 0.5 mm. Sieve. Then the tamarind kernel powder 1.0 g. were dissolved in distill water 1.0 l. Finally the product were the suspension which were transparent and high viscous.

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3.4.2 The preparation of the alum solution

The alum approximate 1 g were dissolved in distill water 1.0 l for alum dose 1000 mg/l.

3.4.3 The preparation of the synthetic dyes solution

The dye synthetic water were prepared in different ratio as follows: (4)

Dystar Indigo Gvan (Vat dyes)	0.0460	g/l
Sulphur Black BR 200	1.0000	g/l
Direct Kayarus Blue BRL 200	0.0882	g/l
Reactive Cibracron Blue CR	0.0650	g/l

3.5 Experiment

The experiment was divided into two parts. The first part was studied the appropriate pH and the highest efficiency to coagulate substance from water sample using alum only. The second part was studied the removal efficiency using alum with suspension from tamarind kernel powder in different ratio to coagulate substance from water sample. At first, two groups of sample were determined the quantity of color, SS, and COD. After that, the experiment were divided into two parts witch were presented as follows:

The first part: the coagulation of sample were performed by using jar test. Five hundred milliliters of water sample which adjusting to pH 6, 7, and 8 were put in each jar test beaker. Various amounts of alum (table 3.1) and pH, subjected to the fast mixing (at 100 rpm) for 1 minute and the slow mixing (at 30 rpm) for 20 minutes. Then, the mixtures were allowed to stand for another 30 minutes to settle the flocs formed. From each jar, the upper liquid were taken out by decanting and subjected to measure color, SS, and COD. By this means, the optimum pH and dosage of alum in coagulation.

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The second part: the procedure were repeated same to part one. The optimum pH was fixed. The optimum dosage of alum was reduced in different ratio (100%, 75%, 50%, and 25%) and was used with various amount of suspension from tamarind kernel powder(1, 3, and 5 mg/l). The efficiency of coagulation was evaluated from the quantity of color, SS, COD.

Table 3-1 The alum dose were use in the water sample

Water sample	The dosage of alum (mg/l)
Dystar Indigo Gvan (Vat dyes) solution	50, 100, 150, 200, 250
Synthetic Sulphur Black BR 200 solution	200, 250, 300, 350, 400
Synthetic Direct Kayarus Blue BRL 200solution	50, 100, 150, 200, 250
Synthetic Reactive Cibracron Blue CR solution	50, 100, 150, 200, 250
wastewater	800, 900, 1000, 1100, 1200, 1300

3.6 Statistics data analysis

Statistical of different in removal efficiency of COD, SS, and color of alum and alum with tamarind suspension were examined by Multivariate Analysis of Variance (MANOVA) at 95% confidence (α=0.05) using Duncan new multiple range test (DMRT). the multi-comparison test was applied to the ANOVA to determine which means were significantly different. All the data were analyzed by using the package program of SPSS 10.0.

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CHAPTER 4
RESULT AND DISCUSSION

4.1 The characteristics of the samples

Before coagulation, the samples - - Dystar Indigo Gvan (Vat dye), Sulphur Black BR200 (Sulphur dye), Direct Kayarus Blue BRL200 (Direct Dye), Reactive Cibracron Blue CR (Reactive dye), wastewater - -were analyzed with six parameters - - pH, The maximum absorbtion spectrum, The maximum absorbence, COD, SS and Alkalinity. The characteristics of the samples were presented in table 4-1 as follows:

Table 4-1 Characteristics of the samples

sample	pH	λ_{max} (nm)	maximum absorbance (%)	COD (mg/l)	SS (mg/l)	Alkalinity (mg/l as $CaCO_3$)
1. Vat dye	5.45	705	0.1946	101.25	33.3	80.0
2. Sulphur dye	10.57	400	11.4300	864.80	12.0	675.0
3. Direct dye	6.45	575	1.6808	37.20	10.0	27.7
4. Reactive dye	5.85	609	0.9146	60.50	2.0	31.0
5. wastewater	11.71	400	1.3037	1840.00	850.0	1850.0

- The pH of the samples for Vat dye, Sulphur dye, Direct Dye, Reactive dye, wastewater were 5.45, 10.57, 6.45, 5.85, 11.71 respectively.

- The maximum absorbtionspectrum, λ_{max} (nm) for Vat dye, Sulphur dye, Direct Dye, Reactive dye and Wastewater were 750, 400, 575, 609, 400 nm, respectively.

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-The maximum absorbance (%) for Vat dye, Sulphur dye, Direct Dye, Reactive dye and Wastewater were 0.1964, 11.4300, 1.6808, 0.9146, 1.3037, respectively.

- COD (mg/l) for Vat dye, Sulphur dye, Direct Dye, Reactive dye and Wastewater were 101.25, 864.80, 37.20, 60.50, 184.00 mg/l, respectively.

-SS (mg/l) for Vat dye, Sulphur dye, Direct Dye, Reactive dye, Wastewater were 33.30, 12.00, 10.00, 2.00, 850.00 mg/l, respectively.

- Alkalinity (mg/l as $CaCO_3$) for Vat dye, Sulphur dye, Direct Dye, Reactive dye, Wastewater were 80.0, 675.0, 27.7, 31.0, 1850.0 mg/l, respectively.

4.2 The Optimum of pH and Alum's dose

4.2.1 Vat dye

Color removal efficiency

Color removal efficiency of Vat dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-2, as follows:

Table 4-2 Vat dye removal efficiency by coagulation using alum

Alum Dose (mg/l)	Color removal efficiency (%)		
	pH 6	pH 7	pH 8
50	58.22	33.92	21.48
100	66.19	43.94	55.86
150	64.44	52.62	71.72
200	57.61	29.34	65.74
250	36.38	19.63	61.77

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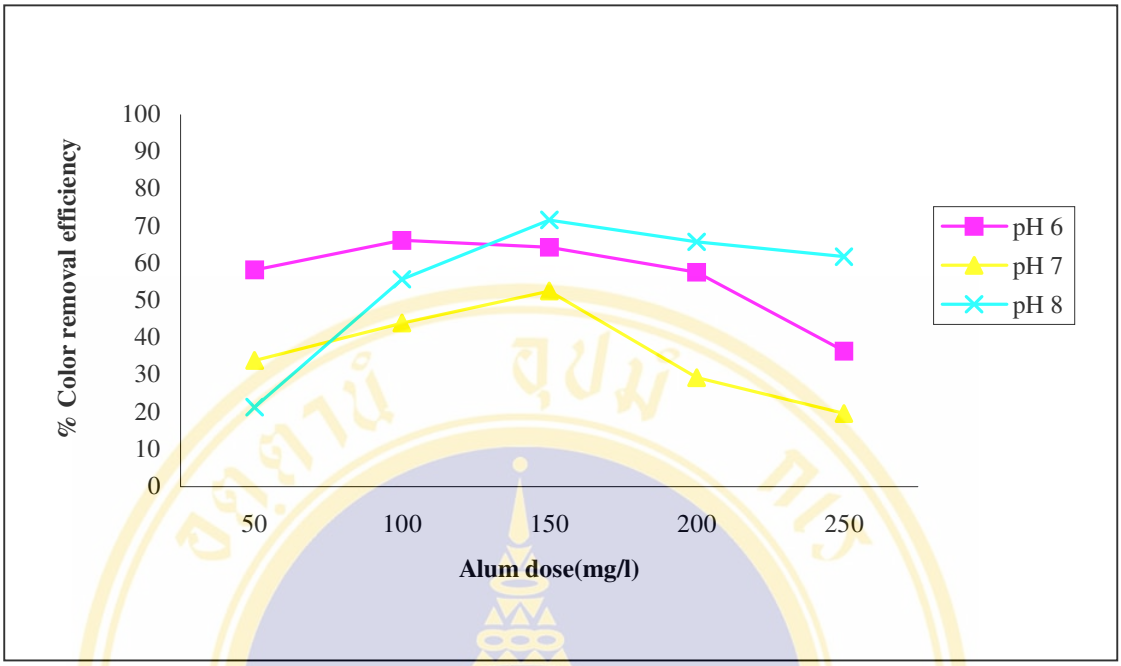

Figure 4-1 Efficiency of Vat dye removal by coagulation using alum

At pH 6.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 58.22, 66.19, 64.44, 57.61, 36.38%, respectively.

At pH 7.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 33.92, 43.94, 52.62, 29.34, 19.63%, respectively.

At pH 8.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 21.48, 55.86, 71.72, 65.74, 61.77%, respectively.

COD removal efficiency

COD removal efficiency of Vat dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-3, as follows:

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Table 4-3 COD removal efficiency of Vat dye after coagulated by alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	COD (mg/l)	COD removal efficiency	COD (mg/l)	COD removal efficiency	COD (mg/l)	COD removal efficiency
50	13.44	86.73	12.65	87.51	12.65	87.51
100	12.54	87.61	14.88	85.30	14.88	85.30
150	13.44	86.73	13.39	86.78	13.39	86.78
200	14.34	85.84	31.25	69.78	31.25	69.14
250	13.39	86.78	35.71	64.73	35.71	64.73

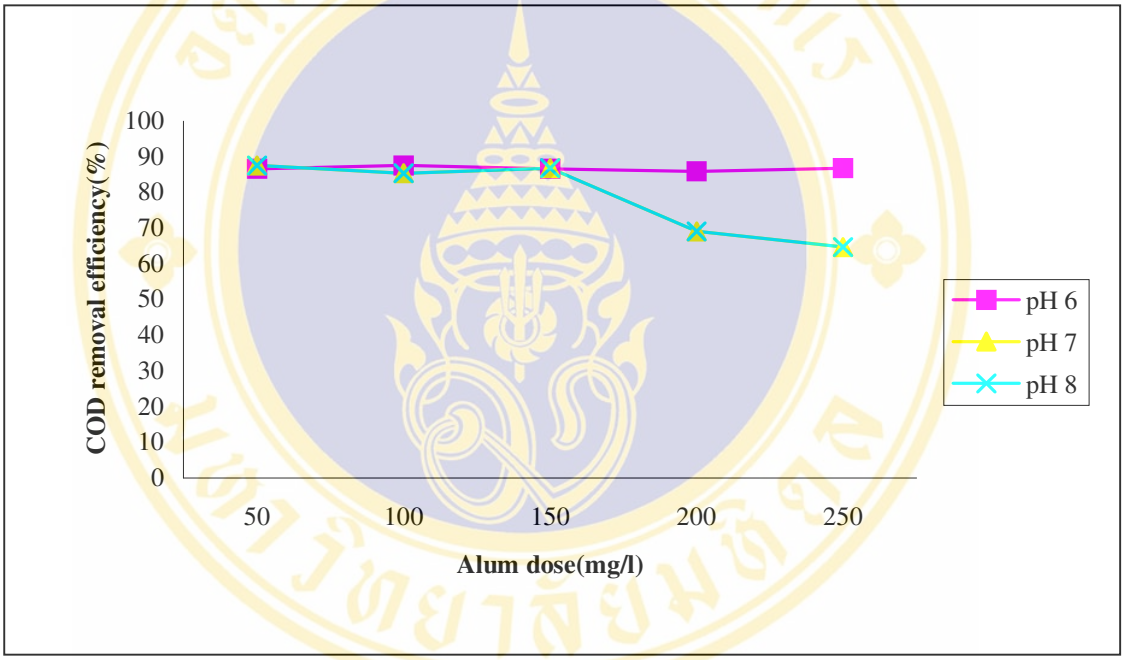

Figure 4-2 COD removal efficiency of Vat dye after it was coagulated by alum

At pH 6.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 86.73, 87.61, 86.73, 85.84, 86.78 %, respectively.

At pH 7.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 87.51, 85.30, 86.78, 69.78, 64.73%, respectively.

At pH 8.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 87.51, 85.30, 86.78, 69.14, 64.73%, respectively.

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SS removal efficiency

SS removal efficiency of Vat dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-4, as follows:

Table 4-4 SS removal efficiency of Vat dye after coagulated by alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	SS (mg/l)	SS removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)
50	8.00	75.98	14.00	57.96	18.00	45.95
100	12.00	63.96	18.00	45.95	10.00	69.97
150	12.00	63.96	18.00	45.95	8.00	75.98
200	14.60	56.16	20.00	39.94	10.00	69.97
250	12.00	63.96	18.00	45.95	10.00	69.97

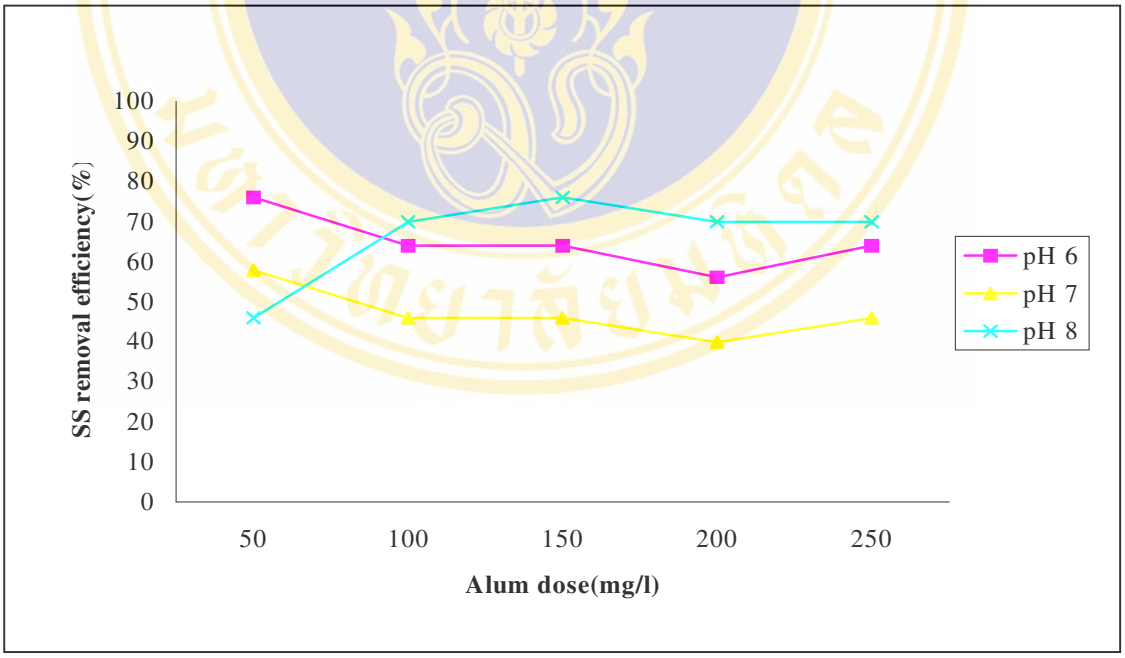

Figure 4-3 SS removal efficiency after Vat dye was coagulated by alum

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At pH 6.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 75.98, 63.96, 63.96, 56.16, 63.96%, respectively.

At pH 7.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 57.96, 45.95, 45.95, 39.94, 45.95%, respectively.

At pH 8.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 45.95, 69.97, 75.98, 69.97, 69.97%, respectively.

Due to important problem of textile wastewater treatment are residual dyes. Therefore the optimum condition of coagulation was selected from highest color removal efficiency. The amount of alum to coagulate substance from Vat dyes was 150 mg/l and pH 8 was appropriate, when the removal efficiency was highest. The color, COD and SS were reduced 71.72%, 86.78% and 75.98%, respectively.

Vat dyes is insoluble, the particle is large and suspend in water. That do not settle out on standing or settle by take along time. Alum can catch Vat dye particle, make it larger and faster to sediment, the color, COD and SS is reduced. Therefore coagulation by alum is a suitable method to remove Vat dyes.

4.2.2 Sulphur Dye

Color removal efficiency

Color removal efficiency of Sulphur dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 200, 250, 300, 350 and 4000 mg/l were presented in table 4-5, as follows:

Table 4-5 Sulphur removal efficiency by coagulation using alum

Alum Dose (mg/l.)	Color removal efficiency (%)		
	pH 6	pH 7	pH 8
200	98.14	99.91	98.91
250	98.44	99.95	98.93
300	98.56	99.88	98.85
350	97.69	99.85	98.78
400	97.51	99.80	98.70

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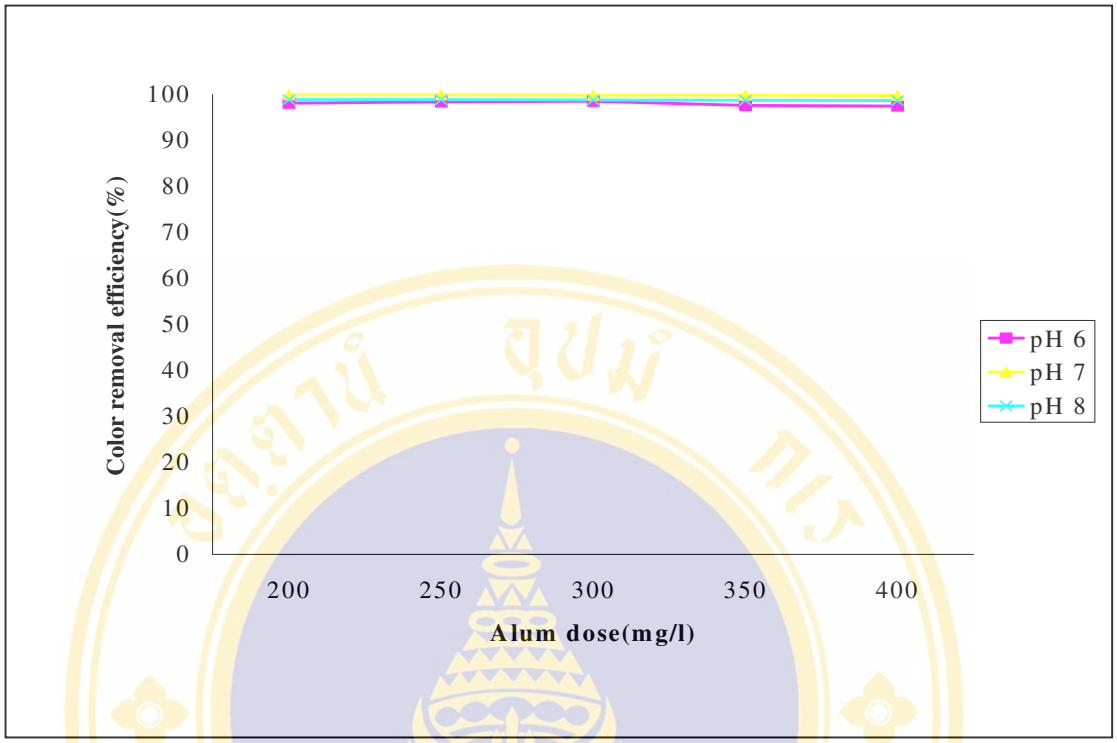

Figure 4-4 Sulphur dye removal efficiency by coagulation using alum

At pH 6.0, the color removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 98.14, 98.44, 98.56, 97.69, 97.51%, respectively.

At pH 7.0, the color removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 99.91, 99.95, 99.88, 99.85, 99.80%, respectively.

At pH 8.0, the color removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 98.91, 98.93, 98.85, 98.78, 98.70%, respectively.

COD removal efficiency

COD removal efficiency of Sulphur dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 200, 250, 300, 350 and 400 mg/l were presented in table 4-6, as follows:

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Table 4-6 COD removal efficiency of Sulphur dye after coagulated by alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	COD (mg/l)	COD removal efficiency (%)	COD (mg/l)	COD removal efficiency (%)	COD (mg/l)	COD removal efficiency (%)
200	86.48	90.00	83.07	90.39	70.04	91.90
250	94.00	89.13	99.97	88.44	82.96	90.41
300	96.26	88.87	98.56	88.60	80.96	90.64
350	94.00	89.13	74.80	91.35	83.07	90.39
400	68.29	92.10	83.64	90.33	79.55	90.80

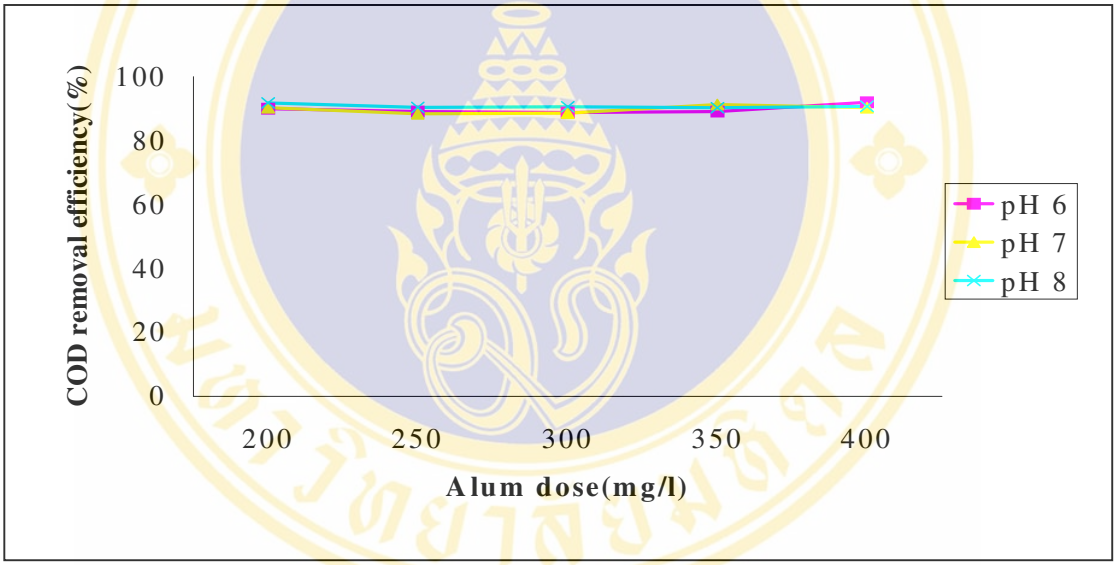

Figure 4-5 COD removal efficiency of Sulphur dye by coagulation using alum

At pH 6.0, the COD removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 90.00, 89.13, 88.87, 89.13, 92.10%, respectively.

At pH 7.0, the COD removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 90.39, 88.44, 88.60, 91.35, 90.33%, respectively.

At pH 8.0, the COD removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 91.90, 90.41, 90.64, 90.39, 90.80%, respectively.

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SS removal efficiency

SS removal efficiency of Sulphur dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 200, 250, 300, 350 and 400 mg/l were presented in table 4-7, as follows:

Table 4-7 SS removal efficiency of Sulphur dye after coagulated by alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	SS (mg/l)	SS removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)
200	6.00	50.00	6.00	50.00	6.00	50.00
250	8.00	33.33	7.00	41.67	6.00	50.00
300	10.00	16.67	10.00	16.67	6.00	50.00
350	6.00	50.00	8.00	33.33	8.00	33.33
400	5.00	58.33	6.00	50.00	8.00	33.33

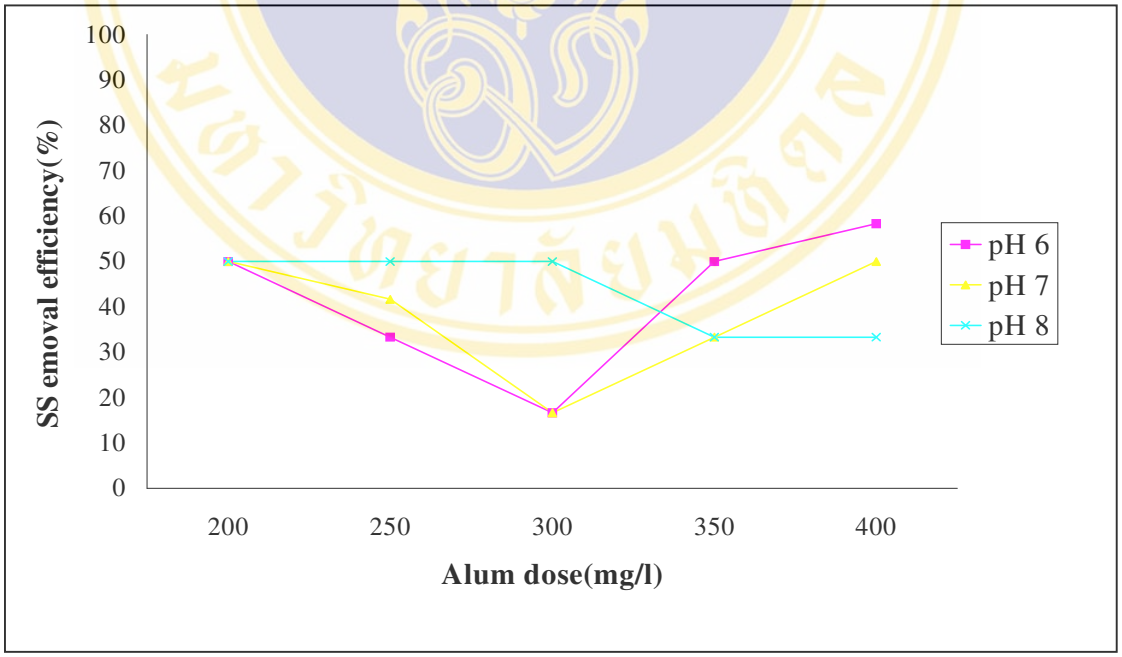

Figure 4-6 SS removal efficiency after dye was coagulated by alum

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At pH 6.0, the SS removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 50.00, 33.33, 16.67, 50.00, 58.33%, respectively.

At pH 7.0, the SS removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 50.00, 41.67, 16.67, 33.33, 50.00%, respectively.

At pH 8.0, the SS removal efficiency for 200, 250, 300, 350 and 400 mg/l Alum's dose were 50.00, 50.00, 50.00, 33.33, 33.33%, respectively.

The amount of alum to coagulate substance from Sulphur Black BR 200 was 250 mg/l and pH 7 was appropriate, when the removal efficiency was highest. The color, SS and COD were reduced 99.95%, 88.44% and 41.67%, respectively.

Sulphur dyes is insoluble, the particle is large and suspend in water like Vat dyes. That do not settle out on standing or settle by take along time. Alum can catch Vat dye particle, make it larger and faster to sediment, the color, COD and SS is reduced. Therefore coagulation by alum is a suitable method to remove Sulphur dyes.

4.2.3 Direct dye

Color removal efficiency

Color removal efficiency of Direct dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-8, as follows:

Table 4-8 Direct dye removal efficiency by coagulation using alum

Alum Dose (mg/l)	Color removal efficiency (%)		
	pH 6	pH 7	pH 8
50	94.44	95.33	96.78
100	96.14	96.86	97.55
150	96.56	97.13	97.39
200	96.69	96.88	97.36
250	96.61	96.51	97.22

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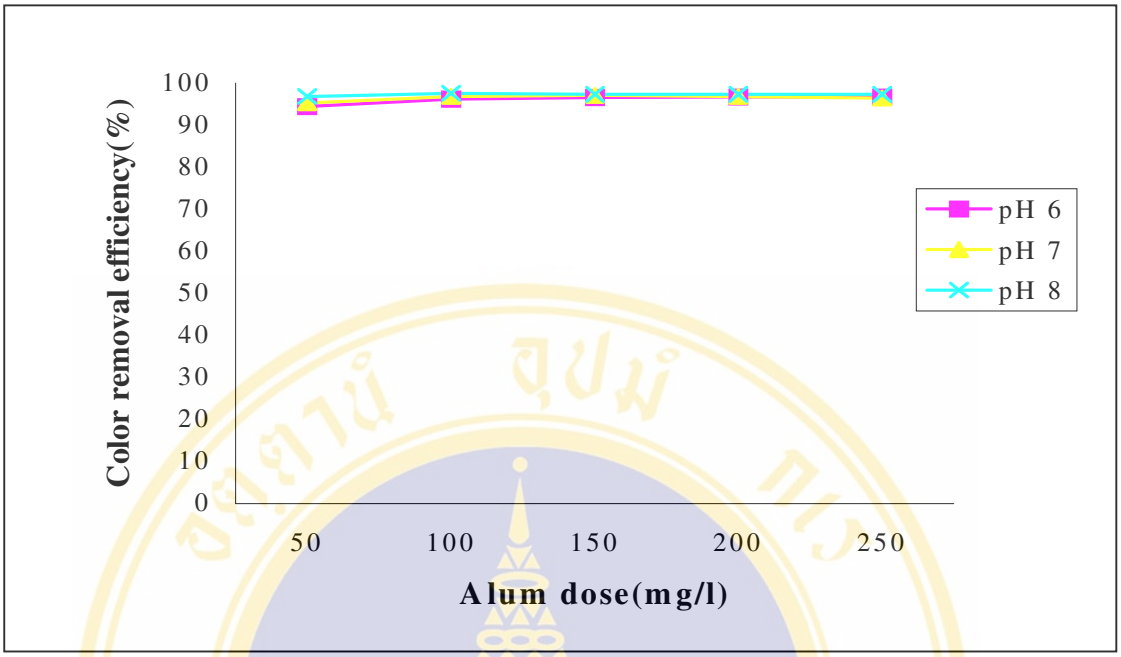

Figure 4-7 Direct dye removal efficiency by coagulation using alum

At pH 6.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 94.44, 96.14, 96.56, 96.69, 96.61%, respectively.

At pH 7.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 95.33, 96.86, 97.13, 96.88, 96.51%, respectively.

At pH 8.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 96.78, 97.55, 97.39, 97.36, 97.22%, respectively.

COD removal efficiency

COD removal efficiency of Direct dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-9, as follows:

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Table 4-9 COD removal efficiency of Direct dye by coagulation using alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	COD (mg/l)	COD removal efficiency (%)	COD (mg/l)	COD removal efficiency (%)	COD (mg/l)	COD removal efficiency (%)
50	7.44	80.00	13.19	64.54	10.44	71.94
100	7.44	80.00	13.97	62.45	2.09	94.38
150	4.46	88.01	18.30	50.81	3.48	90.65
200	4.46	88.01	8.32	77.63	4.87	86.91
250	7.76	79.14	10.82	70.91	5.34	85.65

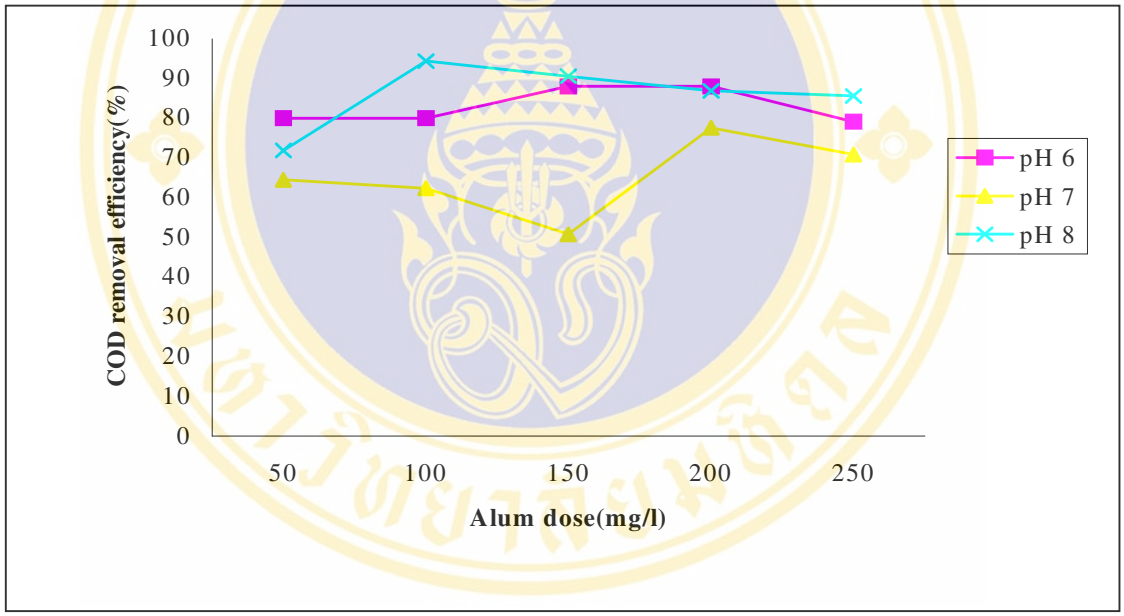

Figure 4-8 COD removal efficiency of Direct dye after coagulated by alum

At pH 6.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 80.00, 80.00, 88.01, 88.01, 79.14%, respectively.

At pH 7.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 64.54, 62.45, 50.81, 77.63, 70.91%, respectively.

At pH 8.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 71.94, 94.38, 90.65, 89.91, 85.65%, respectively.

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SS removal efficiency

SS removal efficiency of Direct dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-10, as follows:

Table 4-10 SS removal efficiency of Direct dye after coagulated by alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	SS (mg/l)	SS removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)
50	4.00	60.00	6.00	40.00	6.00	40.00
100	6.00	40.00	6.00	40.00	3.00	70.00
150	4.00	60.00	6.00	40.00	4.00	60.00
200	4.00	60.00	6.00	40.00	4.00	60.00
250	8.00	20.00	8.00	20.00	6.00	40.00

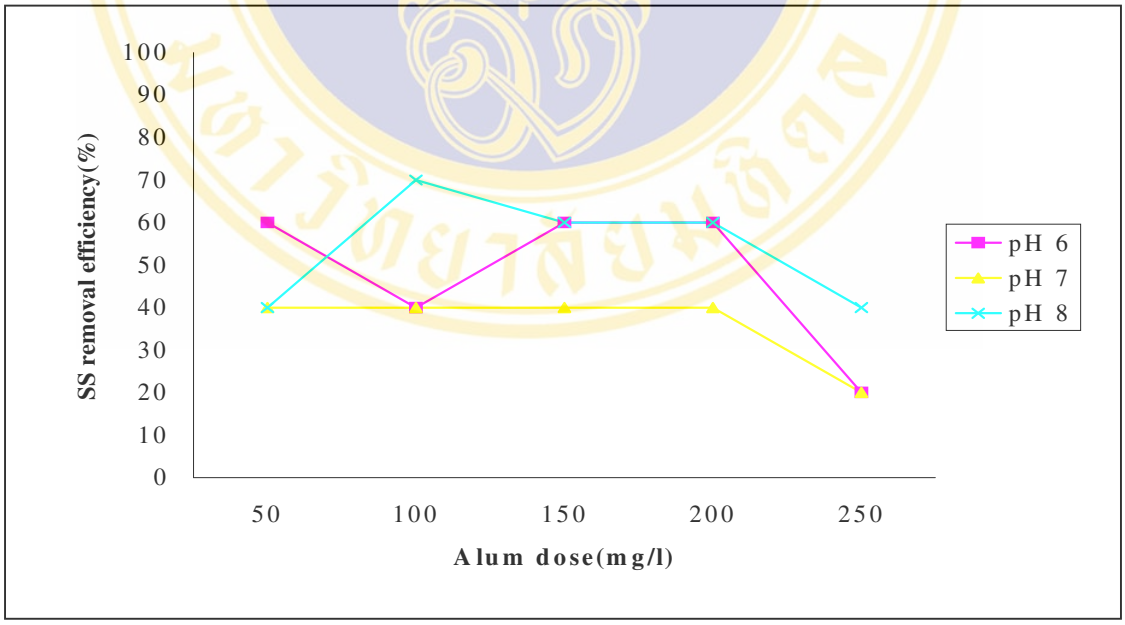

Figure 4-9 SS removal efficiency of Direct dye after coagulated by alum

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At pH 6.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 60.00, 40.00, 60.00, 60.00, 20.00%, respectively.

At pH 7.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 40.00, 40.00, 40.00, 40.00, 20.00%, respectively.

At pH 8.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 40.00, 70.00, 60.00, 60.00, 40.00%, respectively.

The amount of alum to coagulate substance from Direct Kayarus Blue BRL 200 was 100 mg/l and pH 8 was appropriate, when the removal efficiency was highest. The color, SS and COD were reduced 97.55%, 94.38% and 70.00%, respectively.

The particle of Direct dyes is small and soluble. The removal of Direct dyes by coagulation using alum was not satisfied because the sediment was light and did not settle out in limited time. Although the color removal efficiency was 97.55% but the coagulated sample was still objection.

4.2.4 Reactive dye

Color removal efficiency

Color removal efficiency of Reactive dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-11, as follows:

Table 4-11 Reactive dye removal efficiency by coagulated using alum

Alum Dose (mg/l)	Color removal efficiency (%)		
	pH 6	pH 7	pH 8
50	11.82	12.43	15.53
100	35.46	42.54	46.06
150	38.34	45.07	50.24
200	42.64	46.39	50.96
250	41.29	48.27	45.59

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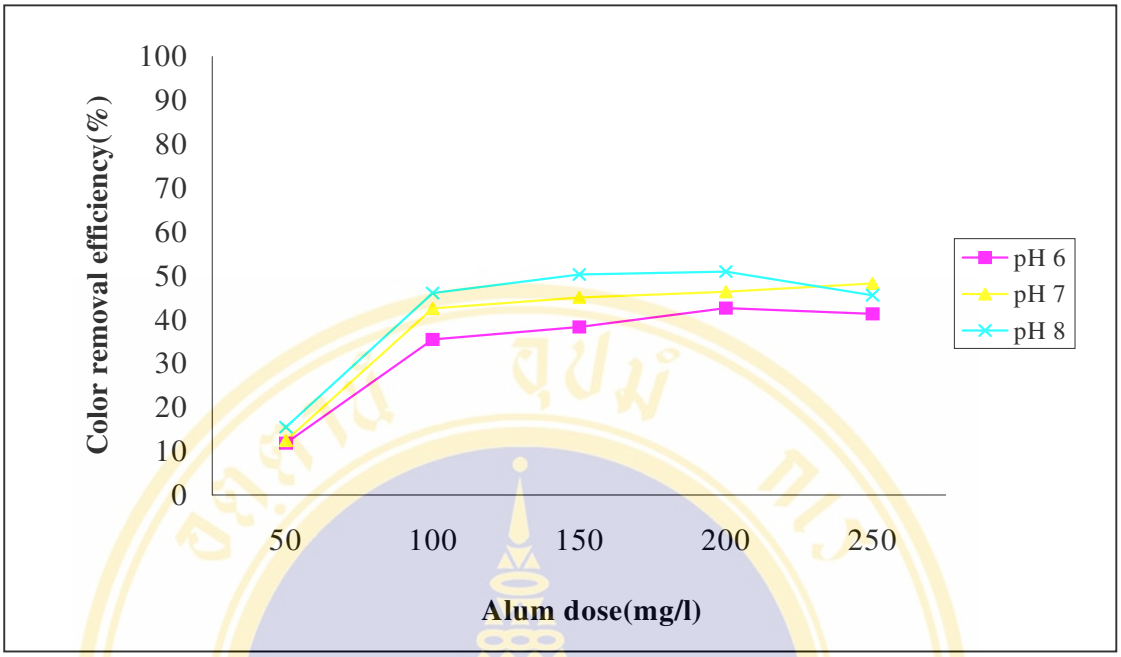

Figure 4-10 Reactive dye removal efficiency by coagulation using alum

At pH 6.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 11.82, 35.46, 38.34, 42.64, 41.29%, respectively.

At pH 7.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 12.43, 42.54, 45.07, 46.39, 48.27%, respectively.

At pH 8.0, the color removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 15.53, 46.06, 50.24, 50.96, 45.59%, respectively.

COD removal efficiency

COD removal efficiency of Reactive dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-12, as follows:

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Table 4-12 COD removal efficiency of Reactive dye after coagulated by alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD removal efficiency (%)
50	51.62	14.68	55.18	8.79	51.62	14.68
100	37.38	38.21	39.16	35.27	34.71	42.63
150	40.94	32.33	35.60	41.16	36.15	40.25
200	44.50	26.45	27.59	54.40	34.71	42.63
250	44.50	26.45	32.93	45.57	35.60	41.16

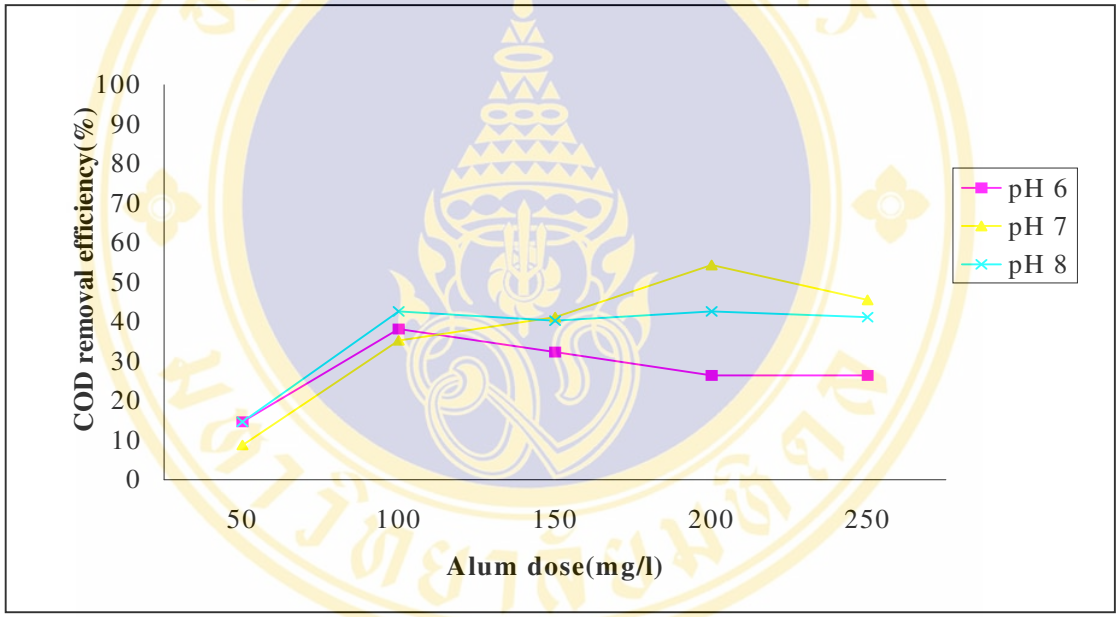

Figure 4-11 COD removal efficiency of Reactive dye after coagulated by alum

At pH 6.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 14.68, 38.21, 32.33, 26.54, 26.54%, respectively.

At pH 7.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 8.79, 35.27, 41.16, 54.40, 45.57%, respectively.

At pH 8.0, the COD removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were 14.68, 42.63, 40.25, 42.63, 41.16%, respectively.

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SS removal efficiency

SS removal efficiency of Reactive dye samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 50, 100, 150, 200 and 250 mg/l were presented in table 4-13, as follows:

Table 4-13 SS removal efficiency of Reactive dye after coagulated by alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)
50	9.00	-350.00	12.00	-500.00	17.00	-750.00
100	8.00	-300.00	10.00	-400.00	7.50	-275.00
150	10.00	-400.00	12.00	-500.00	4.50	-125.00
200	8.00	-300.00	11.00	-450.00	8.50	-325.00
250	8.00	-300.00	8.00	-300.00	8.00	-300.00

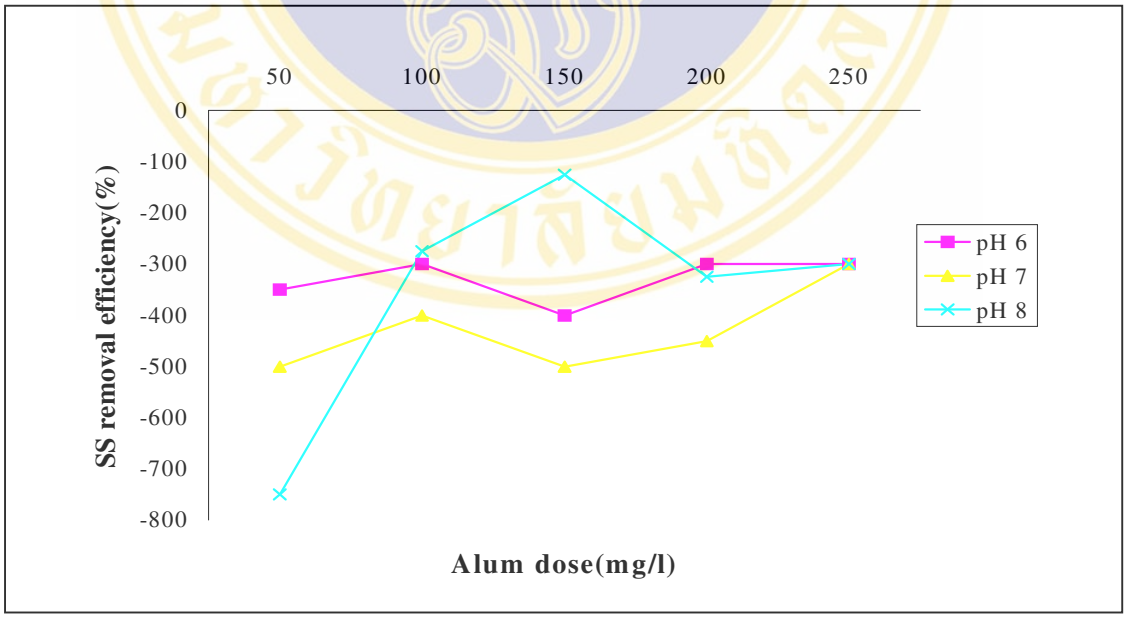

Figure 4-12 SS removal efficiency of Reactive dye after coagulated by alum

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At pH 6.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were -350.00, -300.00, -400.00, -300.00, -300.00%, respectively.

At pH 7.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were -500.00, -400.00, -500.00, -450.00, -300.00%, respectively.

At pH 8.0, the SS removal efficiency for 50, 100, 150, 200, 250 mg/l Alum's dose were -750.00, -275.00, -125.00, -325.00, -300.00%, respectively.

The amount of alum to coagulate substance from Reactive Cibacorn Blue CR was 200 mg/l and pH 8 was appropriate, when the removal efficiency was highest. The color and COD were reduced 50.96% and 42.63%, respectively. But SS increase from 2 mg/l to 8.5 mg/l because the Reactive dyes particle was formed into larger particle, but did not weight enough to settle out. Therefore SS increase from suspend particles.

Reactive dyes is soluble substance, the particle is very small. The sediment from coagulation by alum was light, float and did not settle out. Therefore the efficiency of coagulation was low. The Reactive dyes sample after coagulated was still objection.

4.2.5 Wastewater

Color removal efficiency

Color removal efficiency of wastewater samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 800, 900, 1000, 1100, 1200 and 1300 mg/l were presented in table 4-14, as follows:

Table 4-14 Color removal efficiency of wastewater by coagulation using alum

Alum Dose (mg/l)	Color removal efficiency (%)		
	pH 6	pH 7	pH 8
800	84.27	78.87	76.85
900	85.49	81.48	75.51
1000	86.60	85.23	82.82
1100	85.00	82.24	84.97
1200	87.43	85.24	88.24
1300	86.32	82.94	87.39

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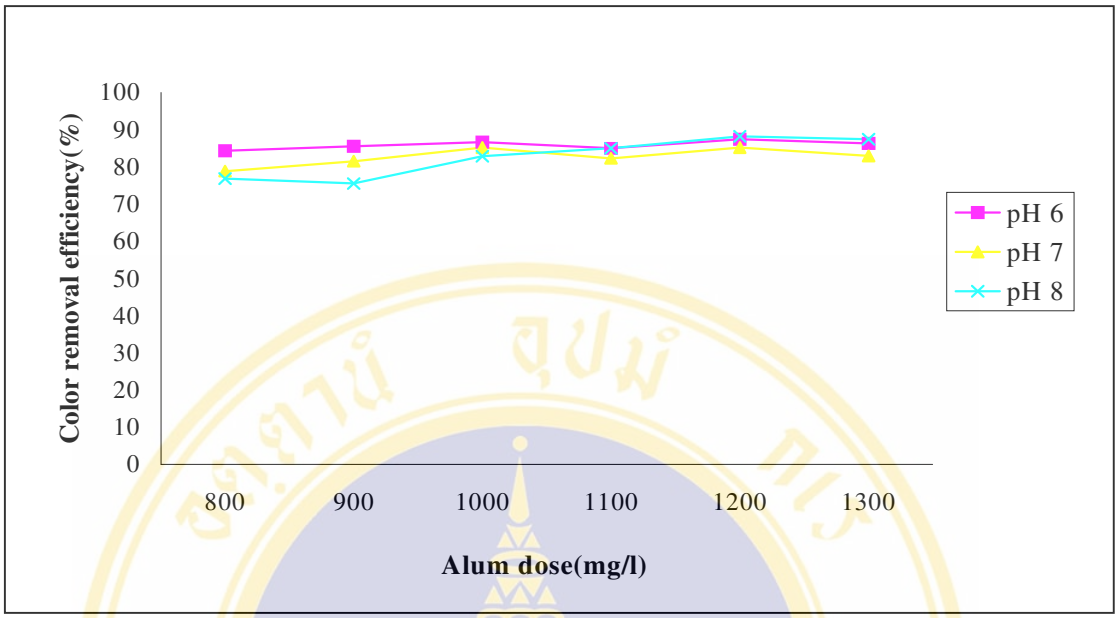

Figure 4-13 Color removal efficiency of wastewater by coagulation using alum

At pH 6.0, the color removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 84.27, 85.49, 86.60, 85.00, 87.43, 86.32%, respectively.

At pH 7.0, the color removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 78.87, 81.48, 85.23, 82.24, 85.24, 82.94%, respectively.

At pH 8.0, the color removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 76.85, 75.51, 82.82, 84.97, 88.24, 87.39%, respectively.

COD removal efficiency

COD removal efficiency of wastewater samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose -- 800, 900, 1000, 1100, 1200 and 1300 mg/l were presented in table 4-15, as follows:

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Table 4-15 COD removal efficiency of wastewater by coagulation using alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD removal efficiency (%)
800	136.00	92.16	152.00	91.74	151.20	91.78
900	132.00	92.83	136.00	92.61	138.40	92.48
1000	160.00	91.30	130.40	92.91	136.00	92.61
1100	124.00	93.26	137.60	92.52	131.20	92.87
1200	124.00	93.26	128.00	93.04	114.40	93.78
1300	132.00	92.83	134.40	92.70	117.60	93.61

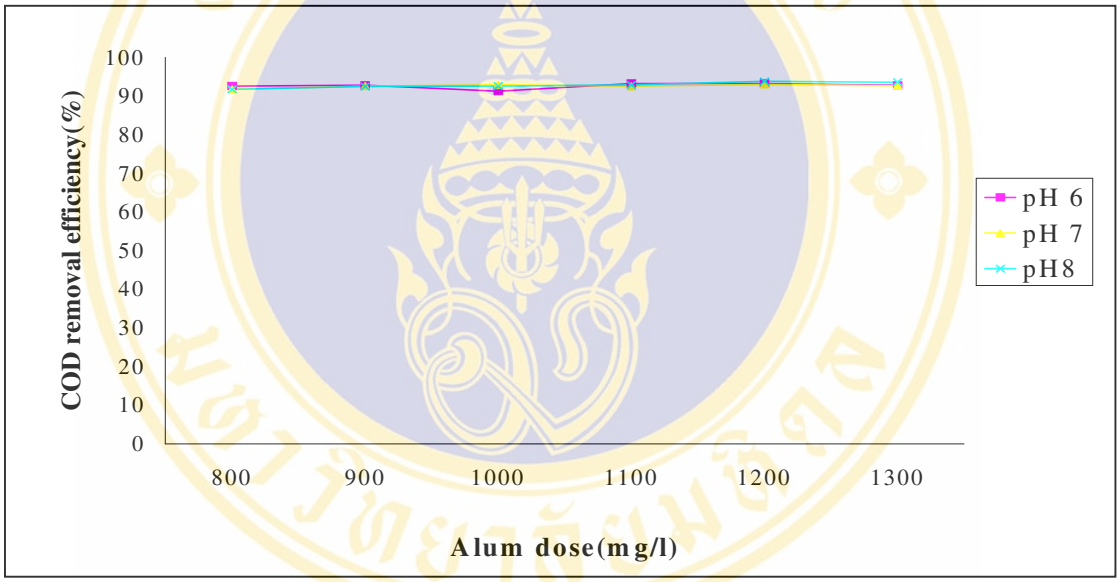

Figure 4-14 COD removal efficiency of wastewater by coagulation using alum

At pH 6.0, the COD removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 92.16, 92.83, 91.30, 93.26, 93.26, 92.83%, respectively.

At pH 7.0, the COD removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 91.74, 92.61, 92.91, 92.52, 93.04, 92.70%, respectively.

At pH 8.0, the COD removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 91.78, 92.48, 92.61, 92.87, 93.78, 93.61%, respectively.

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SS removal efficiency

SS removal efficiency of wastewater samples by coagulation method with various pH - - 6.0, 7.0, 8.0 - - and Alum's dose - - 800, 900, 1000, 1100, 1200 and 1300 mg/l were presented in table 4-16, as follows:

Table 4-16 SS removal efficiency of wastewater by coagulation using alum

Alum Dose (mg/l)	pH 6		pH 7		pH 8	
	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS removal efficiency (%)
800	77.0	90.94	74.0	91.29	124.0	85.41
900	95.0	88.82	74.0	91.29	111.0	86.94
1000	91.0	98.29	57.0	93.29	112.0	86.82
1100	65.0	92.35	106.0	87.53	77.0	90.94
1200	60.0	92.94	100.0	88.24	70.0	91.76
1300	65.0	92.35	110.0	87.06	75.0	91.18

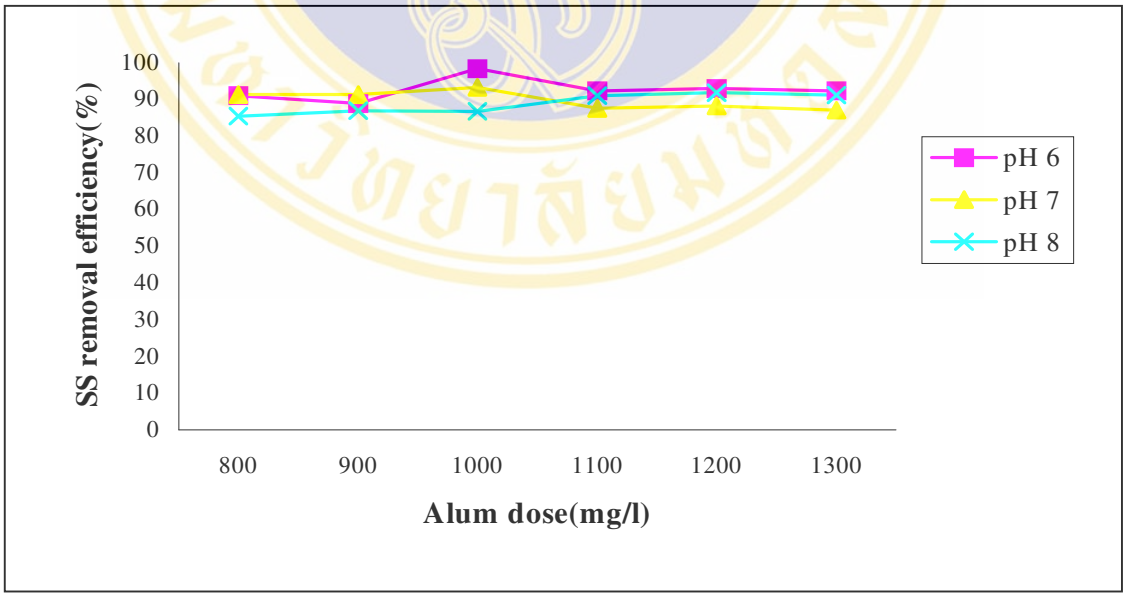

Figure 4-15 SS removal efficiency of wastewater by coagulation using alum

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At pH 6.0, the SS removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 90.94, 88.82, 89.29, 92.35, 92.94, 92.35%, respectively.

At pH 7.0, the SS removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 91.29, 91.29, 93.29, 87.53, 88.24, 87.06%, respectively.

At pH 8.0, the SS removal efficiency for 800, 900, 1000, 1100, 1200, 1300 mg/l Alum's dose were 85.41, 86.94, 86.82, 90.94, 91.76, 91.18%, respectively.

The amount of alum to coagulate substance from wastewater was 1200 mg/l and pH 8 was appropriate, when the removal efficiency was highest. The color, COD and SS were reduced 88.24%, 93.78% and 91.76%, respectively.

Wastewater from storage pond of cotton dyeing factory (Jib Hua Cheang Jun co.ltd.) is composed of 70% of soluble dyes, 30% of insoluble dyes, additive and starch. After coagulated, the sediment was light, float and did not settle out. The coagulated wastewater was still objection even if the color was reduced 82.24%.

4.3 The Optimum of alum's dose and suspension from tamarind-kernel powder

The optimum of pH from first part was fixed, the optimum dosage of alum was reduced in different ratio (100%, 75%, 50% and 25%) and was used with various of suspension from tamarind-kernel powder (1, 3 and 5 mg/l) The results were presented as followss:

4.3.1 Vat dye

Color removal efficiency

Color removal efficiency of Vat dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 150.0, 112.5, 75.0 and 37.5 mg/l were presented in table 4-17, as follows:

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Table 4-17 Vat dye removal efficiency after coagulated by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)			
	0.0	**1.0**	**3.0**	**5.0**
150.0	71.72	74.51	71.22	67.99
112.5	-	71.38	67.99	61.25
75.0	-	71.79	67.01	60.69
37.5	-	71.17	66.50	60.33

Remark : " - " mean Not include in this study

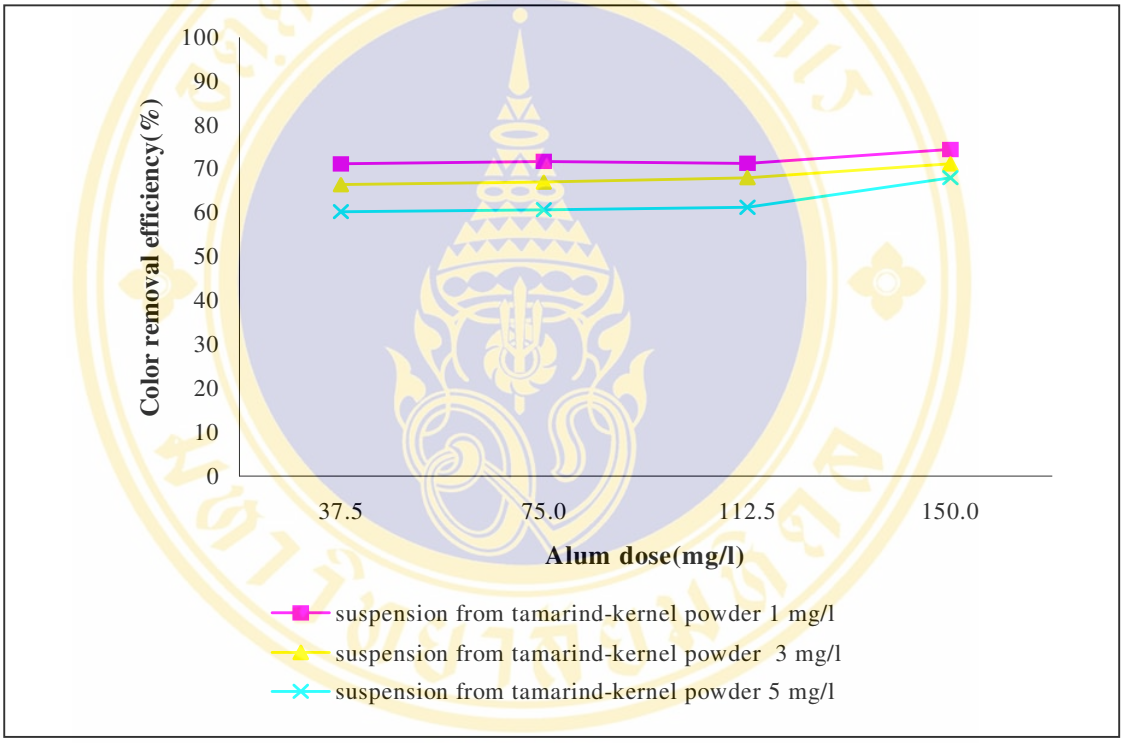

Figure 4-16 Vat dye removal efficiency after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 74.51, 71.38, 71.79, 71.17%, respectively.

At 3.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 71.22, 67.99, 67.01, 66.50%, respectively.

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At 5.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 67.99, 61.25, 60.69, 60.33%, respectively.

COD removal efficiency

COD removal efficiency of Vat dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 150.0, 112.5, 75.0 and 37.5 mg/l were presented in table 4-18, as follows:

Table 4-18 COD removal efficiency of Vat dye after coagulated by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)
150.0	13.39	86.78	14.08	86.09	22.78	77.50	25.63	74.69
112.5	-	-	13.53	86.64	23.14	77.15	26.34	73.99
75.0	-	-	13.24	86.92	23.14	77.15	24.21	76.09
37.5	-	-	14.95	85.23	22.78	77.50	24.65	75.65

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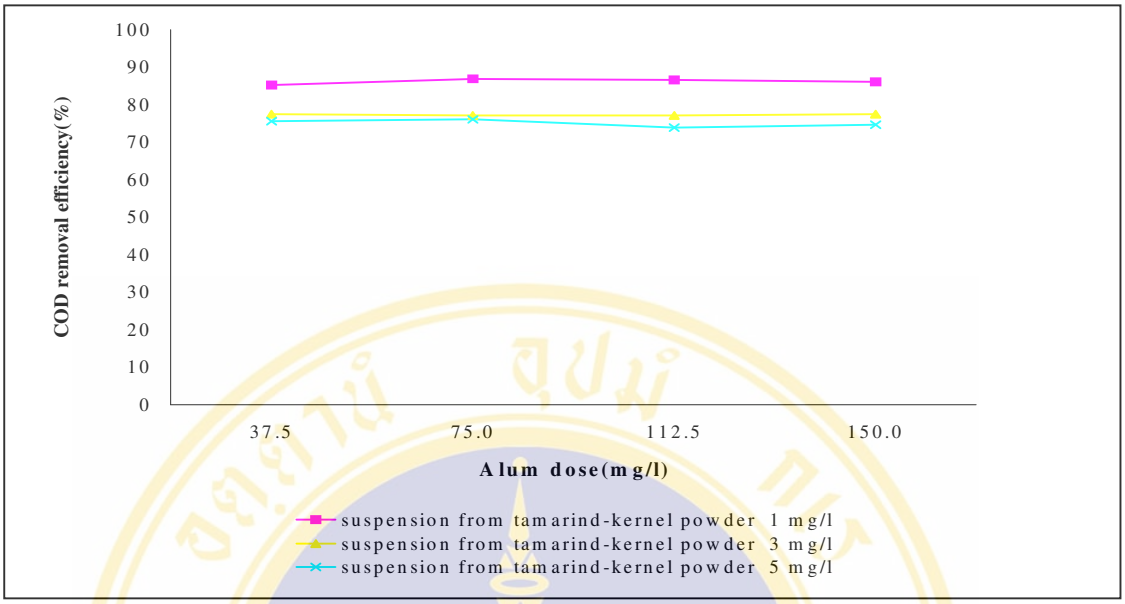

Figure 4-17 COD removal efficiency of Vat dye after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 86.09, 86.64, 86.92, 85.23%, respectively.

At 3.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 77.50, 77.15, 77.15, 77.50%, respectively.

At 5.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 74.69, 73.99, 76.09, 75.65%, respectively.

SS removal efficiency

SS removal efficiency of Vat dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 150.0, 112.5, 75.0, 37.5 mg/l were presented in table 4-19, as follows:

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Table 4-19 SS removal efficiency of Vat dye after coagulated by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)
150.0	8.00	75.98	11.00	66.97	13.50	59.46	11.50	65.47
112.5	-	-	12.50	62.46	12.00	63.96	11.50	65.47
75.0	-	-	13.00	60.96	13.50	59.46	14.00	57.96
37.5	-	-	18.00	45.95	20.00	39.94	21.50	35.44

Remark : " - " mean Not include in this study

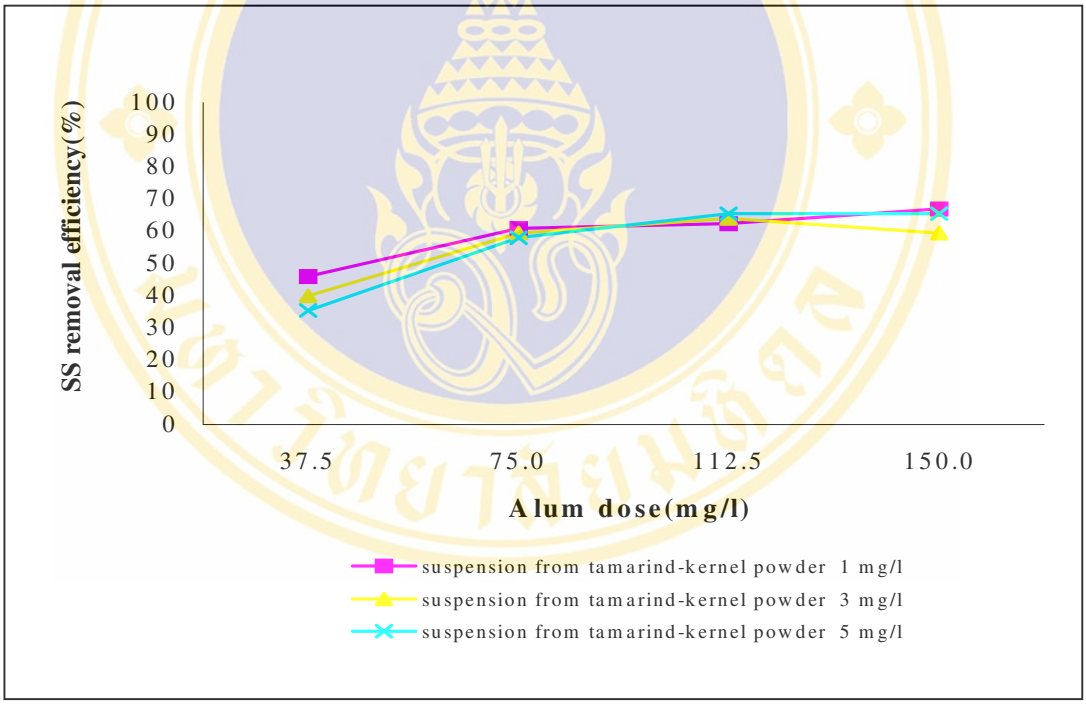

Figure 4-18 SS removal efficiency of Vat dye after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 66.97, 62.46, 60.96, 45.95%, respectively.

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At 3.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 59.46, 63.96, 59.46, 39.94%, respectively.

At 5.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 150.0, 112.5, 75.0 and 37.5 mg/l of Alum's dose were 65.47, 65.47, 57.96, 35.44%, respectively.

When using tamarind-kernel powder suspension 1 mg/l with alum, even if alum was reduced 50% the removal efficiency of Vat dyes was similar to using only alum. The color, COD and SS were reduced 71.79%, 86.92% and 60.96%, respectively.

4.3.2 Sulphur Dye

Color removal efficiency

Color removal efficiency of Sulphur dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 250.0, 187.5, 125.0 and 62.5 mg/l were presented in table 4-20, as follows:

Table 4-20 Sulphur dye removal efficiency by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)			
	0.0	**1.0**	**3.0**	**5.0**
250.0	99.95	99.90	99.97	99.95
187.5	-	99.90	99.95	99.95
125.0	-	99.92	99.93	99.95
62.5	-	45.33	44.37	43.18

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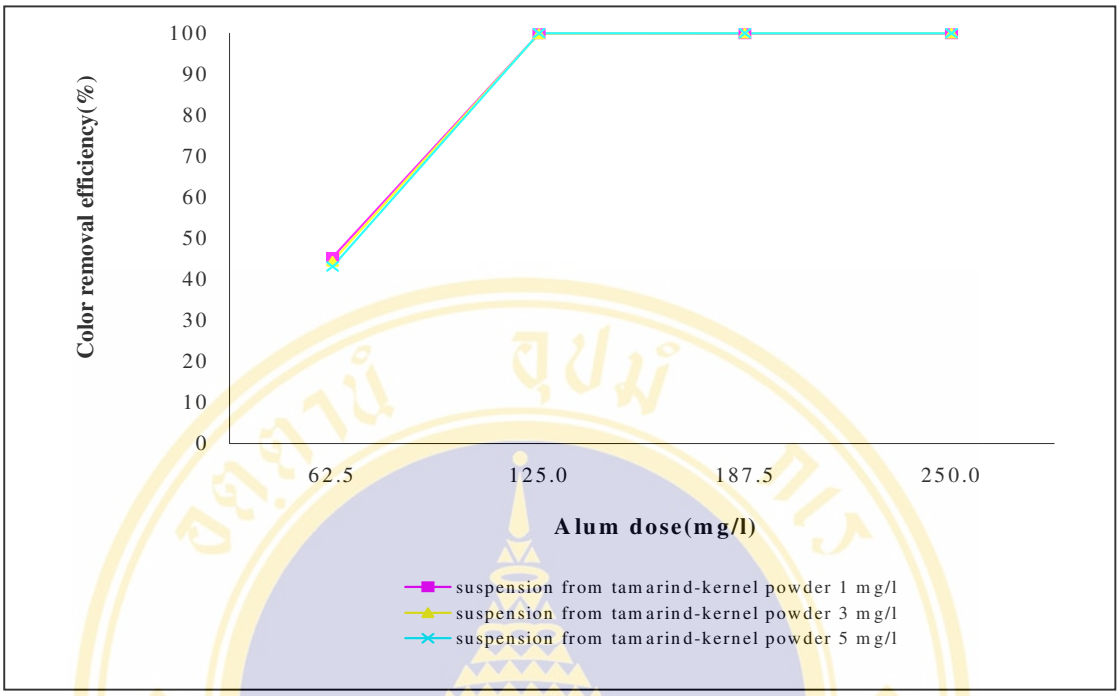

Figure 4-19 Sulphur dye removal efficiency by suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 99.90, 99.90, 99.92, 45.33%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 99.97, 99.95, 99.93, 44.37%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 99.95, 99.95, 99.95, 43.18%, respectively

COD removal efficiency

COD removal efficiency of Sulphur dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 250.0, 187.5, 125.0 and 62.5 mg/l were presented in table 4-21, as follows:

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Table 4-21 COD removal efficiency of Sulphur dye by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)
250.0	99.97	88.44	75.14	91.31	87.05	89.93	82.58	90.45
187.5	-	-	85.56	90.11	93.74	89.16	80.35	90.71
125.0	-	-	92.26	89.33	89.28	89.68	87.05	89.93
62.5	-	-	372.00	56.98	334.80	61.29	461.28	46.66

Remark : " - " mean Not include in this study

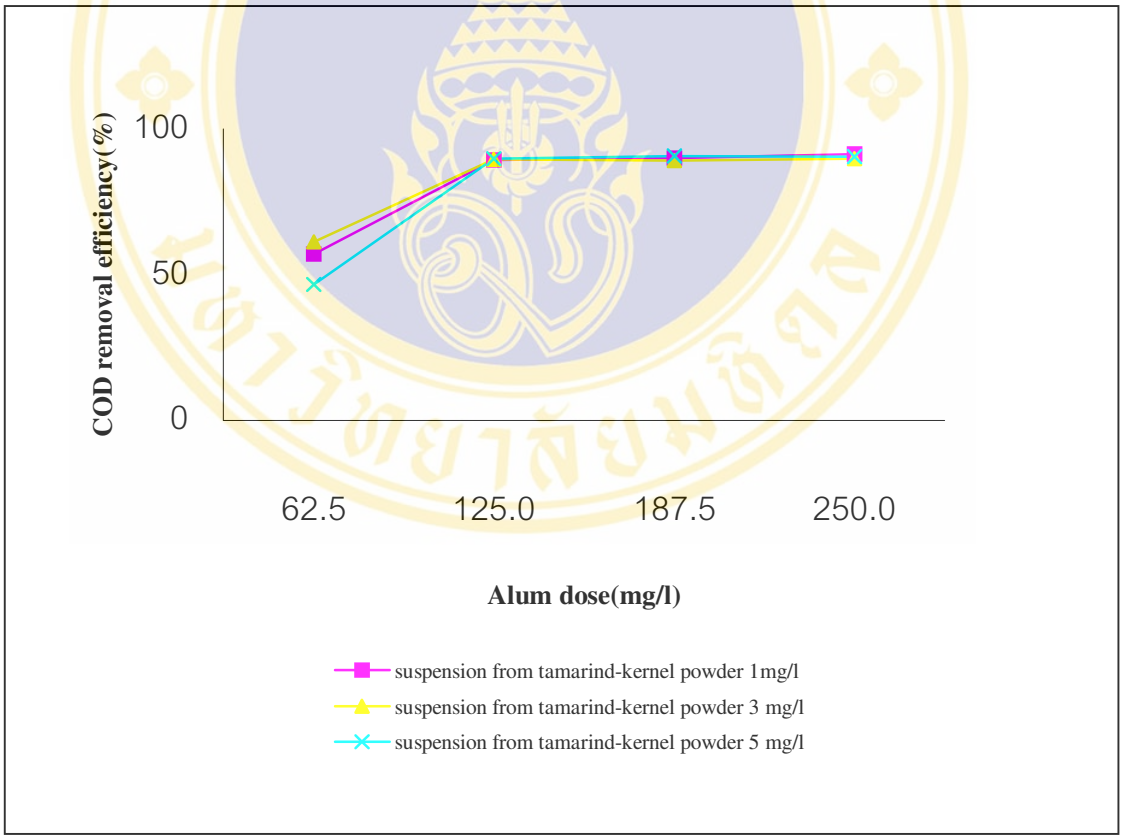

Figure 4-20 COD removal efficiency of Sulphur dye after coagulated by alum and suspension from tamarind-kernel powder

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At 1.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 91.31, 90.11, 89.33, 56.98%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 89.93, 89.16, 89.68, 61.29%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 90.45, 90.71, 89.93, 46.66%, respectively

SS removal efficiency

SS removal efficiency of Sulphur dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 250.0, 187.5, 125.0 and 62.5 mg/l were presented in table 4-22, as follows:

Table 4-22 SS removal efficiency of Sulphur dye by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)
250.0	7.00	41.67	4.00	66.67	4.00	66.67	4.50	62.50
187.5	-	-	3.00	75.00	4.50	62.50	3.50	70.83
125.0	-	-	3.50	70.83	3.00	75.00	3.00	75.00
62.5	-	-	7.50	37.50	6.00	50.00	11.50	4.17

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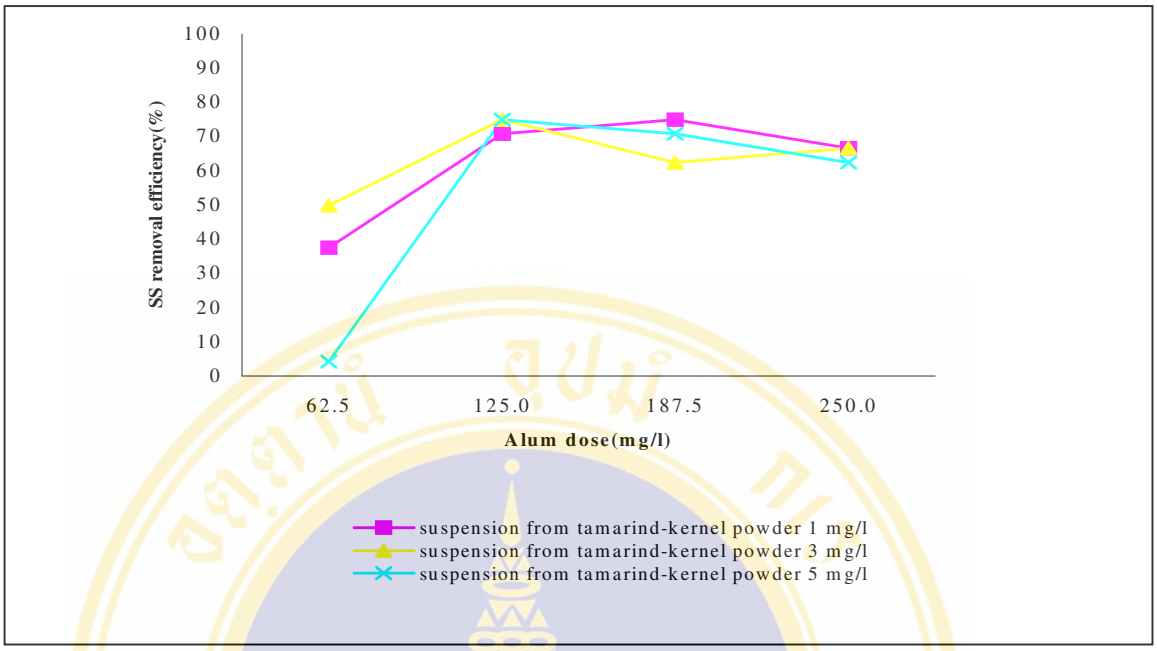

Figure 4-21 SS removal efficiency of Sulphur dye after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 66.67, 75.00, 70.83, 37.50%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 66.67, 62.50, 75.00, 50.00%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 250.0, 187.5, 125.0 and 62.5 mg/l of Alum's dose were 62.50, 70.83, 75.00, 4.17%, respectively

When using tamarind-kernel powder suspension 5 mg/l with alum, even if alum was reduced 50% the removal efficiency of Sulphur dyes was similar to using only alum. The color, COD and SS were reduced 99.95%, 89.93% and 75.0%, respectively.

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4.3.3 Direct dye

Color removal efficiency

Color removal efficiency of Direct dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 1 00, 75, 50 and 25 mg/l were presented in table 4-23, as follows:

Table 4-23 Direct dye removal efficiency by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)			
	0.0	**1.0**	**3.0**	**5.0**
100.0	97.55	97.15	97.03	96.62
75.0	-	96.94	96.27	96.20
50.0	-	96.91	96.13	95.72
25.0	-	75.62	64.08	64.17

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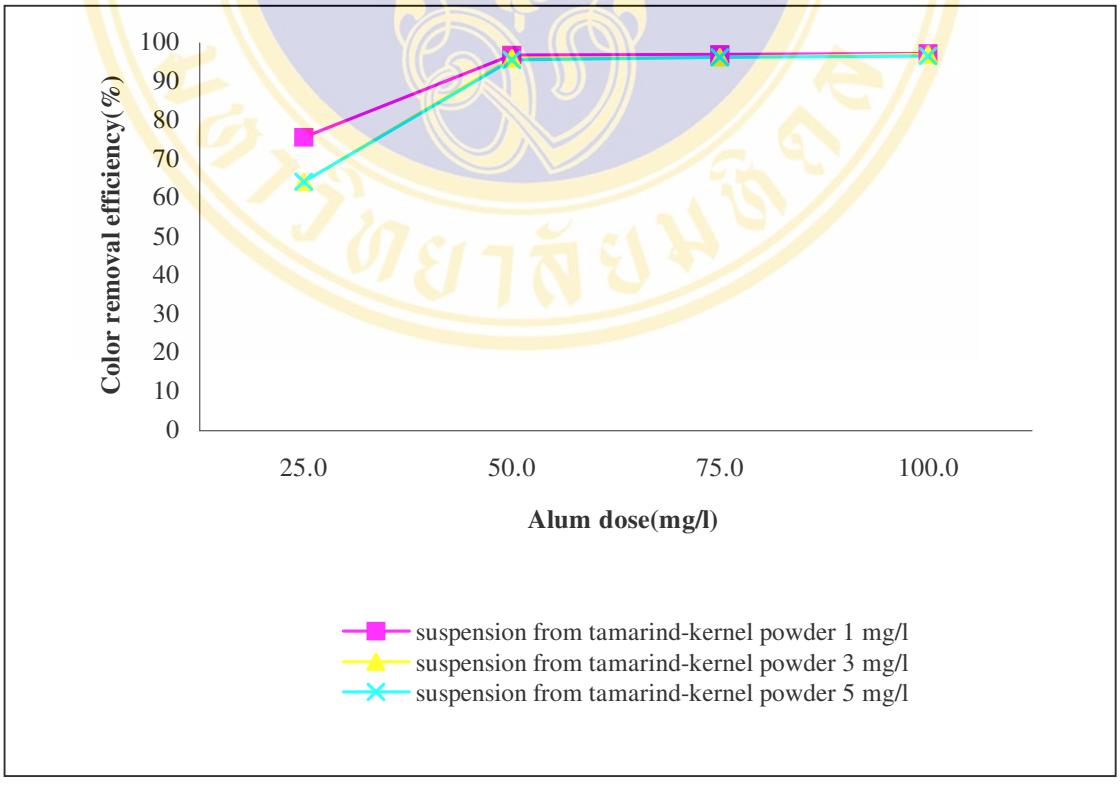

Figure 4-22 Direct dye removal efficiency by alum and suspension from tamarind-kernel powder

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At 1.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 97.15, 96.94, 96.91, 75.62%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 97.03, 96.27, 96.13, 64.08%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 96.62, 96.20, 95.72, 64.17%, respectively

COD removal efficiency

COD removal efficiency of Direct dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 1 00, 75, 50 and 25 mg/l were presented in table 4-24, as follows:

Table 4-24 COD removal efficiency of Direct dye after coagulated by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)
100.0	2.09	94.38	1.42	96.18	8.54	77.04	2.49	93.31
75.0	-	-	0.71	98.09	3.56	90.43	4.98	86.61
50.0	-	-	3.56	90.43	2.85	92.34	3.56	90.43
25.0	-	-	19.22	48.33	27.40	26.34	31.33	15.78

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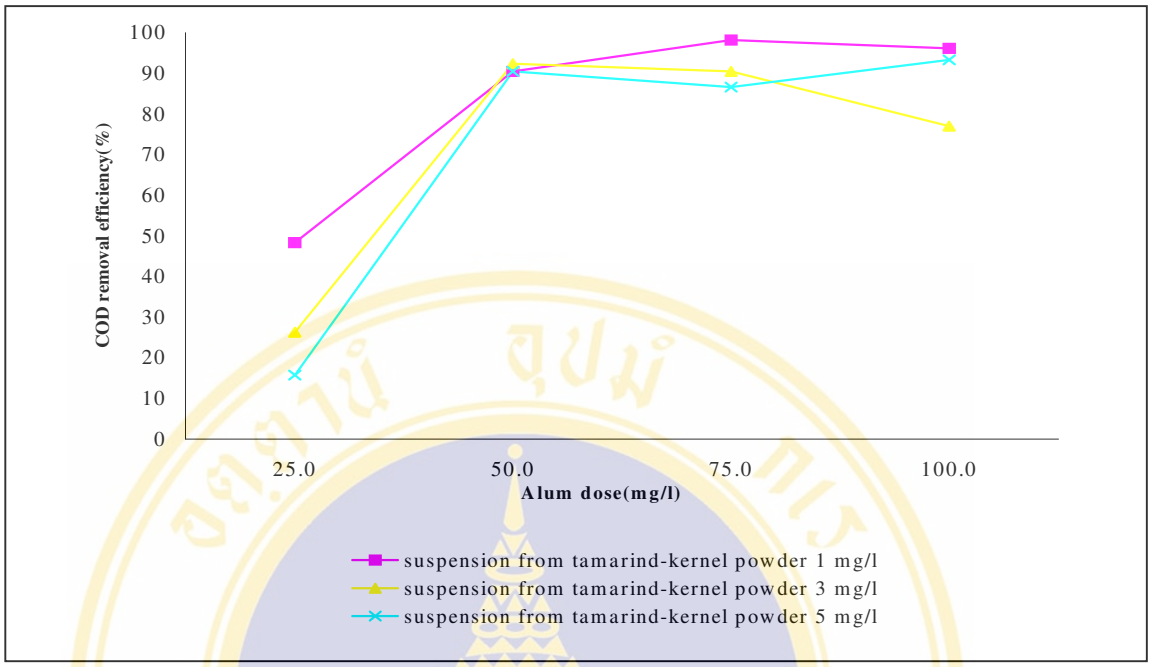

Figure 4-23 COD removal efficiency of Direct dye after coagulated by suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 96.18, 98.09, 90.43, 48.33%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 77.04, 90.43, 92.34, 26.34%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 93.31, 86.61, 90.43, 15.78%, respectively

SS removal efficiency

SS removal efficiency of Direct dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 1 00, 75, 50 and 25 mg/l were presented in table 4-25, as follows:

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Table 4-25 SS removal efficiency of Direct dye after coagulated by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)
100.0	3.00	70.00	5.00	50.00	3.50	65.00	3.00	70.00
75.0	-	-	4.50	55.00	3.00	70.00	2.50	75.00
50.0	-	-	4.50	65.00	2.00	80.00	3.00	70.00
25.0	-	-	16.00	-60.00	20.00	-100.00	25.00	-150.00

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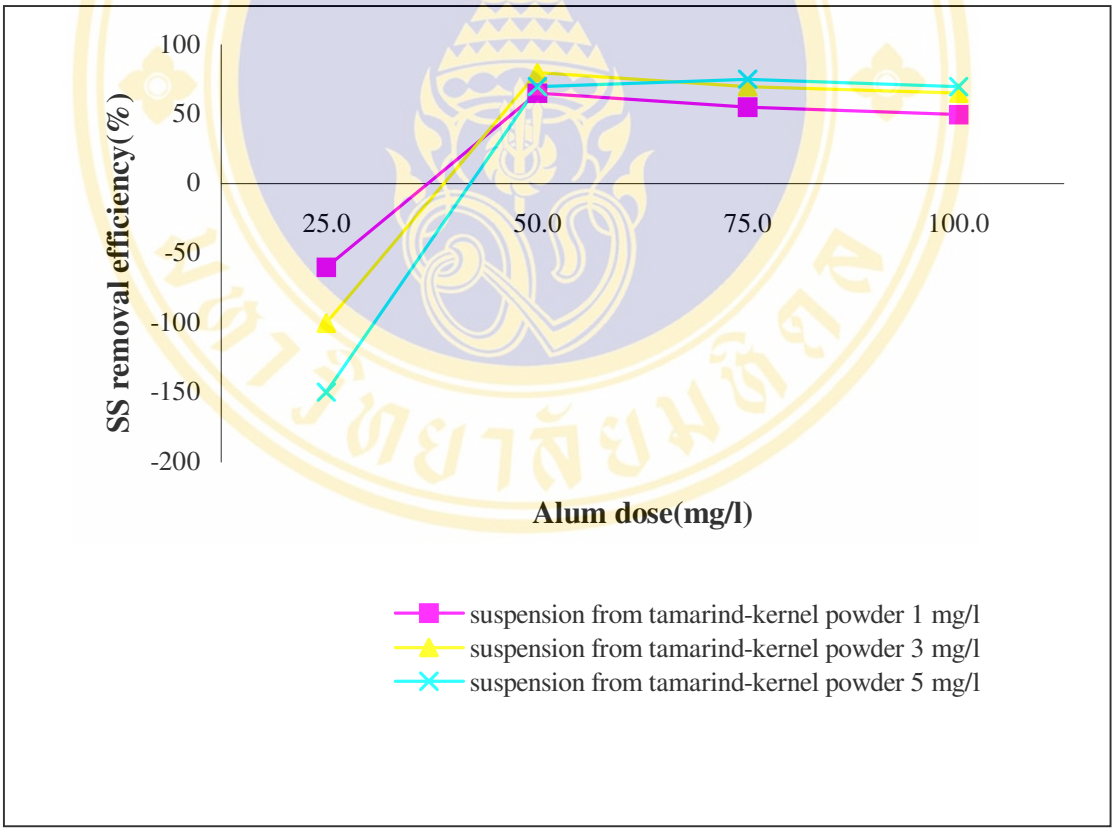

Figure 4-24 SS removal efficiency of Direct dye after coagulated by alum and suspension from tamarind-kernel powder

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At 1.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 50.00, 55.00, 65.00, -60.00%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 65.00, 70.00, 80.00, -100.00%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 100, 75, 50 and 25 mg/l of Alum's dose were 70.00, 75.00, 70.00, -150.00%, respectively

When using tamarind-kernel powder suspension 1 mg/l with alum, even if alum was reduced 50% the removal efficiency of Direct dyes was similar to using only alum. The color, COD and SS were reduced 96.91%, 90.43% and 65.0%, respectively.

4.3.4 Reactive dye

Color removal efficiency

Color removal efficiency of Reactive dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 200, 150, 100 and 50 mg/l were presented in table 4-26, as follows:

Table 4-26 Reactive dye removal efficiency by alum suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)			
	0.0	**1.0**	**3.0**	**5.0**
200.0	50.96	56.70	57.99	62.71
150.0	-	57.68	61.04	62.36
100.0	-	53.44	57.24	58.01
50.0	-	21.06	24.12	23.16

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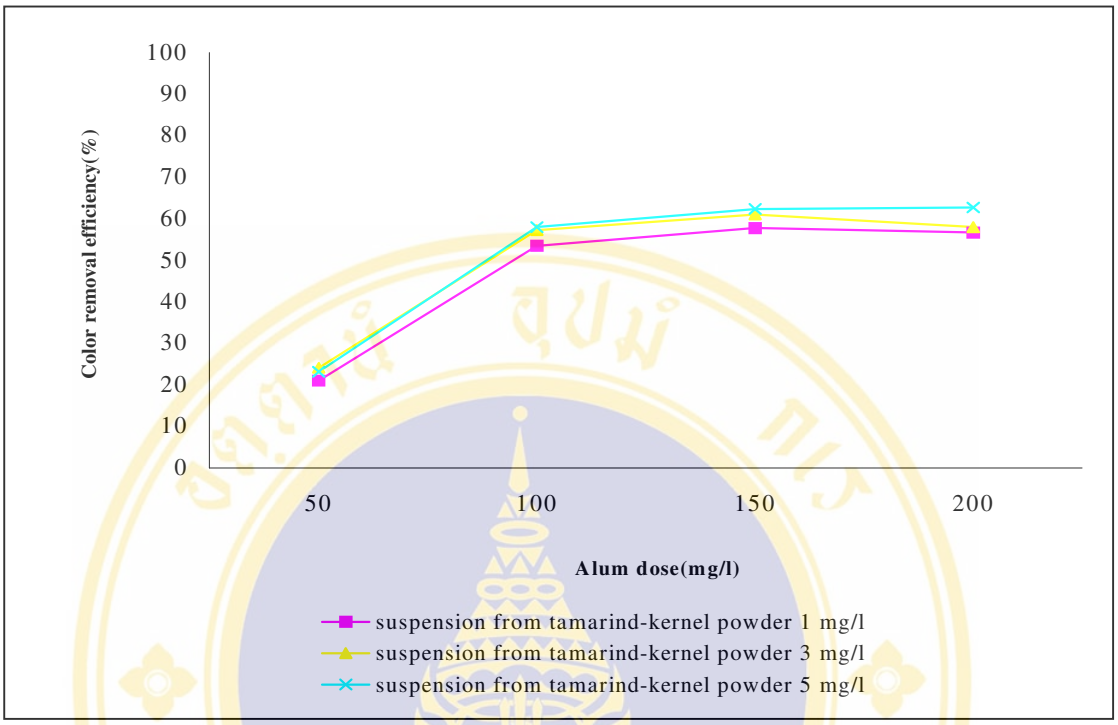

Figure 4-25 Reactive dye removal efficiency by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were 56.70, 57.68, 53.44, 21.06%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were 57.99, 61.04, 57.24, 24.21%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were 62.71, 62.36, 58.01, 23.16%, respectively

COD removal efficiency

COD removal efficiency of Reactive dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 200, 150, 100 and 50 mg/l were presented in table 4-27, as follows:

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Table 4-27 COD removal efficiency of Reactive dye after alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)
200.0	34.71	42.63	25.61	57.67	25.61	57.67	25.22	58.31
150.0	-	-	21.73	64.08	21.73	64.08	20.95	65.37
100.0	-	-	23.28	61.52	27.16	55.11	21.73	64.08
50.0	-	-	52.38	13.42	58.20	3.80	50.44	16.63

Remark : " - " mean Not include in this study

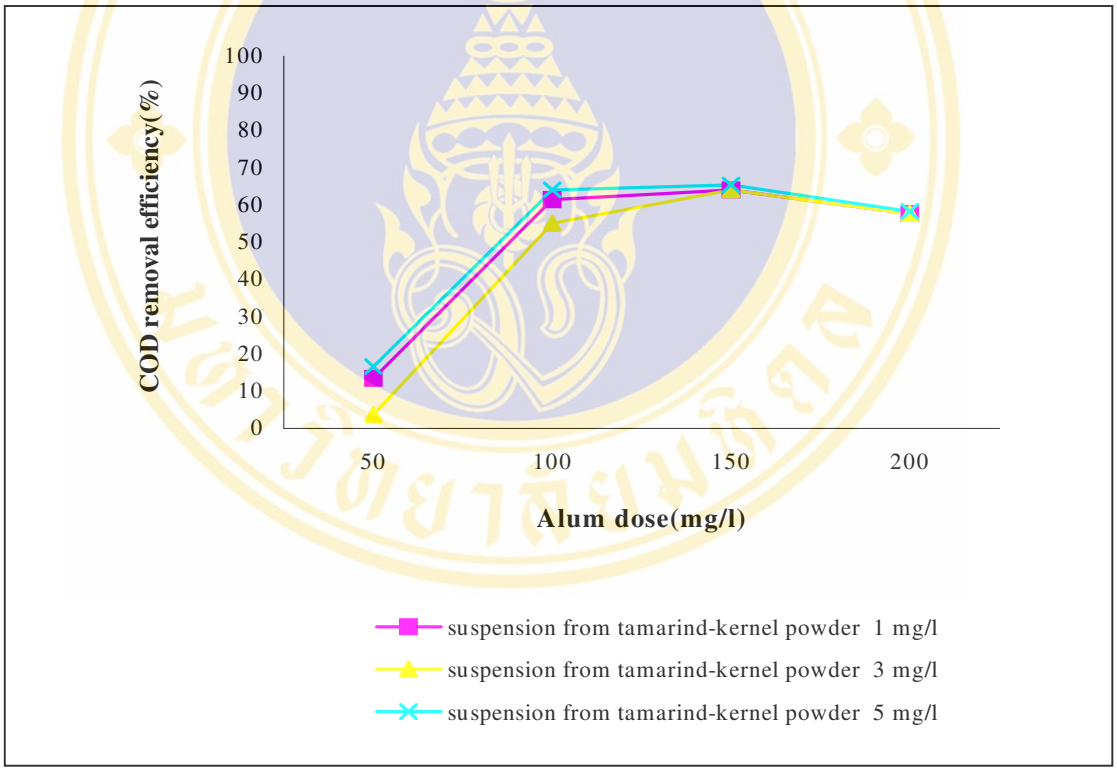

Figure 4-26 COD removal efficiency of Reactive dye after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were 57.67, 64.08, 61.52, 13.42%, respectively

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At 3.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were 57.67, 64.08, 55.11, 3.80%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were 58.31, 65.37, 64.08, 16.63%, respectively

SS removal efficiency

SS removal efficiency of Reactive dye samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 200, 150, 100 and 50 mg/l were presented in table 4-28, as follows:

Table 4-28 SS removal efficiency of Reactive dye after alum suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)
200.0	8.50	-325.00	6.00	-200.00	7.00	-250.00	8.00	-300.00
150.0	-	-	12.00	-500.00	14.00	-600.00	13.00	-550.00
100.0	-	-	19.00	-850.00	20.00	-900.00	17.00	-750.00
50.0	-	-	45.00	-2150.00	55.00	-2650.00	50.00	-2400.00

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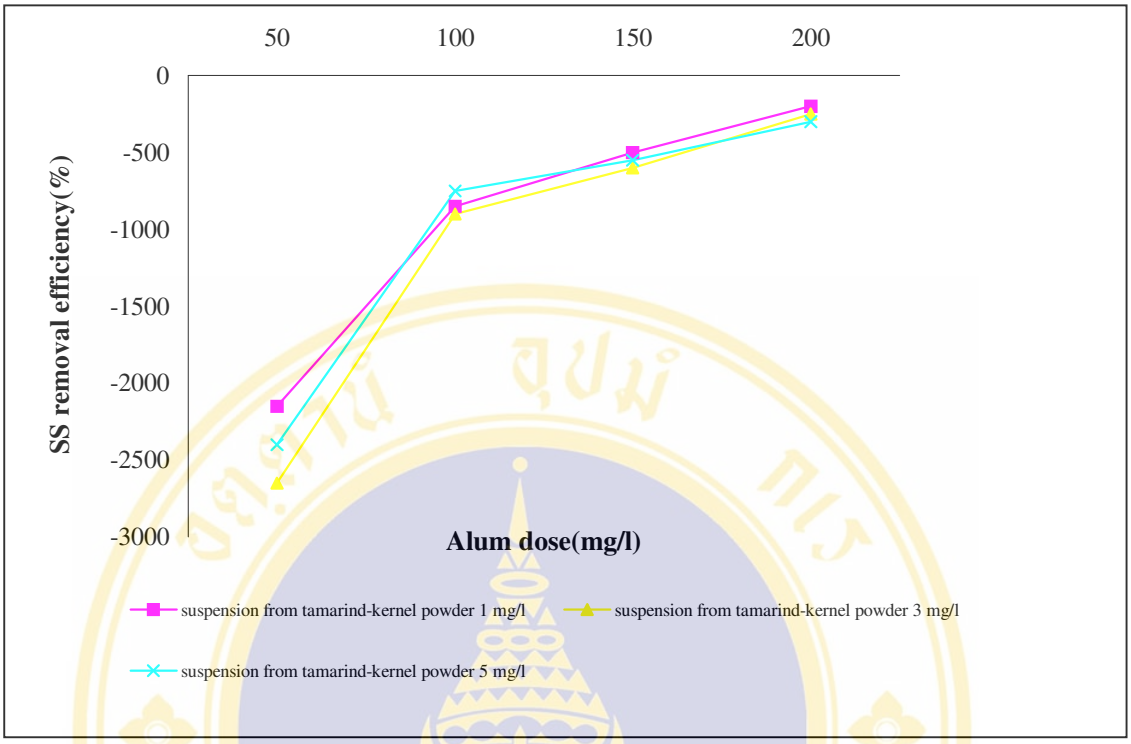

Figure 4-27 SS removal efficiency of Reactive dye after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were -200.00, -500.00, -850.00, -2150.00%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were -250.00, -600.00, -900.00, -2650.00%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 200, 150, 100 and 50 mg/l of Alum's dose were -300.00, -550.00, -750.00, -2400.00%, respectively

When using tamarind-kernel powder suspension 1 mg/l with alum, even if alum was reduced 50% the removal efficiency of Reactive dye was similar to using only alum. The color and COD were reduced 53.44% and 61.52%, respectively. But the SS increase from 8.5 mg/l to 19.0 mg/l.

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4.3.5 Wastewater

Color removal efficiency

Color removal efficiency of Wastewater samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 1200, 900, 600 and 300 mg/l were presented in table 4-29, as follows:

Table 4-29 Corlor removal efficiency of wastewater by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)			
	0.0	**1.0**	**3.0**	**5.0**
1200	88.24	87.33	86.19	87.08
900	-	84.26	83.17	83.96
600	-	73.01	73.11	72.06
300	-	35.64	37.01	39.38

Remark : " - " mean Not include in this study

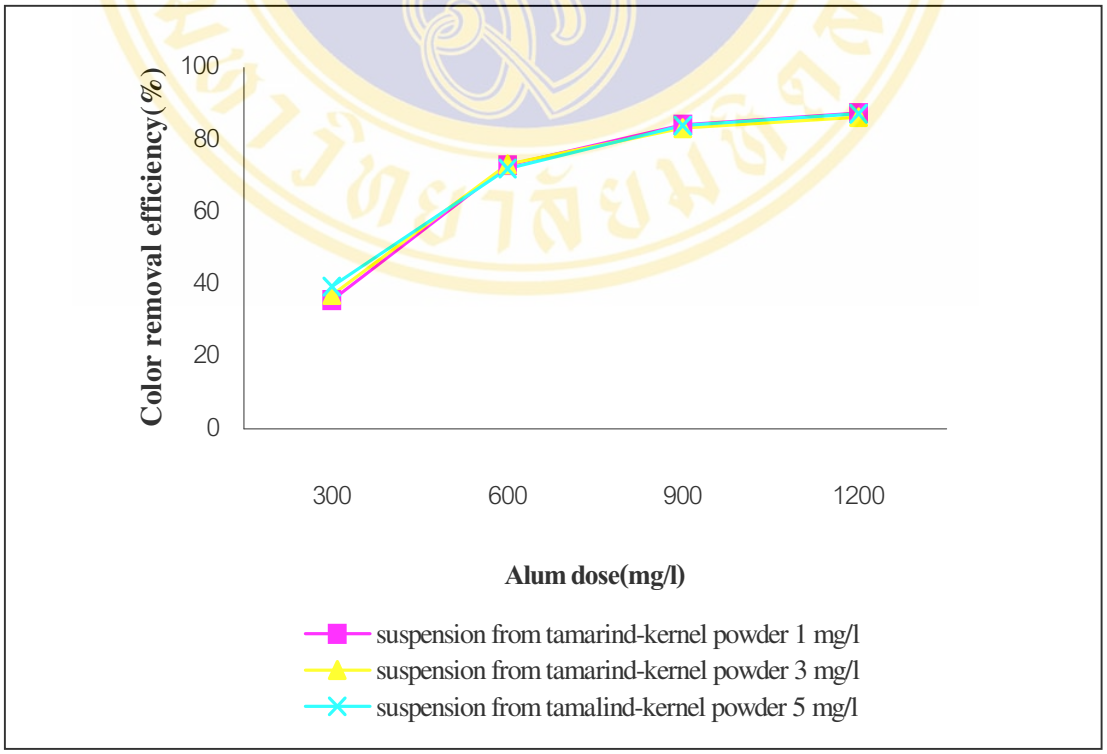

Figure 4-28 Color removal efficiency of wastewater after coagulated by alum and suspension from tamarind-kernel powder

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At 1.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 87.33, 84.26, 73.01, 35.64%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 86.19, 83.17, 73.11, 37.01%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the color removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 87.08, 83.96, 72.06, 39.38%, respectively

COD removal efficiency

COD removal efficiency of Wastewater samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - - 1200, 900, 600 and 300 mg/l were presented in table 4-30, as follows:

Table 4-30 COD removal efficiency of wastewater after coagulated by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)	COD (mg/l)	COD Removal efficiency (%)
1200	114.40	93.78	141.12	92.33	138.24	92.49	139.2	92.43
900	-	-	145.92	92.07	141.12	92.33	143.04	92.23
600	-	-	162.24	91.18	152.64	91.70	152.64	91.70
300	-	-	193.92	89.46	188.16	89.77	184.32	89.98

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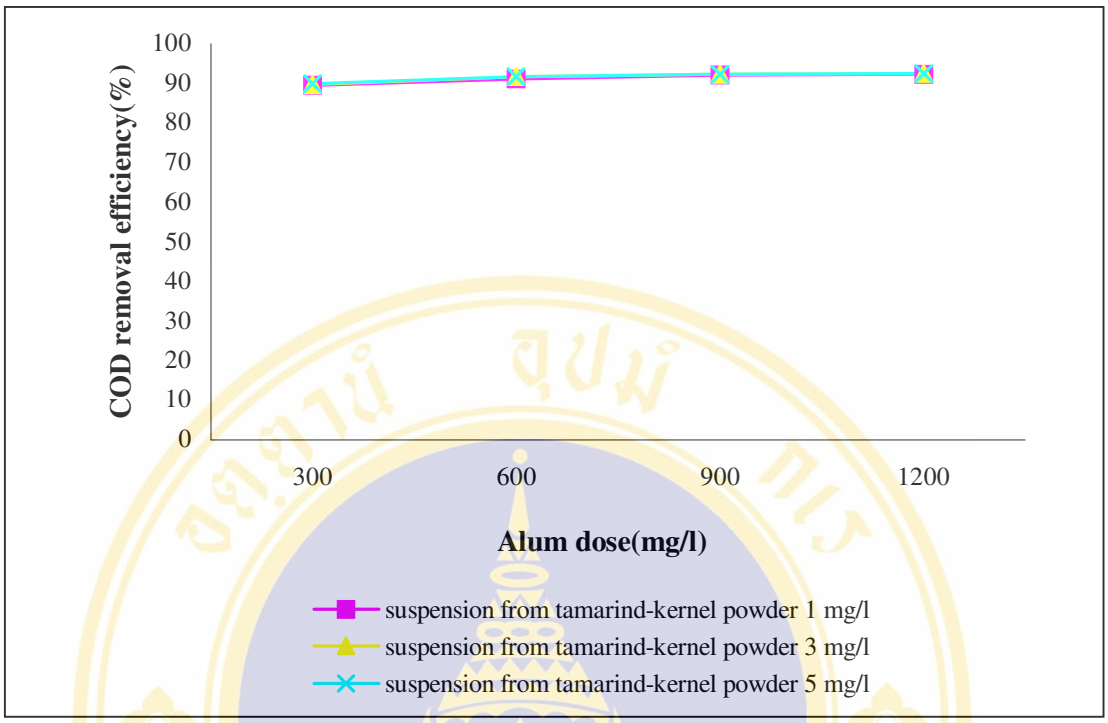

Figure 4-29 COD removal efficiency of wastewater after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 92.33, 92.07, 91.18, 89.46%, respectively

At 3.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 92.49, 92.33, 91.70, 89.77%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the COD removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 92.43, 92.23, 91.70, 89.98%, respectively

SS removal efficiency

SS removal efficiency of Wastewater samples by coagulation method with various Suspension from tamarind-kernel powder - - 1.0, 3.0, 5.0 mg/l and Alum's dose - -1200, 900, 600 and 300 mg/l were presented in table 4-31, as follows:

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Table 4-31 SS removal efficiency of wastewater after coagulated by alum and suspension from tamarind-kernel powder

Alum dose (mg/l)	Suspension from tamarind-kernel powder(mg/l)							
	0.0		1.0		3.0		5.0	
	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)	SS (mg/l)	SS Removal efficiency (%)
1200	70.00	91.76	56.00	93.41	50.00	94.12	88.00	89.65
900	-	-	52.00	93.88	68.00	92.00	84.00	90.12
600	-	-	58.00	93.18	60.00	92.94	118.00	86.12
300	-	-	144.00	83.06	140.00	83.53	258.00	69.65

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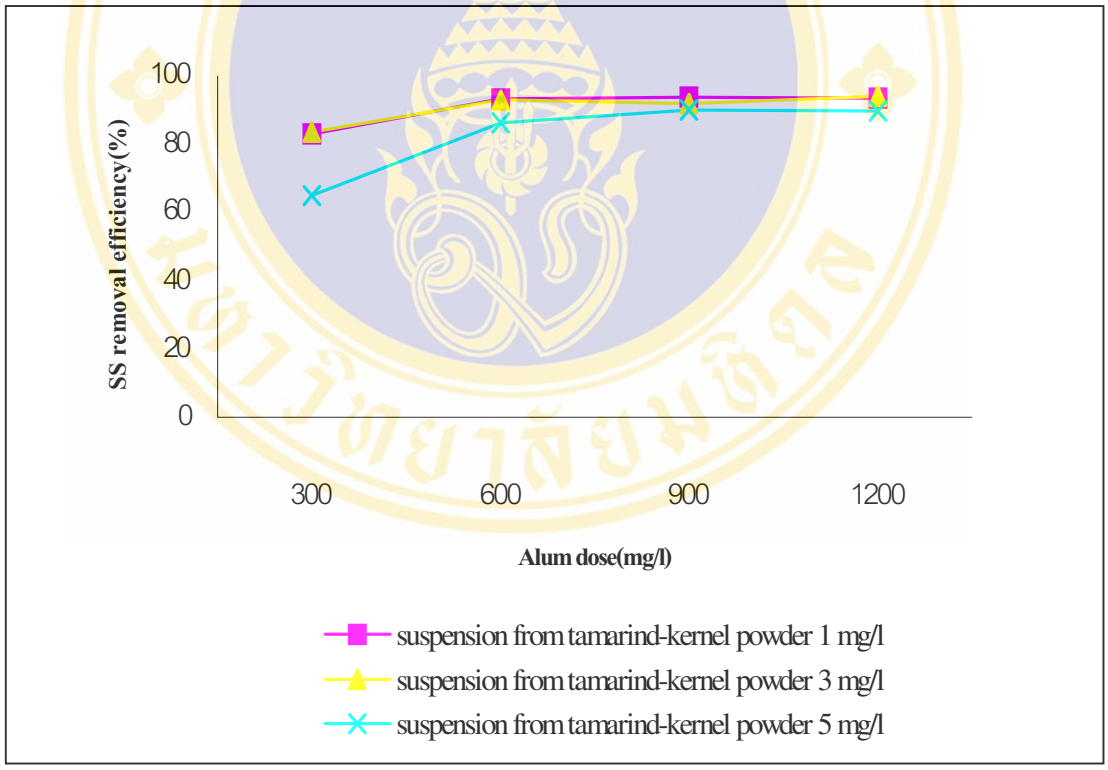

Figure 4-30 SS removal efficiency of wastewater after coagulated by alum and suspension from tamarind-kernel powder

At 1.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 93.41, 93.88, 93.18, 83.06%, respectively

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At 3.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 94.12, 92.00, 92.94, 83.53%, respectively

At 5.0 mg/l of Suspension from tamarind-kernel powder, the SS removal efficiency for 1200, 900, 600 and 300 mg/l of Alum's dose were 89.65, 90.12, 86.12, 69.65%, respectively

When using tamarind-kernel powder suspension 3 mg/l with alum, even if alum was reduced 50% the removal efficiency of wastewater was similar to using only alum. The color, COD and SS were reduced 73.11%, 91.70% and 92.94%, respectively.

The polymers in tamarind kernel enhance coagulation by promoting the growth of large, rapid-settling flocs. Polyelectrolytes from tamarind kernel are high molecular weight polymers, which contain adsorbable groups and thus created when small dosages of polyelectrolyte (1-5 mg/l) are added in conjunction with alum. The polyelectrolyte from tamarind kernel is substantially unaffected by pH and can serve as a coagulant itself by reducing the effective charge on a colloid. The polyelectrolyte from tamarind kernel is negative ion, which replaces the anionic groups on a colloidal particle and permits hydrogen bonding between the colloid and the polymer. This reaction forms the large particle and makes the sedimentation faster and better. Thereby the tamarind solution could be the coagulant with alum to coagulate the dye. Moreover, the tamarind-kernel powder suspension could reduce 50% of alum and the efficiency compared well with only use alum. But if optimum alum was reduced to 25%, the efficiency of coagulation will decrease because the inadequate alum forms the less sediment.

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CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study is the comparison of the color removal from dye synthetic water and wastewater from storage pond of Jib Hua Cheang Jun co.ltd.(cotton dyeing factory) by coagulation with alum and tamarind kernel suspension. The results of study consisted of two parts as follows:

1) Coagulation of the dye synthetic water: the coagulation efficiency by alum of Vat dye and Sulphur dye (insoluble dye) were better than Direct dye and Reactive dye (soluble dye)

2) The coagulation efficiency of the dye synthetic water by alum with suspension from tamarind-kernel powder similar to using only alum. Moreover could reduce using among 50% of alum.

3) Coagulation of wastewater: using alum only could removal color from Jib Hua Cheang Jun co.ltd.'s wastewater, --soluble dye 70%: insoluble dye 30%--while using alum and tamarind kernel suspension for coagulate not only removal color but also reduce using among 50% of alum.

5.2 Recommendation

1) While alum using was increase, the pH was decrease. With the result that the coagulation removal efficiency was reduced. For solving this problem, it should be added buffer to resist pH changing.

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2) As government policy to promote SME development for increasing income per capita, in lead to cooperation among people in their village to build new activities for instance Dye cloth, Agricultural product processing. Such activities have produce wastewater which led to water pollution. Therefore, wastewater should be treated by using tamarind kernel due to it is easily way and reduce agricultural waste.

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APPENDIX

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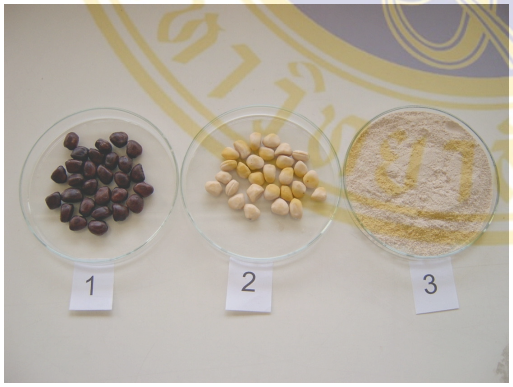
APPENDIX A
FIGURE OF THE EXPERIMENT

Figure A-1 Instruments and materials

Jar Test

Spectrophotometer



1) Tamarind kernel with testae
2) Tamarind kernel without teatae
3) Tamarind kernel power

Tamarind-kernel suspension

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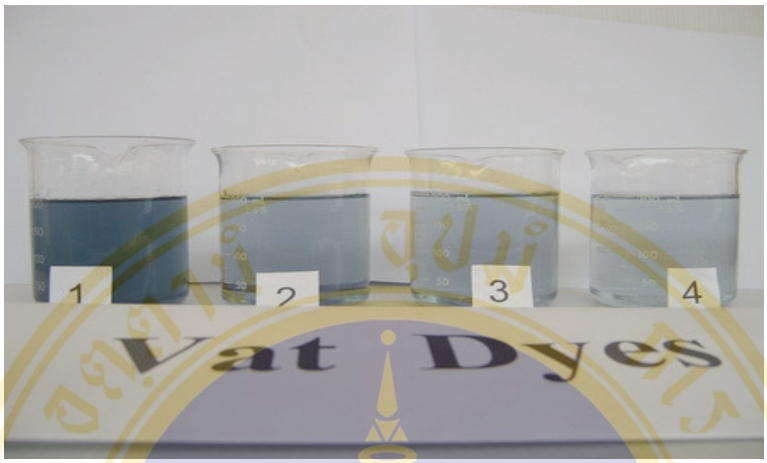
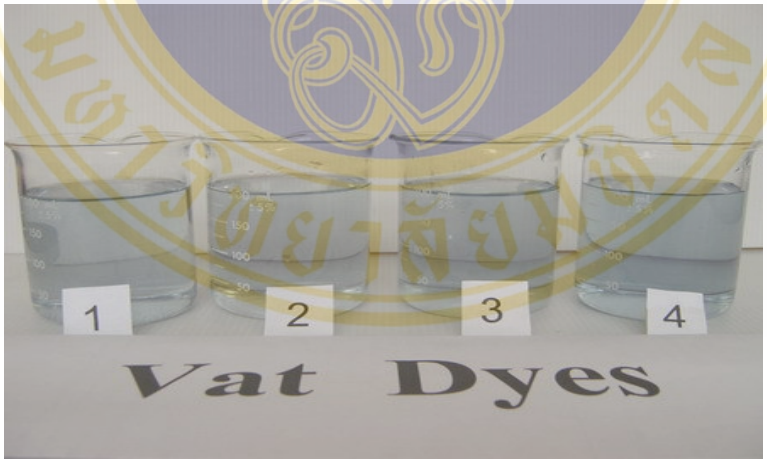
FIGURE A-2 The water samples after coagulation



The optimum removal efficiency of Vat dye by alum coagulation

1) Vat dye Synthetic water
2) The optimum removal efficiency at pH 6
3) The optimum removal efficiency at pH 7
4) The optimum removal efficiency at pH 8 (The best condition)



The optimum removal efficiency of Vat dye by alum and tamarind kernel suspension coagulation

1) The optimum removal efficiency at pH 8 by using 150 mg/l alum
2) The coagulation using 75 mg/l alum and 1 mg/l tamarind kernel suspension(The best condition)
3) The coagulation using 75 mg/l alum and 3 mg/l tamarind kernel suspension
4) The coagulation using 75 mg/l alum and 5 mg/l tamarind kernel suspension

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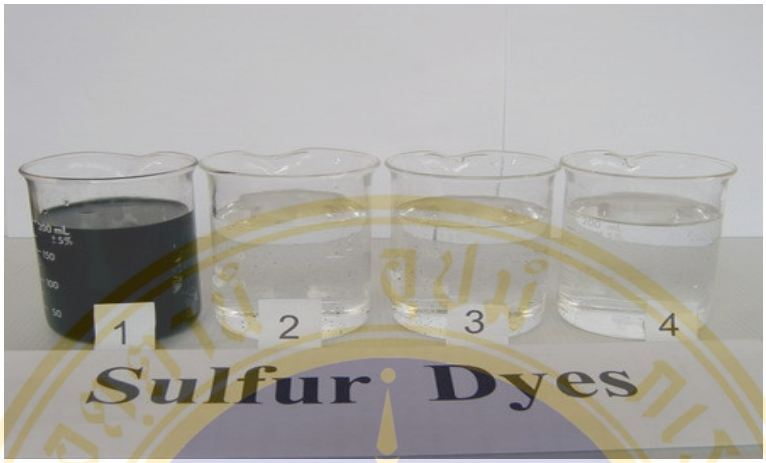

The optimum removal efficiency of Sulphur dye by alum coagulation

1) Sulphur dye Synthetic water
2) The optimum removal efficiency at pH 6
3) The optimum removal efficiency at pH 7(The best condition)
4) The optimum removal efficiency at pH 8

The optimum removal efficiency of Sulphur dye by alum and tamarind kernel suspension coagulation

1) The optimum removal efficiency at pH 7 by using 250 mg/l alum
2) The coagulation using 125 mg/l alum and 1 mg/l tamarind kernel suspension
3) The coagulation using 125 mg/l alum and 3 mg/l tamarind kernel suspension
4) The coagulation using 125 mg/l alum and 5 mg/l tamarind kernel suspension (The best condition)

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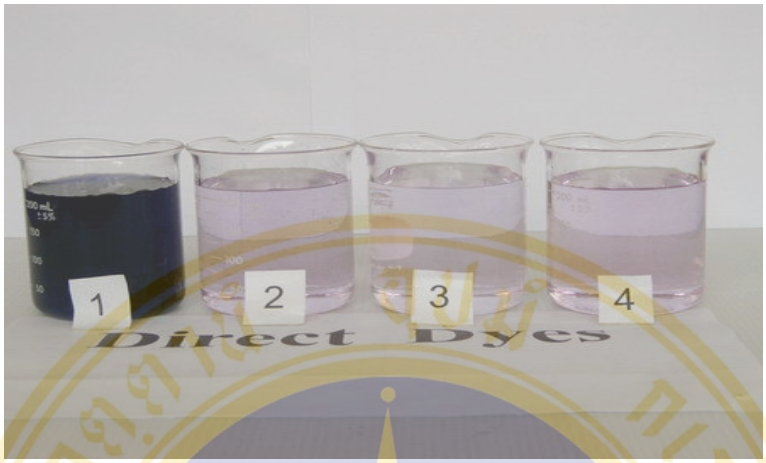

The optimum removal efficiency of Direct dye by alum coagulation

1) Direct dye Synthetic water
2) The optimum removal efficiency at pH 6
3) The optimum removal efficiency at pH 7
4) The optimum removal efficiency at pH 8 (The
5) best condition)

The optimum removal efficiency of Direct dye by alum and tamarind kernel suspension coagulation

1) The optimum removal efficiency at pH 8 by using 100 mg/l alum
2) The coagulation using 50 mg/l alum and 1 mg/l tamarind kernel suspension (The best condition)
3) The coagulation using 50 mg/l alum and 3 mg/l tamarind kernel suspension
4) The coagulation using 50 mg/l alum and 5 mg/l tamarind kernel suspension

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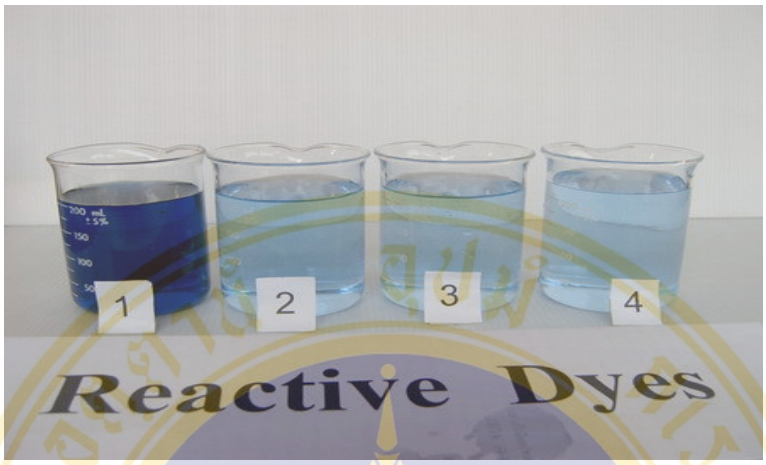
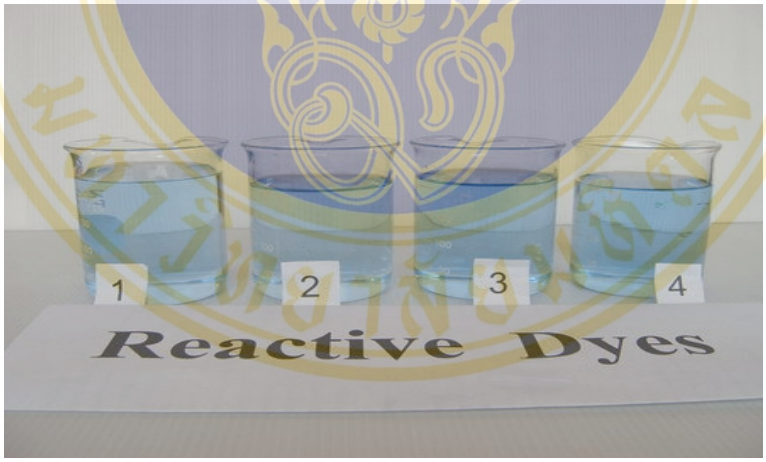


The optimum removal efficiency of Reactive dye by alum coagulation

1) Reactive dye Synthetic water
2) The optimum removal efficiency at pH 6
3) The optimum removal efficiency at pH 7
4) The optimum removal efficiency at pH 8 (The best condition)



The optimum removal efficiency of Reactive dye by alum and tamarind kernel suspension coagulation

1) The optimum removal efficiency at pH 8 by using 200 mg/l alum
2) The coagulation using 100 mg/l alum and 1 mg/l tamarind kernel suspension (The best condition)
3) The coagulation using 100 mg/l alum and 3 mg/l tamarind kernel suspension
4) The coagulation using 100 mg/l alum and 5 mg/l tamarind kernel suspension

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The optimum removal efficiency of Wastewater by alum coagulation

1) Wastewater
2) The optimum removal efficiency at pH 6
3) The optimum removal efficiency at pH 7
4) The optimum removal efficiency at pH 8 (The best condition)

The optimum removal efficiency of wastewater by alum and tamarind-kernel suspension coagulation

1) The optimum removal efficiency at pH 8 by using 1200 mg/l alum
2) The coagulation using 600 mg/l alum and 1 mg/l tamarind kernel suspension
3) The coagulation using 600 mg/l alum and 3 mg/l tamarind kernel suspension (The best condition)
4) The coagulation using 600 mg/l alum and 5 mg/l tamarind kernel suspension

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APPENDIX B
STATISTIC ANALYSIS

Different in removal efficiency of COD, SS and Color of Alum and Alum and Tamarind kernel suspension in Vat dye, Sulphur dye, Direct dye, Reactive dye and waste water was evaluated by Multivariate Test. When significant were observed, the Duncan's multiple range test (DMRT), multi-comparison test was applied to the ANOVA to determine which means were significantly different.

Table B-1 Relation of pH and alum dose in removal efficiency of COD, SS and Color

Multivariate Test

Source	*Dependent Variable*	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Corrected Model	cod	2846.322	14	203.309	1016.544	.000
	ss	683.200	14	48.800	36.600	.000
	colour	12444.888	14	888.921	48.206	.000
Intercept	cod	15070.050	1	15070.050	75350.250	.000
	ss	8160.800	1	8160.800	6120.600	.000
	colour	109544.668	1	109544.668	5940.627	.000
PH	cod	566.141	2	283.070	1415.352	.000
	ss	385.600	2	192.800	144.600	.000
	colour	4078.808	2	2039.404	110.597	.000
CONC	cod	470.129	4	117.532	587.661	.000
	ss	19.200	4	4.800	3.600	.016
	colour	4152.520	4	1038.130	56.298	.000
PH * CONC	cod	1810.053	8	226.257	1131.283	.000
	ss	278.400	8	34.800	26.100	.000
	colour	4213.560	8	526.695	28.563	.000
Error	cod	6.000	30	.200		
	ss	40.000	30	1.333		
	colour	553.198	30	18.440		
Total	cod	17922.372	45			
Total	cod	17922.372	45			
	ss	8884.000	45			
	ss	8884.000	45			
	colour	122542.753	45			
	colour	122542.753	45			
Corrected Total	cod	2852.322	44			
Corrected Total	cod	2852.322	44			
	ss	723.200	44			
	ss	723.200	44			
	colour	12998.085	44			
	colour	12998.085	44			

a R Squared = .998 (Adjusted R Squared = .997)
b R Squared = .945 (Adjusted R Squared = .919)
c R Squared = .957 (Adjusted R Squared = .938)

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Table B-2 The F tests the effect of pH. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Univariate Tests

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
cod	Contrast	566.141	2	283.070	1415.352	.000
cod	Error	6.000	30	.200		
ss	Contrast	385.600	2	192.800	144.600	.000
	Error	40.000	30	1.333		
color	Contrast	4078.808	2	2039.404	110.597	.000
	Error	553.198	30	18.440		

Table B-3 The F tests the effect of conc. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
cod	Contrast	470.129	4	117.532	587.661	.000
cod	Error	6.000	30	.200		
ss	Contrast	19.200	4	4.800	3.600	.016
	Error	40.000	30	1.333		
color	Contrast	4152.520	4	1038.130	56.298	.000
	Error	553.198	30	18.440		

Table B-4 Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .200.

PostHoc Tests by Duncan

Homogeneous Subsets

COD

		N	Subset		
Duncan	pH		1	2	3
	pH6	15	13.4300		
	pH8	15		19.6940	
	pH7	15			21.7760
	Sig.		1.000	1.000	1.000

a Uses Harmonic Mean Sample Size = 15.000.

b Alpha = .05.

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