POLLUTION PREVENTION IN TEXTILE INDUSTRY: RECYCLING WASTEWATER FROM TEXTILE DYEING PREPARATION PROCESS

SOMKIAT THITIPANONT

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....
Mr. Somkiat Thitipanont
Candidate

....
Asst.Prof. Aurapin Eamsiri, Ph.D.
Major-advisor

....
Winai Nutmagul, Ph.D.
Co-advisor

(Deceased)
....
Asst.Prof. Vithya Srimanobhas, D.Sc.
Co-advisor

....
Prof. Liangchai Limlonwongse, Ph.D.
Dean
Faculty of Graduate Studies

....
Asst.Prof. Raywadee Roachanakanan, M.Sc.
Chairman
Master of Science Programme in Tecnology of Environmental Management
Faculty of Environment and Resource Studies

Thesis

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January 7, 2000

Somkiat Thitipanont
....
Mr. Somkiat Thitipanont
Candidate

....
Asst.Prof. Aurapin Eamsiri, Ph.D.
Chairman

Winai Nutmagul
....
Winai Nutmagul, Ph.D.
Member

K. Sanguantrakul.
....
Asst.Prof. Kanit Sanguantrakul, M.Sc.
Member

(Deceased)
....
Asst.Prof. Vithya Srimanobhas, D.Sc.
Member

....
Prof. Liangchai Limlonwongse,
Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

A. Poungsomlee.
....
Assoc. Prof. Anuchat Poungsomlee,
Ph.D
Dean
Faculty of Environment and
Resource Studies
Mahidol University

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This research work investigated the recycling possibility of wastewater from the preparation process of medium-scale textile dyeing mills, applying pollution prevention technology. The expected result of this study is to minimize the environmental pollution and production cost to some extent. In order to conduct this work, the quality of water and wastewater before entering and discharging each step of the preparation process and were collected simultaneously. The samples were analyzed by the *Standard Method* parameters. A coagulation experiment using aluminium sulfate, ferrous sulfate, and ferric sulfate was conducted to seek the optimum dosage of the particles removal under the condition of integrated wastewater as received and at controlled pH 7. To test on the efficiency of the recycled wastewater, fabric quality test was conducted using a *Rapid Dyer Simulator*.. Finally, an economic analysis was also studied to refer the worthiness investment of the plant.

The results from this work revealed that wastewater had high alkaline solutions, and were highly contaminated in all parameters. Approximately, 16% of wastewater from the total consumption process could be integrated and recycled. Coagulation resulted that the optimum dose of aluminium sulfate, ferrous sulfate, and ferric sulfate were 1,176 mg/l, 2,100 mg/l, and 768 mg/l, respectively. More capable with adjusted media for coagulation at the pH 7, the dosage result for aluminium sulfate, ferrous sulfate, and ferric sulfate were 750 mg/l, 850 mg/l, and 620 mg/l respectively. However the recycled wastewater with aluminium sulfate revealed the best result, arising from the result of the fabric test. The fabric appeared whitish with high efficiency to be dyed, while the fabrics prepared by recycled wastewater of ferrous sulfate and ferric sulfate were appeared yellowish and brownish, which is not attractive to the consumer. For the economic analysis using cost comparison between cost of operation, it was discovered that the recycled wastewater or the modified plant was worthwhile and expenditure can be returned within 5 years.

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งานวิจัยนี้เป็นการศึกษาความเป็นไปได้ในการนำน้ำทิ้งจากขบวนการเตรียมการย้อมกลับมาใช้ใหม่ของโรงงานฟอกย้อมผ้าขนาดกลาง ทั้งนี้โดยใช้หลักการในการป้องกันปัญหาสิ่งแวดล้อม ทั้งนี้เพื่อลดปัญหามลพิษและลดต้นทุนในการผลิตของโรงงาน ในการดำเนินการวิจัยครั้งนี้ น้ำที่ใช้และน้ำเสียจากขบวนการเตรียมการย้อมในแต่ละขั้นตอนจะถูกนำมาวิเคราะห์คุณภาพ เพื่อศึกษาความเป็นไปได้ในการนำน้ำตัวอย่างมารวมกันเพื่อนำกลับมาใช้ใหม่ พร้อมทำการศึกษาการตกตะกอนโดยใช้สารเร่งการตกตะกอน 3 ชนิดคือ $Al_2(SO_4)_3$ $FeSO_4$ และ $Fe_2(SO_4)_3$ เพื่อหาปริมาณที่เหมาะสมภายใต้สภาวะน้ำทิ้งที่ได้รับและสภาวะที่เป็นกลาง (pH 7) รวมทั้งศึกษาคุณภาพของผ้าที่ใช้น้ำซึ่งได้ผ่านการบำบัดดังกล่าวโดยใช้เครื่อง *Rapid Dyer Simulator* และศึกษาความเป็นไปได้ในทางเศรษฐศาสตร์

จากผลการศึกษาพบว่า น้ำเสียจากขบวนการการเตรียมการย้อมมีความเป็นด่างค่อนข้างสูงและมีการปนเปื้อนมาก น้ำทิ้งประมาณร้อยละ 16 ของน้ำทิ้งโรงงานสามารถนำกลับมาใช้ได้ และจากการบำบัดด้วยสารเร่งการตกตะกอนทั้ง 3 ชนิดพบว่า หากใช้น้ำทิ้งที่ไม่ได้ปรับสภาวะใดๆ เลยจะต้องใช้ปริมาณสารเร่งการตกตะกอนในปริมาณสูงกว่า คือ ใช้ $Al_2(SO_4)_3$ $FeSO_4$ และ $Fe_2(SO_4)_3$ ในปริมาณ 1176, 2100, และ 768 มก./ลิตร ตามลำดับ แต่ภายใต้สภาวะที่เป็นกลาง (pH 7) ปริมาณสารที่ใช้จะลดลงเหลือเพียง 750, 850, และ 620 มก./ลิตร ตามลำดับ และหลังจากทำการทดสอบคุณภาพผ้าที่ใช้น้ำซึ่งได้จากการบำบัดดังกล่าว พบว่า ผ้าที่ได้จากการใช้ $Al_2(SO_4)_3$ จะมีคุณภาพดีที่สุดด้วยผ้าที่ได้จะมีสีขาว ส่วนผ้าที่ได้จากการใช้ $FeSO_4$ และ $Fe_2(SO_4)_3$ จะมีสีน้ำตาลของเหล็กออกไซค์ นอกจากนั้นจากการศึกษาถึงความคุ้มทุนในการดำเนินการดังกล่าวพบว่าวิธีการดังกล่าวจะสามารถคืนทุนได้ภายในระยะเวลา 5 ปี

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%	Percentage
BOD	Biochemical Oxygen Demand
hr	hour
kW	Kilowatts
kW hr	Kilowatts hour
$l\ kg^{-1}$	Litre per kilogram
l or L	Litre
Lb	Pounds
m	Meter
m^2	Square meter
m^3	Cubic meter
m^3/ day or m^3/d	Cubic meter per day
mg	Milligram
mg/l or $mg\ l^{-1}$	Milligram per litre
ml	Millilitre
Nd	Non detectable
NTU	Nephelometric Turbidity Unit
SS	Suspended Solids
TDS	Total Dissolved Solids
w/v	Weight by volume

CHAPTER I

INTRODUCTION

1.1 Rationale for the Study

In Thailand, textile enterprise counts the most leading industry. It grew rapidly during the last decade. Now, it is still ranking high in GDP and employment rate. Textile enterprise is a large-scale industry because it consists of mass and complex production lines. By the application of changing raw material, such as cotton etc., into fibers, threads, garments, towels, bed coverings, carpets, industrial appliances e.g. automotive components such as tire cords, filters, upholstery, etc., and recreational equipment such as backpacks and parachutes. With the mass productions, there are some problems in this industry namely the limitations of area, and inadequacy of financial inventory. These should be augmented respectively. Therefore, Thai economy is now searching certain solutions for this industry by diversifying its production lines into medium to small-scale textile mills which are so-called factories or enterprises.

According to the production process in the textile industry, the assembly lines of production process is composed of the following five main sections: the fiber production; the spinning; the weaving and knitting; the dyeing-printing (the wet-end process); and the garment production. Each section may be related to each other in the way that the products from a mill will be the raw materials for another mill (1, 2, 3). Because there is such a diversity in the production lines and applications in this industry, the medium to small-scale mills take place in each section. The increase of textile market causes the expansion of the medium to small-scale mills, for example, spinning mill, weaving mill or knitting mill, dyeing and/or printing finishing mill. Now, there are more than 12,000 garment textile mills throughout Thailand (4). These mills cause the mass production of goods. At the same time, with the augmentation of textile productions, the use of resources and chemicals varies respectively. For this circumstance, the pollution has been increased. As regulations, the trade barrier regulations are enforced to comply with the environmental issues. Therefore, the difficulty comes back to the production lines of textile industry in which the wet-end process of dyeing and/or printing finishing mill are of the most produced hazardous waste area.

The application of dyeing and/or printing finishing mill pollutes the environment to a large extent. This is very hard to be avoided because the hazardous chemicals being used make the fabrics appeal to the eye, more colorful, more comfortable, and wider applicable. Another reason is that the characteristics of the medium to small-scale enterprises of dyeing-printing finishing mills are of simple technology, labor-intensive, and equipped with used machines. They are also insufficient capitalization with no update of data and maintenance (3).

The dyeing-printing finishing mills are broadly classified by the ways of dyeing process into three types. Those are continuous, batch, and semicontinuous dyeing mills. The continuous dying process is the process that chemicals are placed in a machine and fabrics is moved through it without interruption, so many chemical reactions of fabrics are done within a single machine (3). Furthermore, the waste streams are easily segregated for heat recovery and low water consumption. Batch dyeing process is totally different, a chemical reaction is done in a single vessel (1). This consumed large volume of water, because after a reaction is done, the vessel must be washed and ready for the next process. In case of the semicontinuous dyeing process, it is the combination of batch and continuous dying processes (5).

In Thailand, most of dyeing mills are of medium to small-scale enterprise. These mills contribute to a limitation of capitalization and land space. Therefore, most of the mills are equipped with batch dyers, only few of them are of highly efficient continuous dyeing machines (6). In addition, they are normally managed by family business, and engaged by other medium to small-scale mills (6). For example, a garment production mill may engage a certain commission dyeing mill to dye its fabrics to meet a desired colors. At the same time, the commission dyeing mill received gray fabrics from different weaving mills. Therefore, various kind of wastes are loaded into the dyeing mill (2).

The typical production line of the dyeing mill appears to be the same, regardless of what its process is batch or continuous dyeing. It starts from the preparation process which is composed of singeing, desizing, scouring, and bleaching units, then it is followed by dyeing and printing process which proceeds fabric to absorb color pigments into the fabric fibers. Finally, it is the finishing process where the final treatment for the fabrics is taken place. This process makes fabrics look smooth and uniform. When the process is proceeded, there is the wastewater effluent discharge from each unit causing a large amount of wastewater is generated during the production then loaded into the wastewater treatment plant before it is discharged. Major effluent from the preparation process, approximately 80%, is the color contaminated wastewater, while only 20% is of highly contaminated desizing agent wastewater. The desizing agent is whitish compound which mostly consists of PVA (polyvinyl alcohol), starch (tapioca or cassava), CMC (carboxymethyl cellulose), Polyacrylic, or the combination of these substances. According to the sedimentation ability of the whitish desizing compound at the bottom of the wastewater treatment pond causing an inefficiency of treatment. The more desizing agents, which are accumulated in the treatment pond, the more BOD loaded into the environment (2, 7). Since more than 3,000 dyeing mills in Thailand are not in the same company line, they are always received gray fabric sized by different sizing formulas. Therefore, the sizing agents are hardly to be recovered due to the specific formula of each compound (2).

In Thailand, wastewater from dyers or dyeing mills were discharged about 150-800 m^3/day (8). They were normally consisted of 16-19% by volume of starch, PVA, CMC or the combination of these substances (2,9). The values of BOD_5 of textile mills wastewater process before going through wastewater treatment plant are normally ranging from 100-2,000 mg/l, while the content of preparation process are varied from 80-1,940 mg/l (10). Thus, the general characteristics of textile preparation wastewater effluent are a solution consisting of high load of BOD, suspended solid, and alkalinity causing the high cost of treating such wastewater (11). During to the most desizing residue lefts over are the suspended solids, over 90% of these SS can be treated with aid of alum and other coagulants such as ferrous sulphate and ferric chloride. Consequently coagulation can be aimed to treat and settle down these suspended solids. Therefore, to solve this problem, the recovery of desizing agents from wastewater could significantly alleviate the treatment burden of the downstream textile wastewater and possibly lead to a significant cost reduction of the overall textile wastewater treatment system (9).

In order to minimize wastewater produced by textile dyeing process and reduce the cost of treating such wastewater simultaneously, the "Pollution Prevention Principles" will be applied. When the desizing agents can be recycle from wastewater effluent discharged from textile dyeing preparation process. All of these activities are done to accomplished under the concepts of "Cleaner Production" (12). This cleaner production will decrease the resources comsumption, but product quality appeared to be the same. Hence, it is reasonable to investigate the recycle of wastewater effluent discharged from textile dyeing preparation process for the Small-Middle Enterprise, like this dyeing mill.

1.2 Objectives of the Study

The objective of this research work is to investigate the possibility of using pollution prevention measure in textile dyeing industry in the area of recycling wastewater effluent discharged from textile dyeing preparation process.

1.3 Scope of the Study

This study will be focussed on the recycling wastewater effluent discharged from textile dyeing preparation process for reusing in the steps of desizing, scouring, and bleaching processes at the dyeing mills of Dee Yuang Dyeing and Finishing Company Limited (as diagram in Figure 1-1).

1.4 Expected Results

Environmental pollution and production cost in textile industry can be minimized to some extent by recycled wastewater effluent discharged from textile dyeing preparation process for reusing in textile dyeing preparation process at the textile dyeing mill.

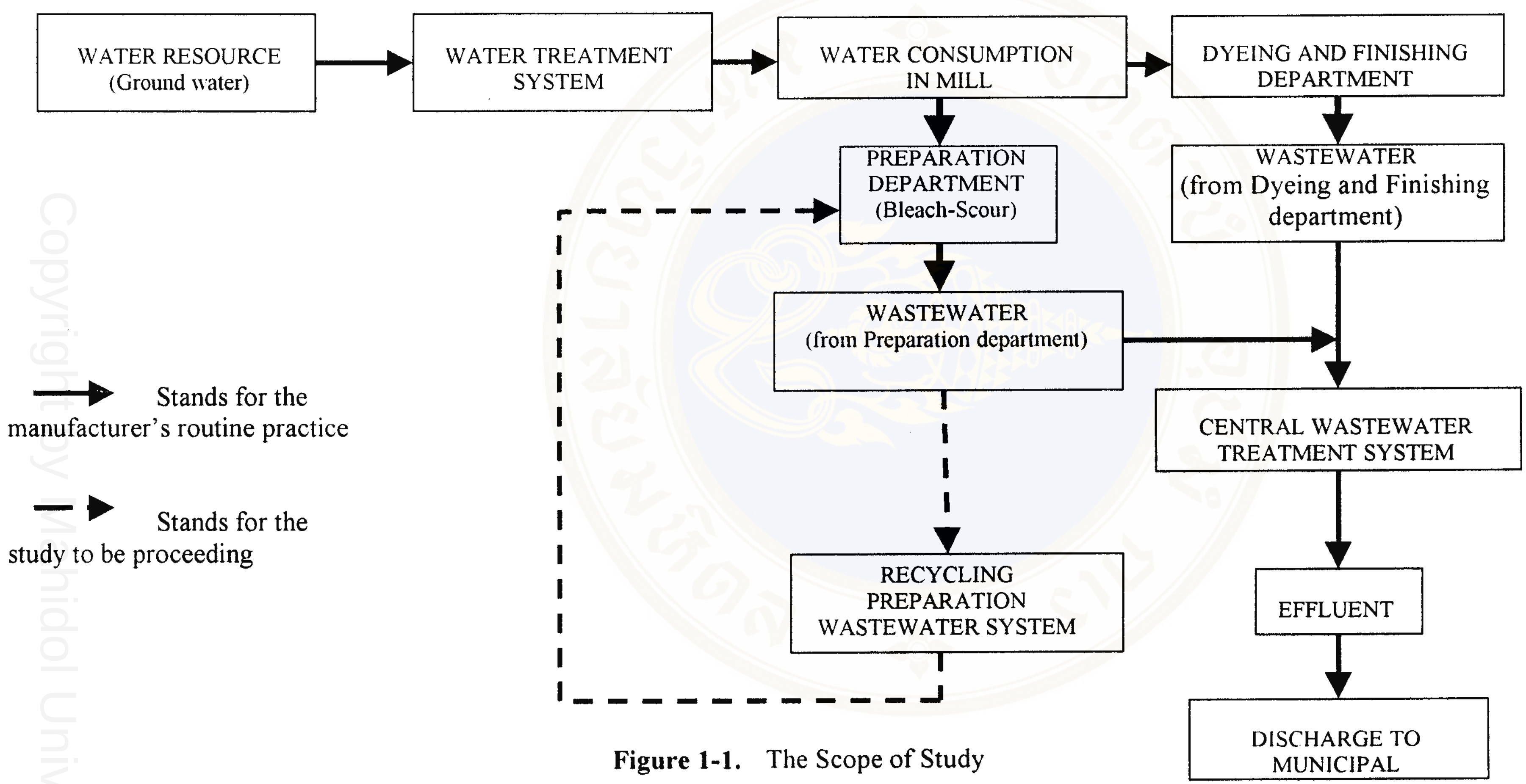


Figure 1-1. The Scope of Study

CHAPTER II

Review of Literature

2.1 Textile Mills in Thailand

It is known that more than 3,000 textile mills in Thailand can export its products about 83,000 million baht in 1989. The value of exported products tends to be increased according to the increase of Thailand's economic growth rate. More or less, those textile mills cause water pollution. In 1986, Industrial Works Department evaluated that the BOD_5 of textile mills was about 8,408 tons per year. This is approximately 1.6% of BOD_5 caused by other industrial plants. However, decreasing ability of BOD_5 before discharging to public water resources is questionable. The unique quality of wastewater discharging from textile mills are that of dark colour with its BOD loading about 100-2,000 mg/l along with its dark colors e.g. red, blue, green, etc. Even this wastewater was treated through water treatment system, its unique qualifications are still problems and it is rather objectionable to the public if it will be discharged to the public water resources. So that, it is necessary to determine wastewater quality before giving it proper treatment in order to make it meets the standards of discharge water set forth by the Industrial Works Department (10).

In textile industry, dyeing and/or printing finishing process has to use a lot of chemicals and dyes. All of them are diversely harmful to the environment. Some of those chemicals and dyes are absorbed by fibers while the rests of them are discharged with wastewater causing discharged wastewater to be colourful. In addition, the chemicals and dyes being used are numerous; it is hard to determine the composition of wastewater definitely. Generally, wastewater discharging from dyeing and/or printing finishing process is colored, contained high load of BOD and suspended substances. Furthermore, it is of high alkalinity and temperature, and may be contaminated with poisonous substances. So that, wastewater discharged from dyeing and /or printing finishing process should be properly treated to meet at least the standards of discharge water set forth by the Industrial Works Department before discharging into public water resources. Therefore, wastewater treatment is an inevitable duty of textile mills, and all expenses for conducting this process should be included into the total production cost. More or less, the cost for conducting wastewater treatment can be reduced by the following important ways: decreasing water consumption; reusing water, dyes, and chemicals; using only chemicals and dyes that are less harmful to the environment; and separating wastewater being discharged. Some of these can reduce the cost for conducting wastewater treatment as well as reduce the quantity of water, dyes, and chemicals being used by the textile mills.

Table 2-1: The characteristics of wastewater samples from 4 textile mills before and after going through current wastewater treatment process (8).

Textile mill	*Wastewater discharging rate m3/day*	*Characteristics of wastewater after before going through the treatment [I]*						*Characteristics of wastewater after going through the treatment like AS or AL. [II]*					
		BOD mg/l	*COD mg/l*	*SS mg/l*	*TKN mg/l*	*PO_4-P mg/l*	*pH mg/l*	*BOD mg/l*	*COD mg/l*	*SS mg/l*	*TKN mg/l*	*PO_4-P mg/l*	*pH mg/l*
A (CTK)	800	80	180	200	4	5	6.8	60	160	84	4	0.7	6.6
B (PSB)	200	1.940	2.250	345	29	20	5.9	1,360	1.947	245	11.5	10.2	6.36
C (NPK)	150	650	200	70	20	13	6.0	20	192	50	12	6	7.3
D(JHCJ)	200	330	2.963	-	-	-	10.1	56	1.097	-	-	-	8.0

Textile mill	*Wastewater discharging rate m3/day*	*Characteristics of wastewater after going through CR+PCT+AS of consultant's laboratory [III]*						*Characteristics of wastewater after going through AS of consultant's laboratory [IV]*					
		BOD mg/l	*COD mg/l*	*SS mg/l*	*TKN mg/l*	*PO_4-P mg/l*	*pH mg/l*	*BOD mg/l*	*COD Mg/l*	*SS mg/l*	*TKN mg/l*	*PO_4-P mg/l*	*pH mg/l*
A (CTK)	800	-	-	-	-	-	-	7	45	13	3	0.5	76
B (PSB)	200	20	188	20	5	1	7.3	18	250	28	3.5	1	6.31
C (NPK)	150	18	89	21.5	4	2	7.0	12	65	16	4	1	7.2
D(JHCJ)	200	-	-	-	-	-	-	-	-	-	-	-	-

REMARKS : *AS = activated sludge process*
AL = aerated lagoon
TKN = total Kjeldahl nitrogen
CR = color removal by using $Ca(OCl)_2$
PCT = physical-chemical treatment
PO_4-P = phosphate phosphorus
Textile Mill A, C, and D use AL
Textile Mill B uses AS

Source : The Greening of Thai Industry

Since there are over 3,000 diversely different textile mills throughout Thailand, four of them were drawn as the example to exemplify the characteristics of wastewater before and after going through wastewater treatment process as illustrated in Table 2-1. It is indicated that the values of BOD_5 of wastewater before going through wastewater treatment process vary from 80-1,940 mg/l. depending on the type of production that only textile or textile and dyeing and/or printing finishing process are carried out. In dyeing and/or printing finishing process, sometimes rinsing starch (tapioca or cassava starch) process has to be conducted to clean the gray fabric. This makes the value of BOD_5 of wastewater increases. The dirty materials in wastewater are diversely different depending on the kinds of textile produced. However, it is remarkable that the values of COD, BOD of wastewater are not much different. This indicates that the wastewater discharging from textile mills, more or less, could be easily treatable by certain biological process.

2.2 Characterization of Textile Wastewater - A Review

The characteristics of wastewater from textile processing operations are comprehensively reviewed. The categorization of wastewater proceeds to a consideration of the nature of the various industrial processes employed by the industry and the chemicals associated with these operations. Chemical pollutants arise both from the raw material itself and a broad range of additives used to produce the finished product. The industrial categories considered include sizing and desizing, weaving, scouring, bleaching, mercerizing, carbonizing, fulling, dyeing and finishing. Pollutants of concern range from non-biodegradable highly-colored organic dyes to pesticides from special finishes such as insect-proving. It is evident that the textile wastewater chemical composition is subjected to considerable change due to both the diversity in the textile process employed and the range of chemical employed within each industrial category.

Industrial Categories

The extreme diversity of raw materials and production schemes employed by the textile industry poses problems in assessing effluent characteristics and subsequently defining pollution control technologies. As a rudimentary simplification, the U. S. Environmental Protection Agency has grouped the industry into various categories representing the different industrial activities (13, 14). The EPA categorization and typical characteristics of the wastewater generated by each of the activities are given in Table 2-2.

Table 2-2: Textile processing categories by US EPA (14).

Parameters	*Categories*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
BOD_5/COD	0.2	0.29	0.35	0.54	0.35	0.3	0.31
BOD_5 (mg l^{-1})	6,000	300	350	650	350	300	250
TSS (mg l^{-1})	8,000	130	200	300	300	120	75
COD (mg l^{-1})	30,000	1,040	1,000	1,200	1,000	1,000	800
Oil and grease (mg l^{-1})	5,500	---	---	14	53	---	---
Total chrome (mg l^{-1})	0.05	4	0.014	0.04	0.05	0.42	0.27
Phenol (mg l^{-1})	1.5	0.5	---	0.04	0.24	0.13	0.12
Sulfide(mg l^{-1})	0.2	0.1	8.0	3.0	0.2	0.14	0.09
Color (ADMI)	2,000	1,000	---	325	400	600	600
pH	8	7	10	10	8	8	11
Temp. (°C)	28	62	21	37	39	20	38
Water usage (l kg^{-1})	36	33	13	113	150	69	150

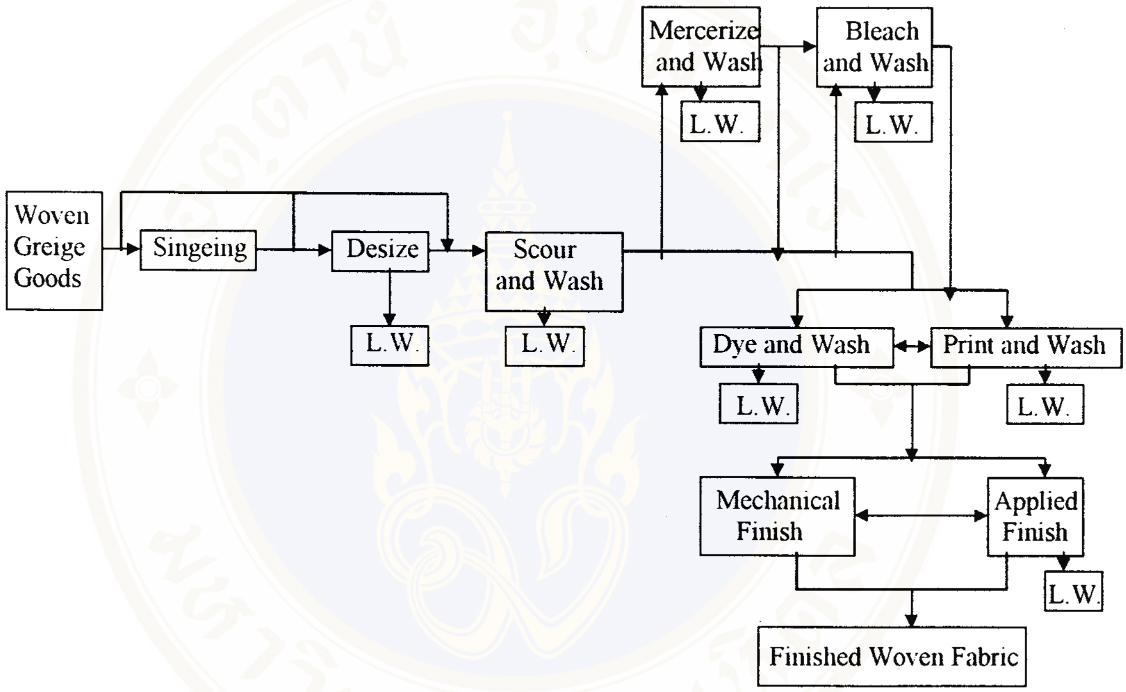
Remark : Categories description:

1. Raw wool scouring. *2. Yarn and fabric manufacturing.*
3. Wool finishing. *4. Woven fabric finishing.*
5. Knitted fabric finishing. *6. Carpet manufacturing.*
7. Stock and yarn dyeing and finishing.

Source: Textile Processing Industry (14).

Main Wastewater Sources and Effluent Characteristics

Correria and others (15), stated that manufacturing processes for each of industrial categories have been used to highlight the operations responsible for wastewater generation. As an example in Figure 2-1 represents the manufacturing process of a woven cotton fabric finishing mills. In order to identify the major sources of pollution, propose pollution, abatement strategies and evaluate the requirements of wastewater treatment systems, it is imparative to further understand both the processing operations themselves and the characteristics of their individual effluents.



L.W. = Liquid Waste

Figure 2-1: Manufacturing process of woven cotton fabric finishing mills (16).

Detailed descriptions of the operations within each category have been reported by Nolan and OECD (17, 18). Process wastewater compositions vary widely due to the variety of recipes, techniques, machinery, raw materials and fabrics, and this is reflected in the reported data. Important parameters such as COD, TOC, TDS and TSS generally go unreported. Values for other parameters, taken from Cooper (16), are reported in Table 2-3 along with water consumption values. These data relate to the expected or most probable pollution loads resulting from each processing operation of various raw materials. The textile processing operations, and their respective relative contributions to the pollutant load, are outlined below.

1) Sizing : In the transformation of cotton yarns to woven fabrics, substances such as starch, modified starch, carboxymethyl cellulose, gums, polyvinyl alcohol, and polyvinyl acetate are applied to the warp in order to increase its tensile strength and smoothness. During this operation, wastewater results from the cleaning of sizing boxes, rolls, size mixer, sizing area, and eventually from the drainage of sizing solution. Their volume is low but, depending on the recipe used, can contain high levels of BOD, COD, and TSS (16). In the case 100% synthetic warps, sizing if used, is usually carried out with lower amounts of synthetic polymers, and the generated effluent therefore has lower levels of BOD. Sizing is rarely practised in woollen or worsted fabrics from 100% wool. Yarns for use as knitted fabrics are treated with lubricants (mineral, vegetable or ester-type oils) or waxes rather than sizes.

Table 2-3: Pollution loads of textile wet operations by Cooper.

Fiber	*Process*	*pH* *($mg\ l^{-1}$)*	*BOD* *($mg\ l^{-1}$)*	*TS* *($l\ kg^{-1}$)*	*Water usage* *($l\ kg^{-1}$)*
Cotton	Desizing	-	1.700-5.200	16.000-32.000	3-9
	Scouring or Kiering	10-13	50-2.900	7.600-17.400	26-43
	Bleaching	8.5-9.6	90-1.700	2,300-14,400	3-124
	Mercerizing	5.5-9.5	45-65	600-1,900	232-308
	Dyeing	5-10	11-1.800	500-14.100	8-300
Wool	Scouring	9-14	30.000-40.000	1.129-64,448	46-100
	Dyeing	4.8-8	380-2.200	3.855-8.315	16-22
	Washing	7.3-10.3	4.000-11.455	4.830-19.267	334-835
	Neutralization	1.9-9	28	1.241-4.830	104-131
	Bleaching	6	390	908	3-22
Nylon	Scouring	10.4	1.360	1.882	50-67
	Dyeing	8.4	368	641	17-33
Acrylic/ Modacry lic	Scouring	9.7	2.190	1.874	50-67
	Dyeing	1.5-3.7	175-2.000	833-1.968	17-33
	Final scour	7.1	668	1,191	67-83
Polyester	Scouring	25-42	---	500-800	---
	Dyeing	---	480-27,000	---	17-33
	Final scour	---	650	---	17-33
Viscose	Scouring and dyeing	8.5	2.832	3,334	17-33
	Salt bath	6.8	58	4,890	4-13
Acetate	Scouring and dyeing	9.3	2.000	1.778	33-50

Source : The Textile Industry, Environmental Control and Energy Conservation (16).

2) Weaving : Weaving is carried out to convert yarns into fabrics and it is usually a dry operation. However looms employing a water jet to insert the weft yarn in-between the warp can be used for this operation. Generally, this water is not reused since it contains sizing ingredients used on the warp yarns. The generated effluent has similar characteristics to sizing wastewater end the volume is a function of the type of loom, loom speed, fabric characteristics, and size of the weaving section (16).

3) Desizing : Desizing removes the substance applied to the yarn in the sizing operation by swelling, solubilising, hydrolysing, or oxidizing the size into a soluble form (15, 19, 20). To verify this, the sizing are starch molecules. In order to desized these molecules, the starch must become the soluble molecules (20). Then, if the more soluble dextrin the more desizing is effective (19). The methods of desizing and therefore the wastewater characteristics, vary according to the size used (cited in Table 2-4). Desizing can be as simple as hot washing with detergents for synthetic sizes or more complicated, for example enzyme-augmented degradation, for starch and modified starch (21).

Table 2-4: Pollution load from desizing by PRG.

Desizing	*pH* (mg l^{-1})	*BOD* (mg l^{-1})	*TSS* (mg l^{-1})	*TDS* (mg l^{-1})	*Oil/Grease* (mg l^{-1})
Enzyme starch	6-8	3,078	6,155	1,583	288
Polyvinyl Alcohol	6-8	200	400	4,029	192
Carboxymethyl Cellulose	6-8	314	400	4,349	751

Source : A Guideline for the Planning, Design and Implementation of Wastewater Treatment Plant in the Textile Industry (21).
Note : (Fabric: 50/50 Polyester/Cotton)

The pollution load of desizing effluent results from additives used in the size recipes, surfactants, enzymes, acids or alkalis as well as the sizes themselves (22). The generated wastewater can be the largest contributor to the BOD and TS in a mill effluent (17), as indicated in Table 2-4. On the other hand, if sizing is carried out using synthetic materials BOD reductions of up to 90% can be achieved on desizing (22). The sizing recovery therefore presents one of the greatest opportunities for saving. Since starch is degraded completely to carbon dioxide and water, so there is not possible to recover for starch. While, other recipe sizing additives are PVA and CMC, can be substitute and rewarding under the proper circumstance (14). Finally, this can be simply concluded as the effluent for preparation process with chemical coagulation is the most effective way for removed the sizing suspended solids, as shown in Table 2-5 (12).

Table 2-5: Anticipated treatment removal efficiencies by US EPA (14).

Treatment Process Unit	*Range of Removal Efficiency (%)*				
	BOD	*COD*	*TSS*	*Grease*	*Color*
Primary treatment					
Screening	0-5	-	5-20	-	-
Equalization	0-20	-	-	-	-
Neutralization	-	-	-	-	-
Chemical Coagulation (removals vary with chemicals and dosage used)	40-70	40-70	30-90	90-97	0-70
Flotation	30-50	20-40	50-60	90-98	-

Remark : Adapted from US EPA Environmental Pollution Control Textile Processing Industry, October 1978.(14)
Source : Textile Process Industry(14).

4) Scouring : Scouring can be applied to both natural and synthetic materials to remove applied or natural substances. The intensity of the scouring process is dependent on the type of material.

Cotton is scoured to remove natural waxes, pectin's, spinning oils and other non-cellulosic components using hot alkaline solutions (usually caustic soda or soda ash) containing detergents or soaps. Herbicides, defoliants and desiccants used in the growing of cotton, along with fungicides such as pentachlorophenols used to prevent mildew during storage and transportation, can also arise in scouring effluents (23).

Cotton scouring waste liquors are thus chemically aggressive and may be toxic. Their solids content, resulting from the alkali and from impurities in the raw cotton material, is generally high (cited in Table 2-3). Along with desizing, cotton scouring generates very high BOD levels. These two processes thus make by far the greatest contribution to effluent BOD in the wet phase processing of cotton goods (17, 22).

When synthetic sizes are used, desizing and scouring are usually carried out in a single operation. One hundred percent synthetic fabrics (woven or knitted) require only light scouring in order to remove sizes and lubricants and the process is not normally a significant source of organic or suspended solids loading. In cases of scouring and dyeing are performed simultaneously, effluent with an increased in pollution load results (cited in Table 2-3).

Raw wool scouring is the highest-polluting operation within the textile industry (illustrated in Table 2-2). The large volumes of effluent and high levels of contaminants generated by this operation have made it an area of major concern of the industry and much research works have been carried out in this area (17, 18, 24). The pollution load results from impurities present in the raw wool (wax, suint, urine, faeces, vegetable matter, and mineral dirt) together with soap, detergent and alkali used during the scouring and washing processes. Persistent organochlorine compounds such as lindane, dieldrin, or other non-toxic substances such as organophosphates are used as parasite control agents by sheep farmers. These chemicals dissolve in grease which coats the wool. They therefore arise in significant quantities in raw wool scouring effluents (25).

Scouring of woolen and worsted fabrics is generally duplicated downstream in order to remove added substances. These include oils and weaving sizes or lubricants, which are removed by using detergents. The pollution load and volume of the effluent depend upon the strength of the scouring process and on the properties of the processed wool material itself.

Due to their non-biodegradability or toxicity, many impurities in scouring effluents, such as antistatic agents (synthetic fibers), pesticides, cotton waxes, and wool grease or wax, can pose problems in the operation of biological treatment systems (listed in Table 2-6).

5) Bleaching : Bleaching removes the natural yellowish coloring of cotton and other fibers, thereby increasing its whiteness. This operation is generally required if the finished fabric is to be white or dyed a light color. It is an oxidation process usually brought about using hydrogen peroxide, sodium hypochlorite or sodium chlorite. Auxiliary chemicals such as sulphuric acid, hydrochloric acid, caustic soda, sodium bisulphite, surfactants, and chelating agents are generally used during bleaching or in the final rinses, contributing to the pollution load (16, 17).

Bleaching wastewater usually has a high solids content with low to moderate BOD levels (was shown in Table 2-3). The dissolved oxygen content of these effluent can be highly due to the composition of hydrogen peroxide (26). Nevertheless, chloride or hydrogen peroxide can cause toxicity problems in biological treatment processes (16).

Only light bleaching, or even none at all, is required when processing 100% synthetic or wool goods, and the generated wastewater is not an important source of pollution in such cases (17).

6) Mercerizing : Mercerization is performed most exclusively on pure cotton fabrics, which are treated by a concentrated caustic soda bath and a final acid wash in order to neutralize them. Its purpose is to impart luster and also to increase dye affinity and tensile strength. Mercerization wastewater have low BOD and total solids levels but are highly alkaline prior to neutralization (16, 17). The low BOD content arises from surfactants and penetrating agents used as auxiliary chemicals (listed in Table 2-6).

Table 2-6: List of pollutants from textile wet processing operations by Nolan (17).

Process/Fibers	*Substances*		
	Inorganic		*Organic (Biodegradability)*
Desizing			
Cotton Linen Viscose	Na^- Ca^{2+} NH_4^+	SO_4^{2-} Cl^-	Carboxymethyl cellulose (SB); Enzymes (A); Fats (SB);Hemicellulose (A); Modified starches (B); Non-ionic surfactants (A); Oils (SB); Starch (B); Waxes (SB)
Silk Acetates Synthetics	Na^+ NH_4^+	CO_3^{2-} PO_4^{3-}	Carboxymethyl cellulose (SB); Enzymes (A); Fats (SB);Gelatine (A); Oils (SB); Polymeric sizes (NB); Polyvinyl alcohol (A); Starch (B); Waxes (SB)
Scouring			
Cotton	Na^+	CO_3^{2-} PO_4^{3-}	Anionic surfactants (A); Cotton waxes (NB); Fats (SB); Glycerol (B); Hemicelluloses (A); Non-ionic surfactants (A); Peptic matter (A); Sizes (A); Soaps (A); Starch (A)
Viscose Acetates	Na^+	CO_3^{2-} PO_4^{3-}	Anionic detergents (B); Fats (SB); Non-ionic detergents (B); Oils (SB); Sizes (B); Soaps (B); Waxes (SB)
Synthetics	Na^+	CO_3^{2-} PO_4^{3-}	Anionic surfactants (A); Anti static agents (NB); Fats (SB); Non-ionic surfactants (A);Oils (SB); Petroleum spirit (A); Sizes (B); Soaps (A); Waxes (SB)
Wool (Yarn and fabric)	Na^+ NH_4^+	CO_3^{2-} PO_4^{3-}	Anionic detergents (A); Glycol (SB); Mineral oils (SB); Non-ionic detergents (A); Soaps (A)
Wool (Loose fiber)	Na^+ NH_4^+ K^+ Ca^{2+}	CO_3^{2-} PO_4^{3-} Cl^-	Acetate (B); Anionic surfactants (A); Formate (B); Nitrogenous matter (U); Soaps (A); Suint (A); Wool grease (SB); Wool wax (SB)
Bleaching			
Cotton Linen Viscose Jute	Na^+ NH_4^+	ClO^- Cl^- O_2^{2-} F^- SiO_3^{2-}	Formate (B)
Synthetics Acetates		SiO_3^{2-} PO_4^{3-} F^-	
Wool	Na^+	O_2^{2-}	Oxalate (B)
Mercerising			
Cotton Linen	Na^+ NH_4^+	CO_3^{2-} SO_4^{2-}	Alcohol sulphates (A); Anionic surfactants (A); Cresols (A); Cyclohesanol (A)
Carbonising			
Wool	Na^+ Mn^{2+}	Cl^- CO_3^{2-} SO_4^{2-}	Suint (A); Surfactants (A); Wool grease (SB)

Table 2-6: (Continued 1)

Process Fibers	*Substances*		
	Inorganic		*Organic (Biodegradability)*
Fulling			
Wool	Na^+	CO_3^{2-} SO_4^{2-}	Acetate (B); Formate (B); Soaps (A); Suint (A); Wool grease (SB)
Dyeing			
Cotton Viscose Linen	Na^+ Cr^{3+} Cu^{2+} Sb^{3+} K^+ NH_4^+	Cl^- CO_3^{2-} CO_4^{2-} F^- NO_2^- O_2^{2-} S^{2-} $S_2O_3^{2-}$ SO_3^{2-} SO_4^{2-}	-Naphthol (A); Acetate (B); Amides of naphtholic acid (B); Anionic dispersing agents (A); Anionic surfactants (A); Cationic fixing agents (NB); Chloro amines (SB); Formaldehyde (A); Formate (B); Nitro amines (SB); Non-ionic surfactants; Resisual dyes (NB); Soaps (A); Soluble oils (SB); Sulphated oils (A); Tannic acid (A); Tartrate (B); Urea (B)
Wool	Na^+ K^+ NH_4^+ Cr^{3+} Cu^{2+} Al^{3+} Sb^{3+}	SO_4^{2-} SO_3^{2-} $S_2O_4^-$ CO_3^{2-} Cl^-	Acetate (B); Dispersing agents (U); Formate (B); Lactate (B); Residual dyes (NB); Sulphonated oils (A); Tartrate (B)
Polyamide	Na^+	Cl^- CO_3^{2-}	Acetate (B); Formate (B); Polyamide oligeines (U); Residual dyes (NB); Sulphonated oils (A)
Acrylic	Na^+ Cu^{2+} NH_4^+	SO_4^{2-}	Acetate(B); Aromatic amines(A); Formate (B); Levelling agents(U); Phenolic compounds(A); Residual dyes (NB); Retardants (U); Surfactants (A) Thioreia dioxide (A)
Dyeing			
Polyester	Na^+ NH_4^+	$S_4O_6^{2-}$ ClO^- NO_3^- Cl^- SO_3^{2-}	Acetate (B); Anionic surfactants (A); Anti static agents (NB); Dispersing agents (A); Dye carriers (SB); EDTA (NB); Ethylene oxide condensates (U); Formate (B); Mineral oils (SB); Non-ionic surfactants (A); Residual dyes (NB); Soaps (A); Solvents (A)
Fireproofing			
Cotton Wool	NH_4^+ Na^+ Sb^{3+} Ti^{2+} Zn^{2+}	PO_4^{3-} $F^-B^-Cl^-$ Br^- NO_3^-	Chlorinated rubber (NB); Melamine resin (NB); Syntheticresin binders (U); Tetrabishydroxymethyl-phosphonium chloride (U); Thiorea resin (NB)

Table 2-6: (Continued 2)

Process/Fibers	*Substances*		
	Inorganic		*Organic (Biodegradability)*
Mothproofing			
Wool	Na^+ K^+ Al^{3+}	F^-	Chlorinated compounds (NB); Formate (B); Pentachlor phenol laurate (NB)
Waterproofing			
Cotton Wool	Na^+ K^+ Al^{3+}	Cl^- SO_4^{2-}	Acetate (B); Dispersing agents (U); Fluoroacrylic esters (U); Formate (B); Gelatine (B); Melamine resins (NB); Paraffin wax (NB); Silicone resins (NB); Stearamidemethyl pyridinium chloride (NB); Stearate (B); Titanates (NB)

Remark : *B = Biodegradable,* *A = Biodegradable after acclimatization,* *U = Unknown,* *NB = Non-biodegradable,* *SB = Slowly biodegradable.*

Source : *Nolan, W.F "Analysis of Water Pollution Abatement in the Textile Industry", (17).*

7) **Carbonizing :** Carbonizing is performed mainly on 100% wool materials in order to remove traces of vegetable matter. The process can be carried out either on fibers in conjunction with raw scouring or at the fabric stage, depending on the level of impurities and the end use of the wool (16, 18).

Carbonizing consists of soaking the material in dilute sulphuric acid followed by drying and baking. The brittle cellulosic matter is mechanically removed in a separated machine and the material is then neutralized using sodium carbonate, rinsed and dried.

The generally low levels of organic materials in carbonization effluents are due to vegetable matter, whilst the acid treatment yields high levels of dissolved solids. When performing in conjunction with raw wool scouring, carbonizing effluent leads to a decrease in the total pollution load of the scouring waste stream (18).

8) **Fulling or Milling :** These operations are mainly restricted to woollen fabrics although some worsted fabrics are milled in practice. Fulling causes the fabrics to mate and shrink and thus become denser. The process is carried out with hot solutions of soda ash or sulphuric acid in presence of detergents and in conjunction with mechanical agitation (17, 18). The fulling solution is then drained

and the treated fabric neutralized, when acid is used, and extensively washed to remove the remaining chemicals.

Fulling wastes in combination with effluents generated by subsequent washing operations present, after raw wool scouring, are the major source of BOD in wool processing wastewaters (16, 17). Most of the BOD arises from soap, detergents, lubricants, and oils added to the wool during the production process (15).

9) Dyeing : Dyeing is carried out to add colour to the fabric. Identification of generic types of dye wastewater is complicated by the diversity of both the dye chemistry and the operational mode of the dyeing process.

In general, dye effluents have a high color content, high TDS, and moderate BOD values (15). Most of dye molecules are not biodegradable. The partial treatment of dyes by biological processes is attributed to precipitation (insoluble dyes) or adsorption on the sludge (27, 28). Wastewaters from batch dyeing of cotton with reactive dyes are usually very high in dissolved solids because this dyeing process demands a significantly high concentration of salts (up to 80 g l^{-1} NaCl) and sufficient alkali to raise the pH to between 12 and 12.5 (15).

Reagents used in dyeing can lead to toxicity. Furthermore, some dyes and surfactants can lead to inhibition of biological systems and to be toxic to fish (28, 29, 30).

10) Special Finishes : In order to improve certain properties or serviceability in a specific way, the fabrics are subjected to special finishing processes, generally following dyeing. Finishing processes involve impregnation of the fabric using a padding technique followed by a fixation step by heat. Subsequent washing may be carried out to remove residual chemicals. Properties such as soil-repellency, permanent setting, waterproof, flameproof, rotproof, and mothproof are normally induced by these finishing operations (18).

Even though they are low in volume, the effluents from these finishing operations are extremely variable in composition and can contain toxic organic substances such as pentachlorophenols and ethylchlorophosphates. A list of substances found in some finishing wastewater and their biodegradability is given in Table 5. Generally, textile wastes are characterized by high volume and extreme variability in composition, which can include non-biodegradable dyes and toxic substances. (15).

2.3 Polyester Fabric

Polyester is the synthetic fibers. This kind of fiber usually is clean and the only impurities may exert during the weaving process. The example of impurities are: the lubricants from the looms and other impurities chemicals of sizing agents (31). Because chemicals impurities are virtually absent from the kind of fibers, hence, light scouring is relatively needed for the fabric preparation (14).

Polyester fabric finishing product is usually carried out by definitely procedure: Scour-Bleach, rinses, dyes, and scour again. The sizing agents consist in the grey fabrics are PVA and Acrylic agents. Usually, PVA able to breakout by hot water, while Acrylic is able to crumble by weak alkali solutions.

Caustic Soda (NaOH) is not the actually the desizing agent, but some sizing agents like acrylic ester polymer is able to be crumble. This polymer is the best desired for sizing the synthetic fibers. After all, these synthetic fibers were weaves into fabric by the water-jet loom. This type of fabric can be easily desized with redox-reaction of caustic soda or Sodium hydroxide (31).

The properties of sizing agents for the synthetic fibers, acrylic ester polymer and PVA, can be prepare by warming it in the batch. These sizing agents are insoluble and structure are shown in Figure2-2.

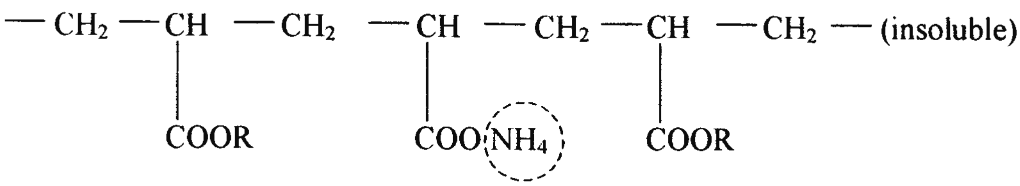


Figure 2-2: The chemical structure of sizing to the polyester fibers (31).

After the agents were sized into the fiber, at this time, fibers are ready to weave in the loom. The sizing agent is formatting it as a film coated into the fibers of the fabric. The mechanism was appeared the ammonium group evaporated (illustrated in Figure 2-3).

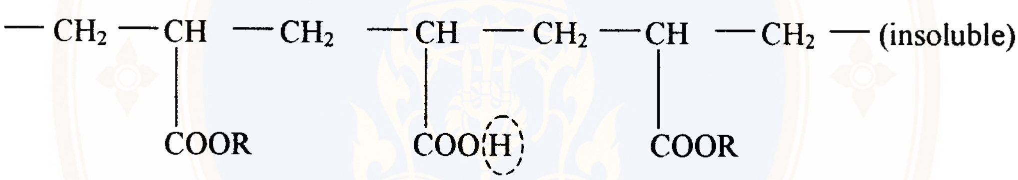


Figure2-3: The chemical structure of fixed (sized) polyester fabric (31).

Finally was the desizing process. When fabric are being desizing in the hot batch solution like, sodium hydroxide, the thin film coated sizing agent in the fibers are eliminating. The chemical mechanism cited below: (illustrated in Figure 2-4)

After scouring, the material is rinsed to remove excess chemicals and to prepare it for dyeing. The polyester scour wastes average 500 to 800 mg/l of BOD. The processing of 100 pounds of polyester fabric will produce 15.5 pounds of BOD, of which 90%is contributed by the anti-static compounds used for lubrication and sizing (Figure 2-5; 14).

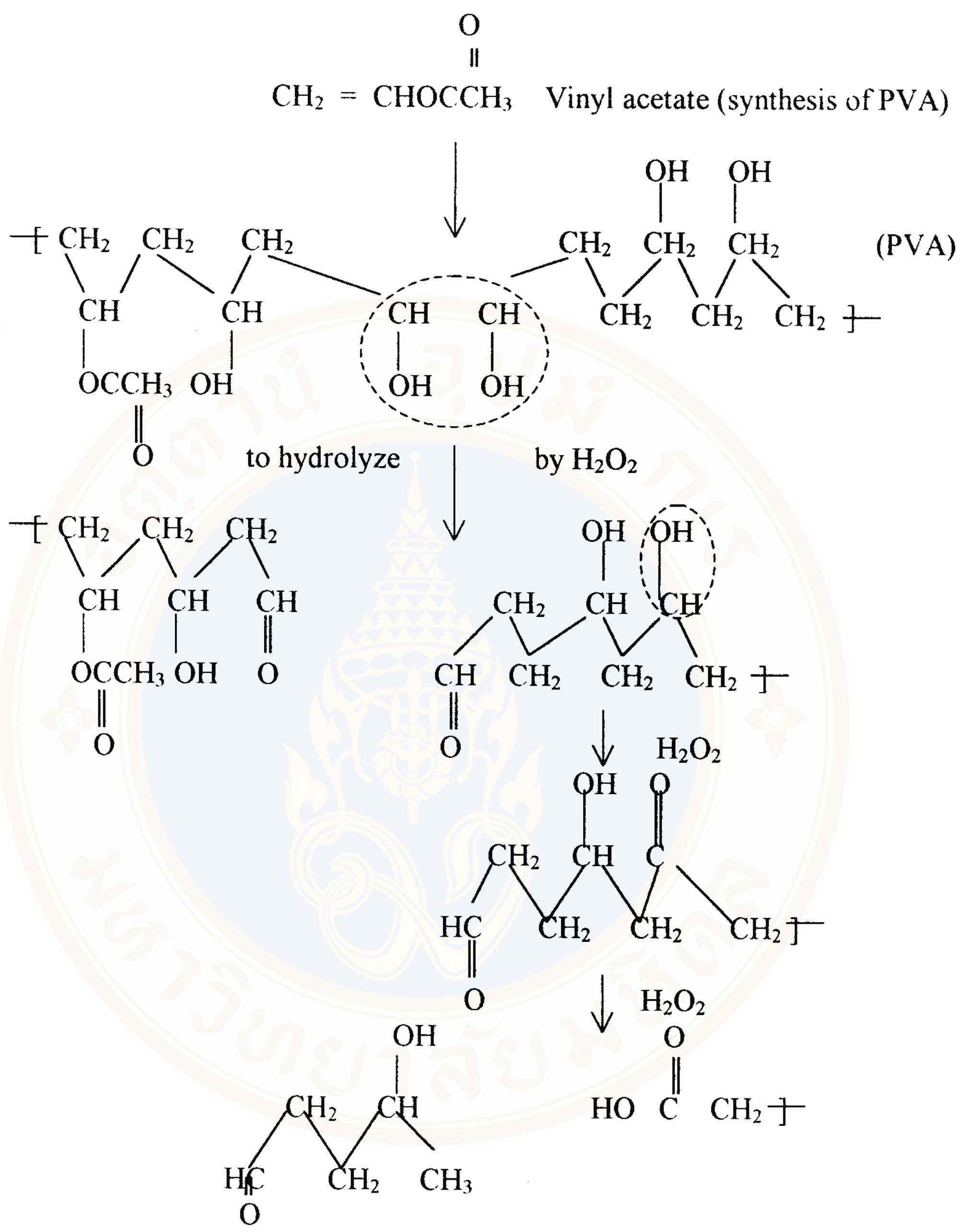


Figure 2-4: The synthesis of PVA and the crumble of PVA by hydrogen peroxide (31).

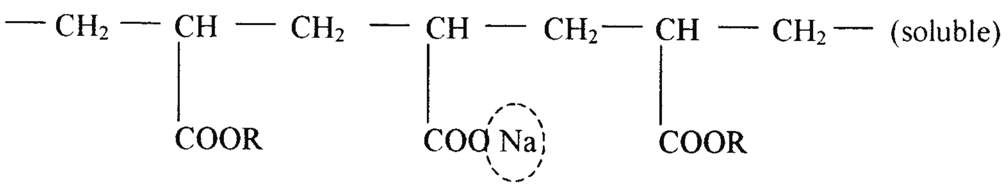


Figure2-5: The chemical structure of the final polyester fabric fibers and the replacement the sodium ions to the fiber of the fabric (31).

Table 2-7: An example of pollution loads contributed by polyester fiber processes by US EPA (14).

Process	pH	*BOD (mg/l)* 1000 Lb Product	*BOD (mg/l)* Contribution of Total (%)	*Total Solid (mg/l)* 1000 Lb Product	*Total Solid (mg/l)* Contribution of Total (%)	*Suspended Solid (mg/l)* 1000 Lb Product	*Suspended Solid (mg/l)* Contribution of Total (%)	*Water use (gal)* 1000 Lb Product
Scour	N/I	15 - 25 (500 - 800)	32 - 3	25 - 35 (N/I)	37 - 9	5 - 15 N/I	45 - 13	3,000 – 5,000
Dye	N/I	15-25 (480-27,000)	32 - 86	30 - 200 (N/I)	44 - 52	-	0	2,000 – 4,000
Final Scour	N/I	15 - 25 (650)	32 - 3	10 - 50 (N/I)	15 - 13	3 - 50 (N/I)	27 - 43	2,000 – 4,000
Special Finishing	N/I	2 - 80 (N/I)	4 - 8	3 – 100 (N/I)	4 - 26	3 - 50 (N/I)	28 - 44	1,000 – 3,000
Grand Total	N/I	47 - 930	100	68 - 385	100	11- 115	100	8,000 – 16,000

Source : Textile Processing Industry (14).

2.4. Coagulation

In water-treatment plants, chemical coagulation is usually accomplished by the addition of trivalent metallic salts such as $Al_2(SO_4)_3$ (aluminium sulfate), $FeCl_3$ (ferric chloride), and $Fe_2(SO_4)_3$ (ferric sulfate). Although the exact method by which coagulation is accomplished cannot be determined, four mechanisms are thought to occur. These include ionic layer compression, adsorption and charge neutralization, entrapment in a flocculent mass, and adsorption and interparticle bridging (32).

Ionic layer compression

The amount of ions in the water surrounding a particle or colloid has an effect on the decay function of the electrostatic potential. When a high ionic concentration compresses the layers composed predominantly of counter ions toward the surface of the colloid. If this layer is sufficiency compressed, then the van der Waals force will be predominant across the entire area of influence, so that the net forcewill be attractive and no energy barriers will exist (32).

Adsorption and charge neutralization

Since the quantity of the ions is of prime importance in the theory of adsorption and charge neutralization. Aluminum sulfate (alum) is used to demonstrate the mechanism below.

$$Al^{3+} + H_2O \longrightarrow AlOH^{2+} + H^+$$

$$Al^{3+} + 2H_2O \longrightarrow Al(OH_2)^{+} + 2H^+$$

$$7Al^{3+} + 17H_2O \longrightarrow Al_7(OH)_{17}^{4+} + 17H^+$$

$$Al^{3+} + 3H_2O \longrightarrow Al(OH)_3 + 3H^+$$

Figure 2-6: The ionization of aluminum sulfate (32)

The ionization of aluminum sulfate in water produces sulfate anions (SO_4^{2-}) and aluminum cations (Al^{3+}). The sulfate ions may remain in this form or combine with other cations. However, the Al^{3+} cations react immediately with water to form a vaiety of aquometallic ions and hydrogen (32).

The ions formed become part of the ionic cloud surrounding the colloid, moreover, these ions have a great affinity for surfaces, are adsorbed onto the surface of the colloid where they neutralize the surface charge. Once the surface charge has been neutralized, the ionic cloud dissipates and the electrostatic potential disappears so that contact occurs freely (32).

Sweep coagulation

The $Al(OH)_3$ forms in gelatinous flocs that are heavier than water and settle by gravity. Colloids may become entrapped in a floc as it is formed, to they may become enmeshed by the sticky surface as the flocs settle.

Interparticle bridging

Large molecules may be formed when aluminum or ferric salts dissociate in water. Synthetic polymers also may be used instead of or in addition to, metallic salts. These polymers may be linear or branched and are highly surface reactive. Therefore, several of the polymer-colloid groups may become enmeshed, resulting in a settable mass.

Aluminum sulfate, the most commonly used coagulant in water purification, is most effective between pH range of 5.0 and 7.5. Although less expensive, this coagulants (alum), sometime is more advantageous to synthetic polymers in an additional, because the polymers bind small flocs together to make lager masses for faster settling.

Alum dosage may range variety, depending upon the turbidity and nature of the water. With regard to coagulation, this water can be grouped into the four general groups describe below:

Group 1: High turbidity -low alkalinity. With relatively small dosages of coagulant, water of this type should be easily coagulated by adsorption and charge neutralization. Depression of pH makes this method more effective, since the aquometallic ions are more effective at lower pH values. However, care should be used to prevent excessively law pH.

Group 2: High turbidity-high alkalinity. The pH will be relatively unaffected by coagulant addition. Because of the high alkalinity, adsorption and charge neutralization will be less effective than in waters of low alkalinity. Higher coagulant dosage should be used to ensure sweep coagulation.

Group 3: Low turbidity-high alkalinity. The small numbers of colloids make coagulation difficult, even if the particle charge has been neutralized.

The principal coagulation mechanism is sweep coagulation with moderate coagulant dosage. Addition of some turbidity may decrease the amount of coagulant needed.

Group 4: Low turbidity -low alkalinity. The small number of colloids make coagulation difficult, and low alkalinity prevents effective $Al(OH)_3$ formation. Additional turbidity can be added to convert this water to that of group1, or additional alkalinity can be added to convert it to a Group 3 type. It may be advantageous to add both turbidity and alkalinity (32).

Since, the coagulation can be employed for treating the wastewater or purified the water, many researchers had defined coagulation in purifying the wastewater effluent of textile dyeing mills. The optimum dose usage applies for textile-dyeing mills is 250 mg/l with the pH of 7-8 at the simultaneous rate (5,10). While, Yongyuth Boonkant, stated that for the dyestuff to remove the SS from the waste stream, better acquire the dosage of alum at 200 mg/l with pH of 9 and 250 mg/l with pH of 8. Insufficiency, to reuse the alum sludge when there is highly concentration of TSS (33). Lin *et al.* stated that the alum 2-3 ml may sufficient in combining with the ozonation treatment (34).

2.5. Precepts in Preventing Pollution Occurrence in Textile Industry

During the last decade, textile industry in Thailand was drastically augmented to be one of the greatest industries. It's exported value was continuously climbed up to the topmost for many years. The more the augmentation of textile industry, the more the increase of new textile mills e.g. fiber producing mill, spinning mill, weaving and knitting mill, and dyeing-printing mill. With poor and limited environmental management, many mills had been inevitable sources of environmental pollution. In order to maximize dyeing process efficiency and production scale leading to the minimization of the production cost, and the decrease of wastewater, polluted air, and garbage produced, a certain production process that can make the minimization of water, dyes, chemicals, and energies being used in textile industry possible should be developed and employed. Moreover, wastewater treatment cost will be cheaper. The following precepts, as the environmental management guides, should be followed step by step to prevent the pollution caused by textile industry.

- Avoid or prevent to increase any waste.
- Reduce the waste produced.
- Reuse all materials if possible.
- Recycle chemicals, dyes, water, etc. for using in the next production.
- Recovery materials as much as possible.
- Treat or dispose waste produced by appropriate means.

To make these precepts practicable, the quantity of inputs e.g. chemicals, dyes, water etc. as well as the outputs e.g. wastewater, dregs, etc. produced daily should be known. Those information are necessary and worthwhile in planning management guide to setback the pollution occurrence in textile industry (10, 12).

CHAPTER III

METHODS AND PROCEDURES

3.1 Framework of the Study

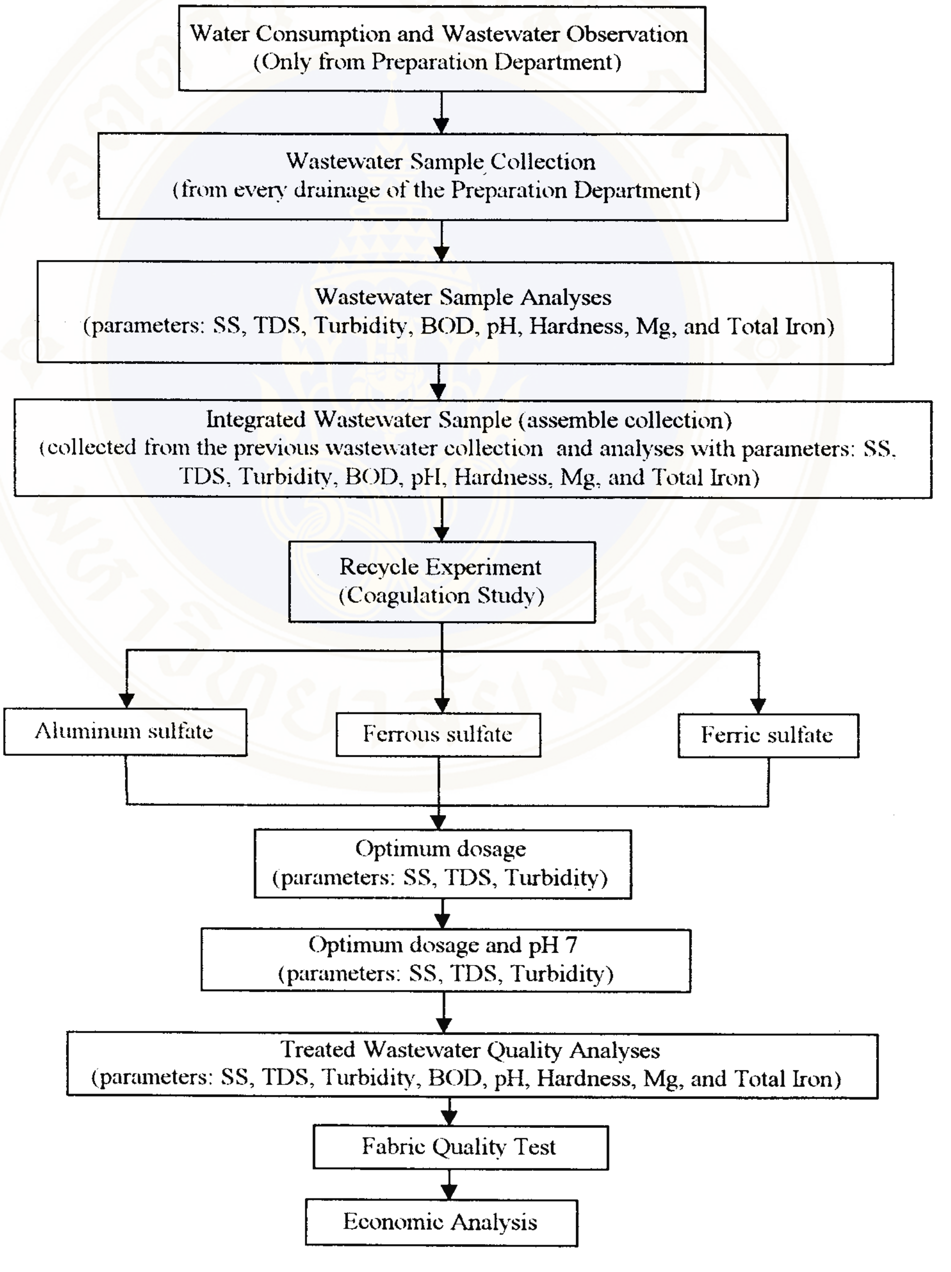


Figure 3.1: Framework of the study

In order to carried out this research work, the above frameworks are followed. It has been conducted using the samples collected from the a commission textile dyeing mills of the Dee Yuang Dyeing and Finishing Company Limited that produces the dyed 100% polyester fabrics, which are sold and supply to the local market. This mill located at the south western part of Bangkok Metropolis, Krathumbaen District, Samutsakorn Province. All the samples were analysed at the Faculty of Environment and Resource Studies, Mahidol University.

3.2 Apparatus and Materials

All apparatus and materials used in this work were :

Apparatus

- The uniform stirrer, *Phipp and Bird Inc.* Series .
- Beakers.
- *Rapid Color Dyer Simulator* with probe or pots as shown in Figure 3.2.

Figure 3.2: *Rapid Color Dyer Simulator*, with probe.

Materials

- Coagulants (AR grade of Aluminium sulfate, Ferrous sulfate and Ferric sulfate).
- Sodium hydroxide 50% (w/v).
- Concentrated Hydrosulfuric acid.

- Hydrosulfuric acid 1N.
- 100% Polyester gray fabric (2.5 gram).
- Treated wastewater samples.
- Sodium hydroxide (NaOH) 50% (w/v).
- Detergent (non-ionic), *UNIPAL JET* of *Union Compound Co., Ltd.*
- Stabilizer and sequensterings, *KAOSTAB-02*, of *Kao Industrial (Thailand) Co., Ltd.*
- 0.1% of I_2 and 1.0% of KI solution prepared by concentrated Iodine N/50. Weighed 15 grams of Potassium Iodide (KI) and dissolved in 20 ml. of pure water, then mixed platelet of Iodine (I_2) well stirred into a homogenous solution. Finally, diluted into a liter of solution.
- Boric Acid in Iodine solution prepared by Boric Acid (H_3BO_3) dissolved in 30 grams in the Iodine Solution (N/50) to a liter solution. Warmed the solution into a homogenous solution (31).

3.3 Methods

The methods had been conducted in this work were as follows :

3.3.1 Water Consumption and Wastewater Observation

The water consumed in this mill was the ground water, which was drawn up within the mill's boundary. In general, the groundwater were rich in hardness thus it was treated to be more consumable and then was kept in the reservoir which ready to be used. The treated groundwater was used in two departments of the mill, namely Preparation Department and Dyeing Department. Figure 1-1, illustrated the source of influent and effluents, where the source of influent was coming from a single source of groundwater reservoir. The volume of water consumption of the mill's process, Preparation Department and Dyeing Department, was calculated from the input flow-rate of water.

This study focused on the preparation department, as demonstrated in Figure 3.2, because this department is potentially implemented for the wastewater recycle options. This department employed mostly the batch jigger dyers, which serve as the desized-scoured-bleahced for the next process dyers. As every jigger is equivalent in efficiency and the product of 100% polyester fabric is dyed. Although, the production is occasionally employed a bit difference, but the appearance of wastewater quality is more or less the same. Therefore, only one jigger was selected to be studied.

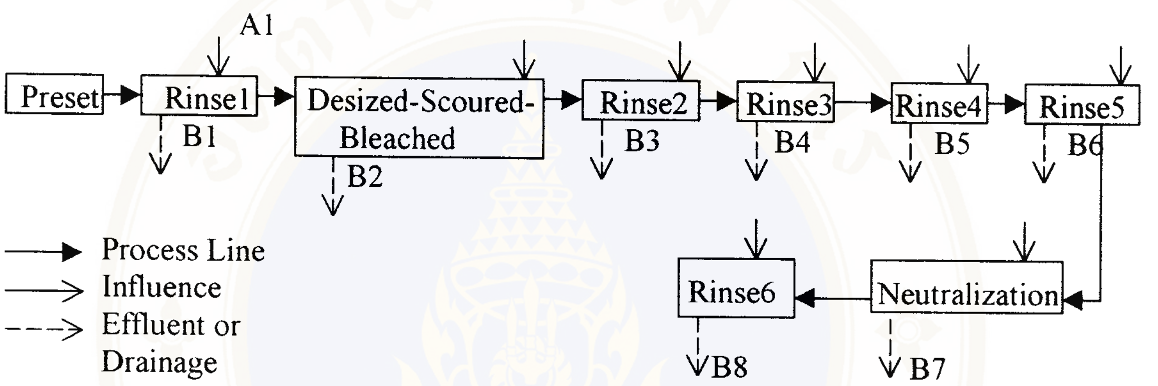


Figure 3.3: The diagram of the dyeing preparation process.

3.3.2 Wastewater Sample Collections

Two series of sample collections were follows

3.3.2.1 Influent and Effluent Sample Collections: According to the mill's routine operations, in the Preparation Department, wastewater was generated and drained to the central treatment plant. As the diagram in Figure 3.2, cited the sites of wastewater sample collection. And Table 3-1, are the labeling substitute at different sites of wastewater sample collections, as belowed. The entirely nine samples, as labeling A1 and B1 to B8, were collected by grab sampling method. Every samples were collected in each 20 liters of polyethylene container, then were preserved at the 4°C until they were analysed. Before going to the next collection, the water and wastewater properties must be considered to identify the recycled possibility of each step. The revealed results was to be judged and designed for another following wastewater integration sample collection.

Table 3-1: The sample label, whereas, each sample was collected and represented at each site of the sample collections.

Sample Labels	*Sample Representation*
A1	The raw water from the reservoir for preparation usage.
B1	Wastewater generated from washed or rinsed the gray by hot water (Rinsed 1).
B2	The waste solution collected after treated the gray fabric with chemical solution has Desized-Scoured-Bleached like NaOH, soap, and hot water.
B3	The wastewater collected after first washing the fabric treated by Desized-Scoured-Bleached (Rinse 2).
B4	The second washing wastewater after Desized-Scoured-Bleached (Rinse 3).
B5	The third washing wastewater after Desized-Scoured-Bleached (Rinse 4).
B6	The fourth washing wastewater after Desized-Scoured-Bleached (Rinse 5).
B7	The wastewater disposed from the Neutralization process, treated with acetic acid.
B8	The final wash with the fabric to get rid of the acetic acid.

Source : Figure 3.2

3.3.2.2 Integrated Wastewater Sample Collections: After the analysis of influent and effluent samples were conducted and the results revealed, the integrated wastewater collection were designed. As these samples will be used as the media for coagulation study. Therefore, some steps of wastewater, which is highly loaded in turbidity, suspended solid (SS) and Total suspended solid (TDS) will be deleted.

Eventually, this sample will served as the wastestream to be recycled. In case, each selected steps effluents were equally collected (20 liter per steps), then mixed, and kept it in the polyethyene container at 4°C, until ready to be analysed. This sample will labelled as " I".

3.3.3 Wastewater Sample Analyses.

After the samples were collected and preserved, all of samples will be analyzed for revealing their physical and chemical properties of wastewater quality in laboratory. Eight parameters, as listed in Table 3.2, were analysed . The method used for wastewater quality analysis, as listed in Table 3.2, were conducted in the manner of the APHA, AWWA, and WEF "Standard Methods for the Examination of Water and Wastewater"(35).

Table 3-2: The parameter measurement in both water and wastewater quality were summarized.

Parameters	*Probes, Measurements, and Methods*
Suspended Solids (SS)	Suspended Solid Dried
Total Dissolved Solids (TDS)	Total Dissolved Solid Dried
Turbidity	Naphelometric Method
BOD_5	Azide Modification
pH	pH meter
Hardness	Titricmetric Method

Source : APHA, AWWA, AND WPCE, Standard Methods for Examination of Water and Wastewater, 1995 (35).

3.3.4 Coagulation Experiment.

At this stage, coagulation process was employed to aim the increasing rate of sedimentation, since coagulation was the mechanism to agglomerate the colloid particles or suspended solid to the larger gravitational size. At this part of the experiment, Jar test method was conducted to determine the optimum dosages of the coagulants. This coagulation was conducted with three coagulants like of Alum or aluminium sulfate {$Al_2(SO_4)_3$}, ferrous sulfate ($FeSO_4$) and ferric sulfate {$Fe_2(SO_4)_3$}.

3.3.4.1 Study of the Optimum Dosage of Coagulant.

The integrated wastewater samples were dosed with various amounts of three different coagulants as the Jar Test procedure listed below. These different amounts of coagulants revealed the different rate of sedimentation at various dosages.

The Jar Test procedure listed were:

- Make up stock of each coagulant solution using 100 grams of each coagulant in 1 liter of water; in order to get the concentration of 100 mg/l.
- Separately pouring the collected integrated wastewater samples (I) into several beakers (1 litre).
- Marked a beaker as a control, while the rest of beakers were dosed with different concentration of coagulant with gradually increase each beaker from 100 mg/l to 200mg/l, 300 mg/l until the reaction of sedimentation is met.
- Place the beakers to the uniform stirrer using rapid mixing with the constant speed of 100 rpm for 3 minutes, then follow with slow mixing at 40 rpm for 10-20 minutes , and finally 25 rpm for 30 minutes respectfully. After the mixing was done the beaker were left until the sedimentation was accomplished or 5 hours.
- After the coagulation was taken place, the top part of treated wastewater from each beaker was collected to be analysed for Turbidity, Total dissolved solid (TDS), and Total suspended solid (TSS) to reveal the required properties for wastewater recycle.

3.3.4.2 Study of the Optimum Dosage of Coagulant at pH 7.

Since, some research discovered for the coagulant to floc and sediment at the neutral media (pH 7). Therefore, integrated wastewater samples were initially adjusted to pH 7 before dosing with various amounts of three different coagulants as the Jar Test procedure listed.

As the accepted water quality used in the preparation department must has the turbidity lower than 30 NTU, therefore the most effective treated wastewater (turbidity lower than 30 NTU) with lowest consumption dosage of coagulants will be selected. In order to determine the water quality (as parameter in Table 3.2) and conduct the fabric quality test, the volume of chosen samples from each coagulant have to be increased applying the selected optimum dosage with 2 litres of integrated wastewater sample

3.3.5 Fabric Quality Test

After the actual optimum dosage of treated wastewater was discovered and volume increased. The treated wastewater was subjected to the *Rapid Color Dyeing Simulator* by *RAPID-LABORATORY LARBORTEX LABORTORY DYEING & FINSHING SYSTEM* (Figure 3.2), to indicate the efficiency of treated wastewater in the mill usage. This apparatus is situated in Dee Yuang Dyeing and Finishing Co., Ltd. This dyeing simulator instructions are listed below.

- Taken a 2.5 grams of gray sample fabric put into the *Rapid Color Dyer Simulator* probe or pot along with the Sour-Bleach solutions like 15 ml. of NaOH, 1 ml. of detergent (non-ionic), 0.5 ml. of stabilizer and sequensterings, with 100 ml. of treated wastewater.
- Enclosed the pot or probe. Set the temperature to 90°C and kept it for 15 minutes then left until it is cooled.
- Opened the pot or probe, taken out the fabric then ironed or dried it.

- Dropped each indicator, 0.1% of I_2 in 1.0% of KI solution and Boric Acid (H_3BO_3) in Iodine solution, on the fabric then observed the color change. If the color change as listed below (Table 3-4), the efficiency results will be discovered

Table 3-3: The coloured appearance of the gray fabric after treated with KI and Boric acid solution. (20, 31)

Coloured Appearance	*Represent*
KI solution	
Dark blue	desizing is ineffective
Light blue	most sizings (starches) are desized
Violet red	sizing (starches) turns to Dextrin
Yellow	desizning is effective
H_3BO_3 Acid in Iodine solution	
Dark blue/green	desizing is ineffective
Light blue	most sizings (starches) are desized
Yellow	desizning is effective

Source: Kasaem Phephatpanyanukun (31).

3.4 Data Analyses.

3.4.1 Conceptual Design.

According to the received data, the conceptual design of the treatment and recycled wastewater had been considered and calculated for the system construction. These data were also used for the assessment of the economic analysis in the next part of this work.

3.4.2 Economic analysis.

This study is to investigate the possibility of wastesteam recycle from the textile dyeing preparation process. In order to meet the requirement for the preparation process, some wastewater treatment must be applied. This application of the treatment exerted some cost to be manipulated. At the same time, there should be some cost needed for plant construction. Therefore, the cost analysis is needed to take a study in the cost of both operating cost and plant construction investment..

For this analysis, a project acceptance or worth was rigid for the Benefit and Cost Ratio Analysis to be determined. Since, the project was hardly defined the term "Benefit". Usually benefits were occurred indirect ways. Mostly the Cost was exerted almost every part of plant treatment. Thus, Cost Comparison Method was the best way to determine by the project worth or acceptance (36). Since, then, the mill was having the pretreatment plant for the total water consumption. If this project were induced, then would be an investment project. Then the cost needed to compare and weight on the possibility of the project.

In order to analyse the project acceptance on the investment, the cost comparison must determine in two cases. According to the mill consumed groundwater to proceed for the production, so the cost exerted was electricity bill for pumps and new pumps adhered. The cost pumps (1) was 800,000 Baht for the whole set. After the groundwater was pumped, before consumption, groundwater would be treated in the "Soft-watering Plant". Again this plant exerted the operation cause the operational cost like the chemical cost (1). Therefore, the water consumption, itself, exerted the cost in three categories were groundwater cost, chemical cost (chemical cost (1)), and the electricity cost (electricity cost (1)).

After groundwater being consumed, before disposal to the municipal cannel, treatment was required for the wastewater to discharge in the acceptance quality manner. This activity, in addition, may cause cost to exert. The cost exertion was the electricity cost to run the turbine for disturbance of wastewater, because the mill employed Activated Sludge for final treatment. Labor was a necessary requirement, because some portions of the plant were not automations, which need labor to watch over the treatment plant. Since the groundwater and the total consumption plant is exist and operated daily in the mill. Thus, civil and mechanic constructions were not accounted in the recycle treatment plant. Finally, these costs were grouped as a case for the Cost Comparison Method (36).

For the Recycle Plant, the manipulation of the civil and equipment were included in the account. Besides, the groundwater was added into the plant for increase the volume to the required consumption. Furthermore, electricity was billed for the pump efficiencies into the recycle plant. Consequently, the costs were kept into an account for recycle preparation wastewater cost calculation. These represented another case to be compare with the previous case in the Cost Comparison Method (36).

The comparison of costs in this work was distinguished into two Cases:

Case 1: The cost of the underground water consumption.

Case 2: The cost of the underground water and some recycled water consumption.

By the criterion of:

- The rate of cost of the pumping groundwater was 7 Baht per cubic meter.
- The Preparation Process water consumption was 180 cubic meters per day.
- In case of consumed underground water with some of the recycled water, it is necessary to construct the wastewater treatment higher than 180 cubic meter per day and recycle plant approximately 160 cubic meters per day.
- Electricity consumed each day, cost 1.87 baht per kilowatt-hour.
- The cost of coagulant was judged from the recycle experiment, which contained highest efficiency of coagulation, reuse, and cost would be increasing 5 percent in every 5 year.
- 20 years project.
- The cost of mechanical maintenance at 10 percent of the construction cost and need to be expire within 10 years.

- Electricity cost (1) refers to the groundwater pump power supply cost.
- Electricity cost (2) refers to the power consumed by the Recycle Plant.
- Electricity cost (3) refers to the power to rotate the turbine in the Activated Sludge Plant.
- Chemical cost (1) refers to the chemicals consumed for the "Soft-watering Plant" to supply for whole mill.
- Chemical cost (2) refers to the Hydrosulphuric acid (H_2SO_4).

In order to find the benefit received from the modified process, the criterion of Incremental Return has been applied to find the payback period of the project. The Incremental Return could be calculated by the difference between operating cost of present system and the cost of both investment and operating cost of the modified process.

$$Incremental\ Return = Cost\ of\ present\ system - Cost\ of\ modified\ system$$

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Wastewater Consumption

The result of the mill's wastewater observation was discovered that the mill produced or dyed only 100% polyester fabrics. Based on the available data, the production process is highly demanded in water consumption. Since water is the primary resource of the mill's production, therefore the mill had divided the area into departments for convenience of the assembly line production. At each department consist of several types of machinery. The semi-continuous washer machine and jiggers employed for preparation process, while the dyeing process used the jet and continuous dyers.

Generally, the mill's water was mainly used in two departments, the preparation and dyeing department. The dyeing department consumed highest volume of 70-80%, since the water used in this department was tremendously consumed in cleaning each batch dyeing, while the preparation department was adversely. In addition, the routine implementation in dyeing department was more varied in chemicals usage than in the preparation department in which the chemicals were nearly the same in every batch productions.

In case of wastewater, It is found that the mill produced about 950 m^3/day or 24,700 m^3/month. However, the wastewater from dyeing preparation process was generated only 16-19 % or approximately 150-180 m^3/day.

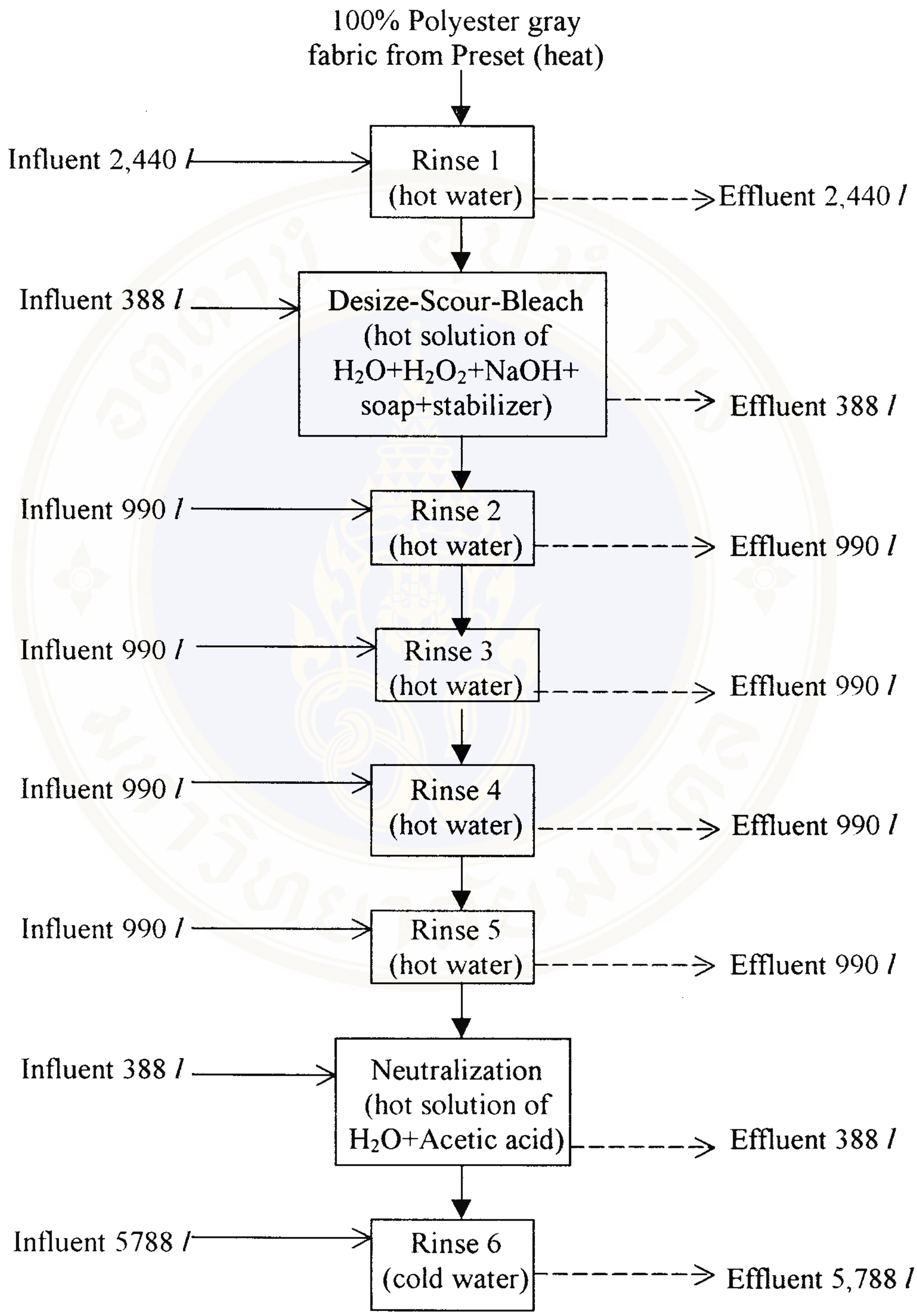


Figure 4.1: Water consumption at each step of Desized-Scoured-Bleached process in a single batch.

From Figure 4.1, it is demonstrated that, each volume of the influent and effluent were not constantly the same. This is due to the overflow technique with different flow-rates need to be applied in some step of the process. The detailed daily water consumption in each step of preparation process is shown in Table 4-1, it can be seen that the average water usage of the process (180,804 l/day or 181 m^3/day) was less than the result (365 m^3/day), studied by US. EPA (14). As the working days per month were 26 days, then the total volume of generated wastewater was approximately 4,700,904 l/month or 4,700 m^3/month. These details serve as data for the wastewater recycle strategies.

Table 4.1. Daily water consumption at each step of preparation process.

Categories	*Desized-Scour-Bleach (at each process)*				
	Rinse (warm)	*Scour-Bleach*	*Rinse (warm)*	*Neutralize (Acetic)*	*Rinse (cold)*
Average Batches per day [a]	13	64	39	27	13
Batches Volume (liter) [b]	388	388	388	388	388
Batch Proceeded Time (min.) [c]	60	60	60	60	60
Total Batches Time (min.) [a] x [c] = [d]	780	3,840	2,340	1,620	780
Overflow rate (liter/min.) [e]	34.2	0	10.0	0	90.0
Amount of water overflow per batch (liter) [c] x [e] = [f]	2,052	0	600	0	5,400
Amount of water per batch (liter) [b] + [f] = [g]	2,440	388	988	388	5,788
Amount of Wastewater generated in each step (liters/day) [a] x [g] = [h]	31,720	24,832	38,532	10,476	75,244
Total amount of wastewater generated in Preparation Process	*180,804 (liters/day)* *4,700,904 (liters/month)*				

4.2 Water and Wastewater Quality

4.2.1. Water and wastewater from preparation process.

According to the mill's operations, there has been some difference occurred between each step of preparation, namely the chemical treatment only occurs in one batch, which means desizing, scouring, and bleaching reacts in a process while washing and neutralization appeared six times. Therefore, eight wastewater sample (B1 to B8) were collected from the preparation department's effluent (Figure 4-1), and then were analyzed in comparison with water influent (A1).

Results of the water and wastewater quality have been shown in Figure 4-2 (Table A1 in Appendix A). It can be seen that, sample A1 that was the treated water from the reservoir tank appeared not polluted. The highest volume of waste appeared on wastewater samples of B1 and B2 in comparison with B3, B4, B5, B6 B7 and B8. However, B2 revealed the high volume of SS (765 mg/l) than B1 (575 mg/l), while the rest of samples (B3 to B8) were slightly high Other parameters such as TDS, Turbidity, BOD, and Hardness were ranged the constituted as the SS. Simplified these results (see Figure 3-2) stated the batch solution of B1 as the initial wash of sizing waste and dirt eliminated from the fabric; while B2 was the desized-scoured-bleached chemical like to eliminate the sizings which cannot be eradicated easily (31). Such as caustic soda (NaOH), hydrogen peroxide (H_2O_2), soaps (non-ionic) or detergents, and stabilizers including the remained sizing and dirt. These results were agreed with work done by Cooper (16). Since the B2 contained the highest volume of waste and B3, B4, B5, and B6 were the washing batch, therefore the effluent waste of these batch were decreasingly appeared. This phenomenon exerted because the constituent was eliminated out of fibers by washing with hot water.

Refer back to the sample B2, the "stabilizer" was employed in the desized-scoured-bleached reaction batch to aid the bleaching agent, Hydrogen Peroxide (H_2O_2), to fully oxidized the target fibers. As stabilizer used was Sodium Silicate which is best available along with Magnesium ions (Mg^{2+}), hence the chemical

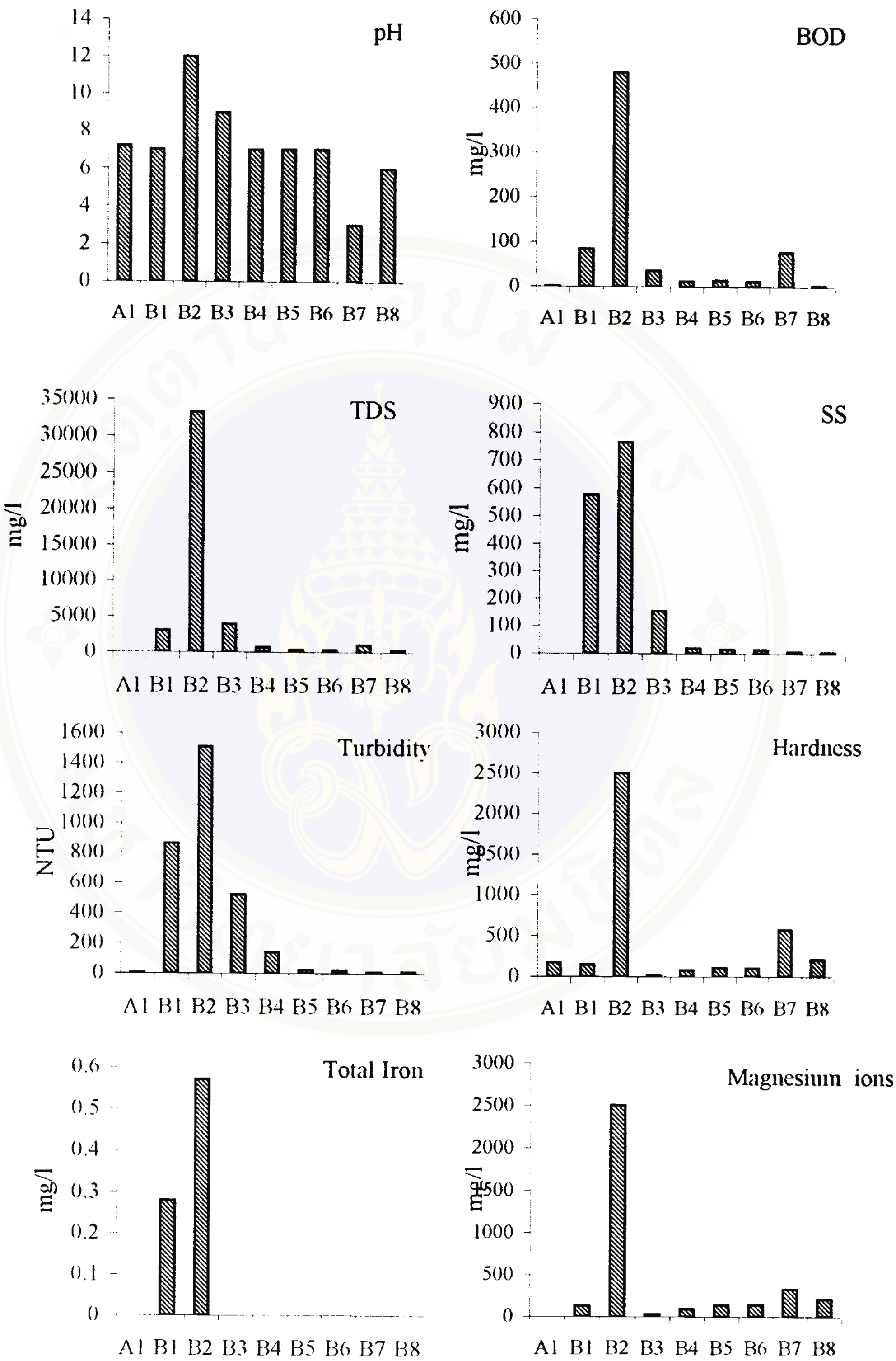


Figure 4-2: The Comparison of Water and Wastewater Quality.

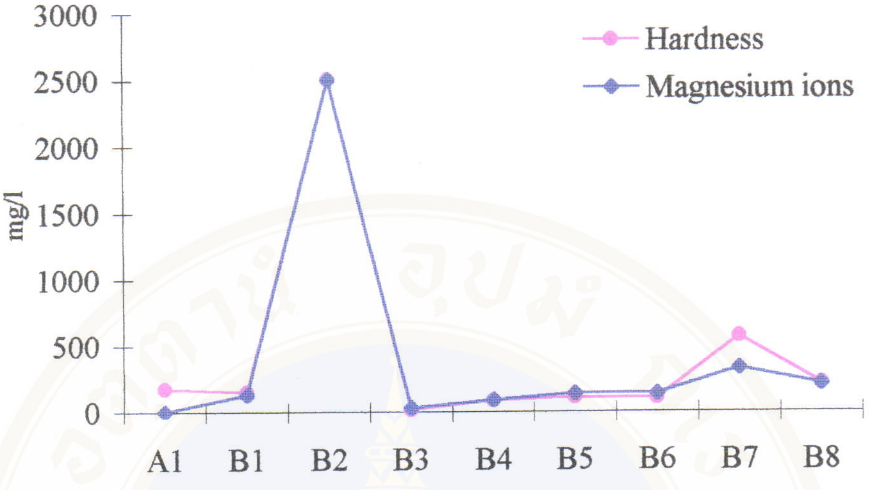


Figure 4-3: The compared parameters between hardness and magnesium obtained in the wastewater

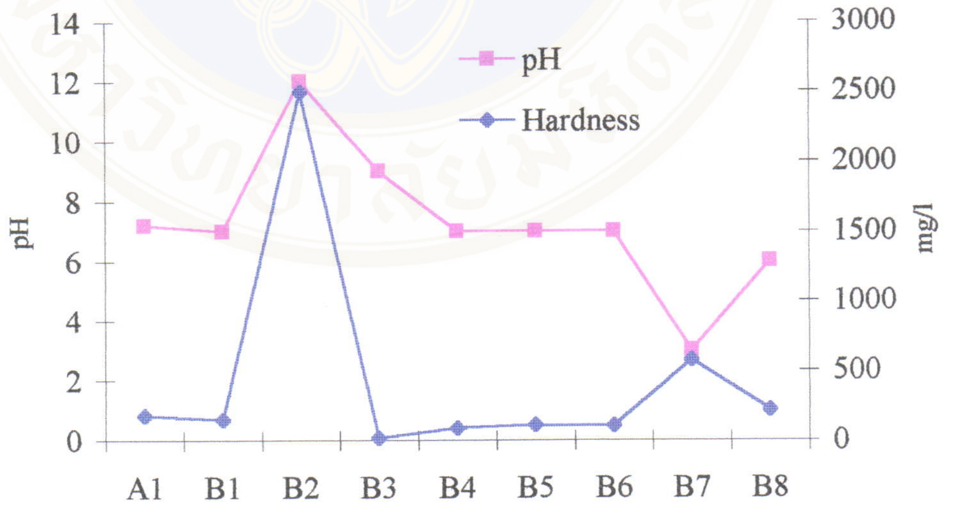


Figure 4-4: The compared parameters between pH and hardness obtained in the wastewater

venders blended the stabilizer constituent with $MgCl_2$ or $MgSO_4$ (35). Consequently, the Magnesium was highly seen in B2 and gradually decreased in B3, B4, B5, and B6. Magnesium content was again increased in B7 and then decreased in B8 due to it was removed from the fabrics with acid at neutralization step. As shown in Figure 4-3, hardness and Magnesium content obtained from the preparation process effluent were proportionally varied according to the concentration of each batch effluent

As data received, the parameters were illustrated, solely, B1 and B2 carried the highest load of all parameter wastewater. These contributions of b1 and B2 were unacceptable to be recycled, therefore the rinsed water or B3 to B8 were the possible wastewater that could be applied for recycle. The wastewaters from B3 to B8 were to be grouped and labeled as "I" for further coagulation experiment.

4.2.2. Integrated wastewater from preparation process

As previous study, it is discovered that the wastewater from B3 to B8 could be recycled as they carried a very low waste load in comparison with B1 and B2.. In addition, focused Figure 4-1 may understand that the influents or water consumption due highly during washing process. Thus, the further implementation to be proceeding some treatment must be applied. Jar test method has been used to examine and as the data collection or analyst technique on the treatment implementation proceed. Due to the facts that washing water or Rinse 2 to Rinse 6 consumed the largest volume of water. Therefore, the experiment conducted by mixing the sample B3 to B8 as I. So, by mixing the effluent can due to the actual, conceptual implementation for recycle wastewater. Table 4:3 cited the quality of the integrated wastewater and treated groundwater sample, which all parameters would act as the initial quality of wastewater before treatment and the required water quality.

From Table 4.3, it can be seen that Integrated wastewater quality, after the water was grouped (B3 to B8), was more polluted than the treated groundwater (A1). It is also discovered that integrated wastewater was highly in alkalinity (pH 9.5), more suspended solid (182 mg/l), total dissolve solids (1,342 mg/l), turbidity (540 NTU), BOD 189 mg/l, hardness (264 mg/l) and Magnesium (248 mg/l) than treated groundwater except for total iron which was not detectable in both case. Therefore, it is necessary to be treated before use.

Table 4.2: Results comparison between Integrated Wastewater (I) and Treated Groundwater Quality.

Parameters		*Quantity*	
		Integrated wastewater (I)	*Treated groundwater (A1)*
pH		9.5	7.2
Suspended Solids (SS)	(mg/l)	182	Nd
Total Dissolved Solid (TDS)	(mg/l)	1,342	Nd
Turbidity	(NTU)	540	3.6
BOD	(mg/l)	189	1.0
Hardness	(mg/l)	264	174
Total Iron	(mg/l)	Nd.	Nd
Magnesium	(mg/l)	248	Nd

4.3 Coagulation Experiment.

4.3.1 Optimum coagulant dosage.

This Experiment was conducted to investigate the recycle possibility of integrated wastewater (I) using Jar Test Method. The coagulants employed in the experiment were Aluminium sulfate, Ferrous sulfate ($FeSO_4$), and Ferric sulfate {$Fe_2(SO_4)_3$}. This experiment used the 1 liter of integrated wastewater sample as received in each beaker then dosed with each coagulant solution ranging from 100 to 1,500 mg/l, 200 to 2,400 mg/l, and 100 to 1,100 mg/l for Aluminium sulfate (Alum; $Al_2(SO_4)_3$), Ferrous sulfate ($FeSO_4$), and Ferric sulfate ($Fe_2(SO_4)_3$ respectively.

During the experiment, after dosing the Aluminium sulfate (Alum), the wastewater was settled and two layers was distinguishable. The clearance solution appeared in the upper layer, while the whitish agglomerated contents were settled as the sludge bed. After dosed and increased Aluminium sulfate 100 mg/l to each jars of

I, it is found that the initial turbidity, SS and TDS was decreased from 540 NTU, 182 mg/l, 1,342 mg/l to 18 NTU, 11 mg/l, and 347 mg/l at dosage of 1,500 mg/l respectively. (Figure 4-5 and Table B-1 in Appendix B). Since, the acceptable criterion of water quality use in the preparation process was at the turbidity of lesser than 30 NTU. and the hardness was not higher than 300 mg/l (13, 16, 26, and 31). However, the only parameter employed in this experiment was turbidity. The initial hardness before treatment was less than 300 mg/l (264 mg/l), therefore, this parameter was ignored. Hence, the optimum dosage of Aluminium sulfate appeared only at 1,176 mg/l

The result of using Ferrous sulfate as a coagulant, it is appeared that dosage were varied differently with Aluminium sulfate. The flocculants were settled at the bottom of the beaker. The initial turbidity, SS and TDS were decreased from 540 NTU, 182 mg/l, and 1,342 mg/l to 22 NTU, 11 mg/l, and 347 mg/l at dosage of 2,400 mg/l respectively (Figure 4-5 and Table B-3 in Appendix B). While the optimum dosage of Ferrous sulfate found at 2,100 mg/l

Followed with the result of Ferric sulfate ($Fe_2(SO_4)_3$) as a coagulant, it is showed that the dosage of Ferric sulfate varied almost the same as Aluminium sulfate ($Al_2(SO_4)_3$) ranging from 100 to 1,100 mg/l with the final turbidity, SS, and TDS at 11 NTU, 8 mg/l and 332mg/l respectively (Figure 4-5 and Table B-5 in Appendix B). And the optimum dosage appeared on 768 mg/l.

Results from the study demonstrated that the higher content of the coagulant dosed to the sample varied the higher possibility of the constituent of the sample, PVA or other sizings, to be settled. The results of cited content of turbidity, suspended solid and total dissolved solid seemed to be decreased along with the increasing dosage of coagulant uniformly.

Since, the sample media (I) used in this experiment was not adjusted, it was used as received at pH 9.5. It is found that the dosages of coagulants were highly consumed as those found by Yongyut Boonyakan (33). This result supports the ideal concept of coagulation that the high turbidity-high alkalinity of water, the pH will be relatively unaffected by coagulant addition. Because of the high alkalinity, adsorption and charge neutralization will be less effective than in waters of low alkalinity. Therefore, higher coagulant dosage should be used to ensure sweep coagulation (32). To make a better condition for coagulation, the concentrated Hydrosulfuric acid (H_2SO_4) was induced to make the media of high turbidity and low alkalinity.

4.3.2 Optimum coagulant dosage at controlled pH 7

From the previous experiment discovered the consequence as the concepts of the coagulation (32). At this time, the sample (I) needed to be treated or adjusted with concentrated hydrosulfuric acid to make it neutral at pH of 7. Then, dosed the media or sample of each beaker with aluminium sulfate, ferrous sulfate, or ferric sulfate at the dosage varied from 100 to 1,000 mg/l.

At this moment, the settlements or precipitation were appeared more rapidly, and the dosages of coagulant consumed were lesser than the previous experiment. Ferrous sulfate found to be settled more slowly than Aluminium sulfate and Ferric sulfate but consume the highest amount of dosage among the rest of the coagulants to make the particle to floc and settled. Aluminium sulfate, the precipitant appeared whitish floc settled in the beaker while Ferrous sulfate and Ferric sulfate were brownish and reddish respectively.

After the Aluminium sulfate were dosed, the turbidity, SS and TDS were decreased from 540 NTU, 182 mg/l, 1,342 mg/l to 25 NTU, 15 mg/l, and 317 mg/l at dosage of 1,000 mg/l respectively (Figure 4-6 and Table B-2 in Appendix B). In case of Ferrous sulfate, the turbidity, SS and TDS were decreased from 540 NTU, 182 mg/l, 1,342 mg/l to 8 NTU, 8 mg/l, and 317 mg/l at dosage of 1,000 mg/l respectively (Figure 4-6 and Table B-4 in Appendix B). Ferric sulfate caused flocculation and sedimentation at the dosage of 900 mg/l and revealed the results from each parameter that turbidity, SS, TDS were also decreased to 3 NTU, 1 mg/l and 264 mg/l respectively (Figure 4-6 and Table B-6 in Appendix B).

The graph of Figures 4-7 cited the comparison results of turbidity of three different coagulants. The dash line indicated the 30 NTU, which intersected the graph of different coagulants. This represented the area under the intersections line were the optimum dosages. The maximum dose of Aluminium sulfate ($Al_2(SO_4)_3$), Ferrous sulfate ($FeSO_4$) and Ferric sulfate ($Fe_2(SO_4)_3$) were approximately 750 mg/l, 850 mg/l and 620 mg/l respectively to meet the requirement of 30 NTU at the pH 7.

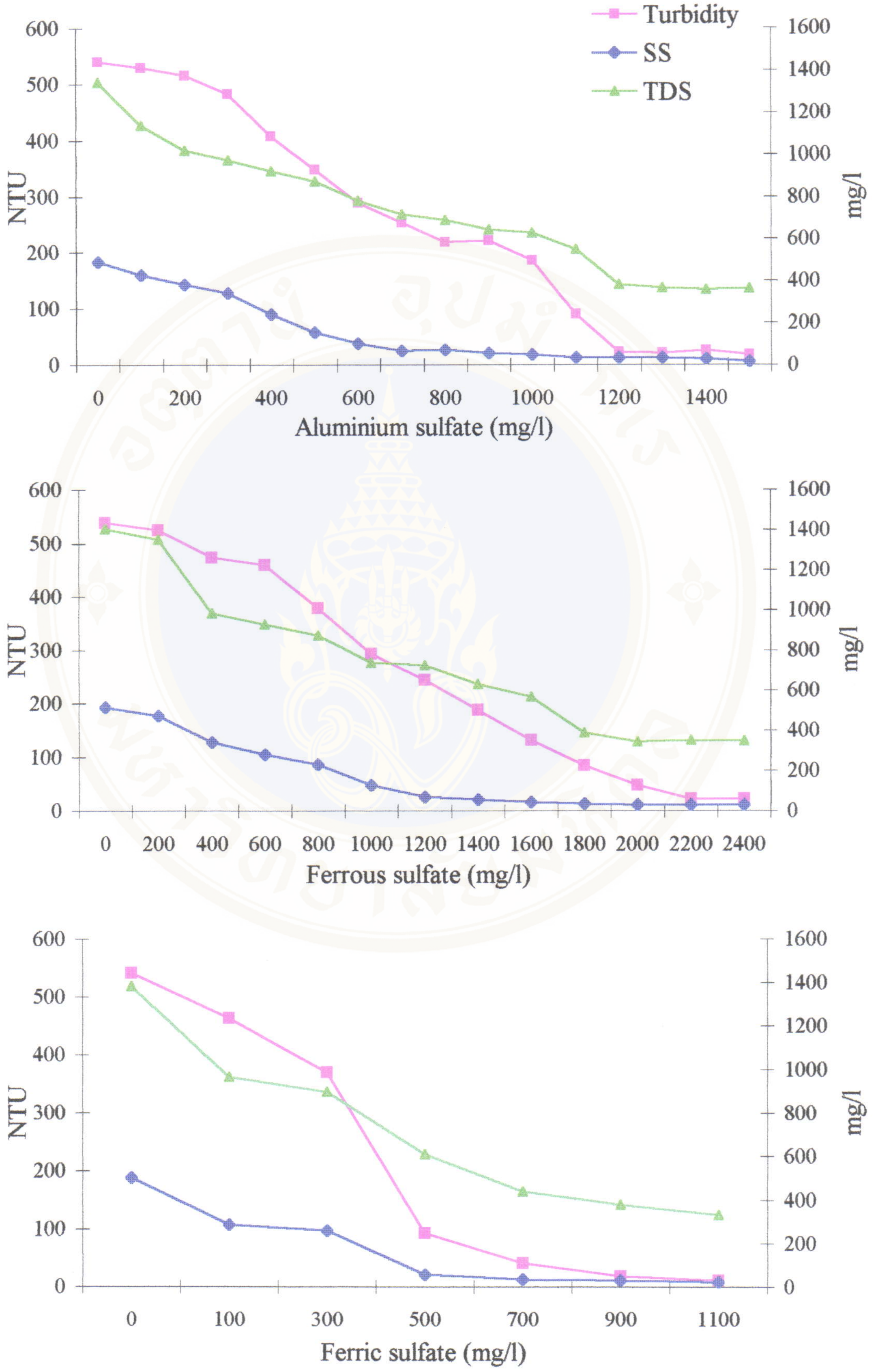


Figure 4-5: Results of coagulation experiment of integrated wastewater (I) as received using $Al_2(SO_4)_3$, $FeSO_4$ or $Fe_2(SO_4)_3$ at pH 9.5.

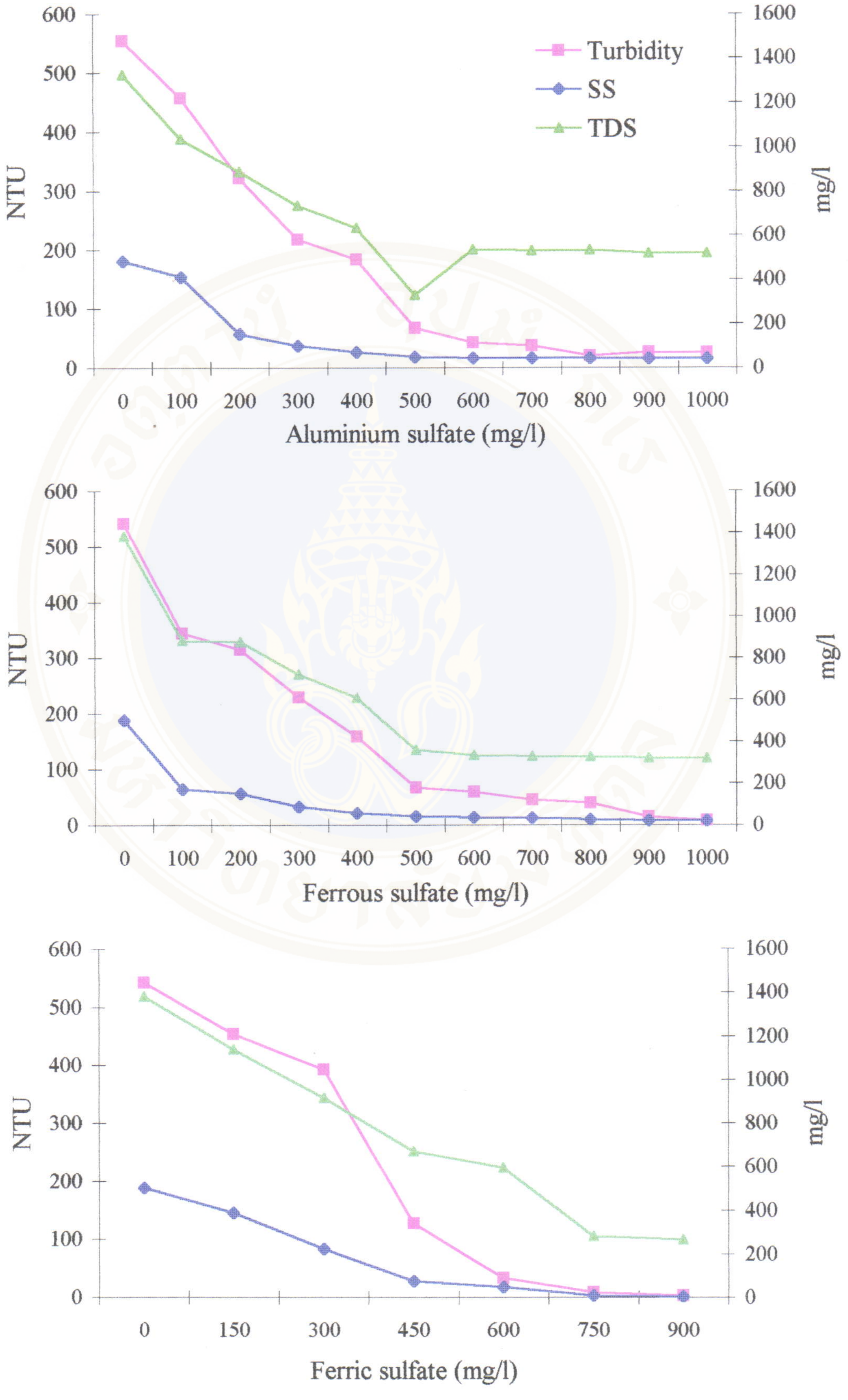


Figure 4-6 : Results of coagulation experiment of integrated wastewater (I) using $Al_2(SO_4)_3$, $FeSO_4$, or $Fe_2(SO_4)_3$ as coagulant at controlled pH 7.

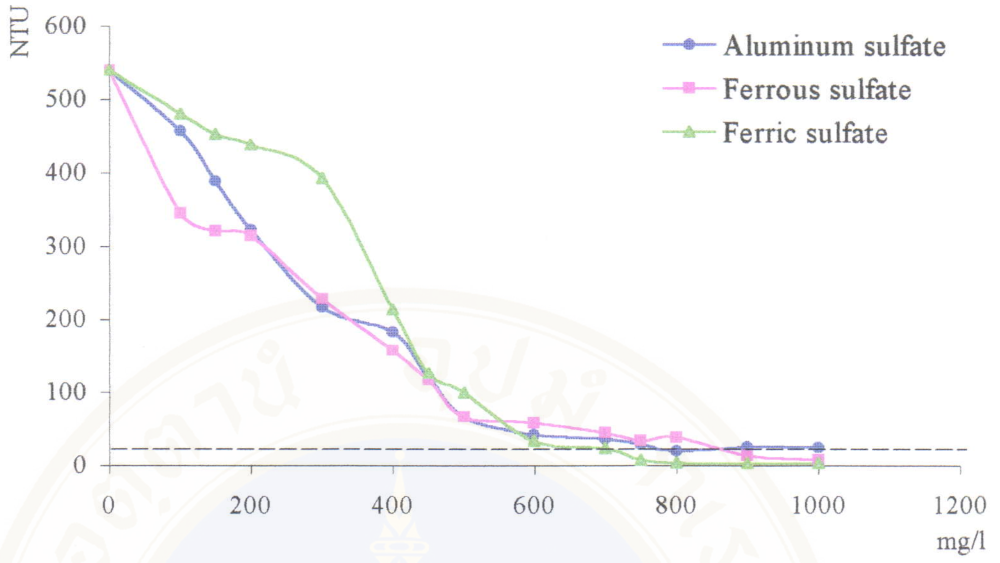


Figure 4-7 : Results of turbidity comparison of three coagulants showing the optimum dosage at 30 NTU.

As data shown in Table 4.3. The treated integrated wastewater was examined with the water quality parameters to judge as the criteria for recycle. The results revealed that most of all parameters were ranged similarly in quality except for the value of total iron which has been found at 0.2 and 0.6 mg/l after dosed with Ferrous sulfate and Ferric sulfate, respectively. Only Aluminium sulfate had no iron found.

Table 4.3: The water quality comparison, before and after dosing with several of optimum dosage of coagulants.

Parameters		Before Treatment	After Treatment		
			$Al_2(SO_4)_3$	$FeSO_4$	$Fe_2(SO_4)_3$
pH		9.5	6.7	6.9	6.2
Suspended Solids (SS)	(mg/l)	182	16	10	17
Total Dissolved Solid (TDS)	(mg/l)	1,342	331	323	367
Turbidity	(NTU)	540	30	28	33
BOD	(mg/l)	189	39	37	36
Hardness	(mg/l)	264	27	28	34
Total Iron	(mg/l)	0	0	0.2	0.6
Magnesium	(mg/l)	248	20	25	26

4.4 The Fabric Quality Test.

The results were revealed with 15 pieces of fabric. These fabrics were loomed and packed from the same pack of the Grey. Thus, the quality of the Grey uniformly appeared the same. All of these greys were processed with same amount of chemicals for Preparation process. The only different were the media consequent from different coagulants. These greys were examined to the efficiency of the reuse. Tables 4.5 were the consequence of the reuse efficiencies.

Table 4.4 : The result of fabric quality test with $Al_2(SO_4)_3$, $FeSO_4$, or $Fe_2(SO_4)_3$ by KI Sol^n and H_3BO_3 in I_2 Sol^n.

Grey No.	Remark			KI Sol^n	H_3BO_3 acid in I_2Sol^n
	$Al_2(SO_4)_3$	$FeSO_4$	$Fe_2(SO_4)_3$		
1	white	Yellow	brownish	yellow	yellow
2	white	Yellow	brownish	yellow	yellow
3	white	Yellow	brownish	yellow	yellow
4	white	Yellow	brownish	yellow	yellow
5	white	Yellow	brownish	yellow	yellow

Consequently, the recycled water was consumed with the same amount of chemicals for tested the efficiency. The Aluminium sulfate reveals the best among the efficiency of other coagulants. Even though, Aluminium sulfate must dosed with higher dosage than Ferric sulfate. But, Ferric sulfate was not able to meet the Preparation efficiency. The same as Ferrous sulfate, did not economize in dosage. Because, Ferrous sulfate must dosed with highest dosage for the SS to be settle. Therefore, it was not convenience to be consume.

4.5 Conceptual Design of the Preparation Wastewater Recycle Treatment

Resulted from the previous experiments, in order to manipulate the preparation wastewater to be possible, the recycle plant has to be design. This plant was designed under the profile experiment condition of the actual routine practice. Verified this, the volume of wastewater generated from each mill were ranging variously, hence, volume, dosage of coagulant, and other related factors must be varied according to the routine practice of the mill. Figure 4-8, was the flow diagram demonstrated the concepts of this recycle plant appear. Table C-1 (in Appendix C), was cited the calculation design of the civil constructions and cost exert. The mechanical construction was calculated and designed in Table C-2 (in Appendix C). Then, finally, Table C-3 (in Appendix C) was the summations costs exert in the construction of both civil and mechanics.

All civil constructions were built with concrete. Concrete construction might lasted for 25 year of usage. Beside this, the cost is higher than all the categories. Ten tanks were built and applied with various sizes with different usages, furthermore, each were cost variously. The total cost of civil construction was 939,384.62 Baht. Another cost was the mechanical engineering cost, the cost were the categories of pumps. The purposes of pumps were varied directly to the usages. According to the size and power, pumps were transferred the media wastewater from tank to tank, until the wastewater was treated. Therefore, pumps cost varied according to the power and usage. The mechanical was costed 435,000 Baht, which cost was coded from Central Inventory Market Place in Metropolitan. Both civil and mechanic was sum totally of 1,374,384.62 Baht.

4.6 Economic Analysis

The result of economic analysis was calculated from the previous revealed data of every experiments. The calculations were illustrated by the following cases: 1) Cost of Operation for Water Consumption and Disposal Treatment, which

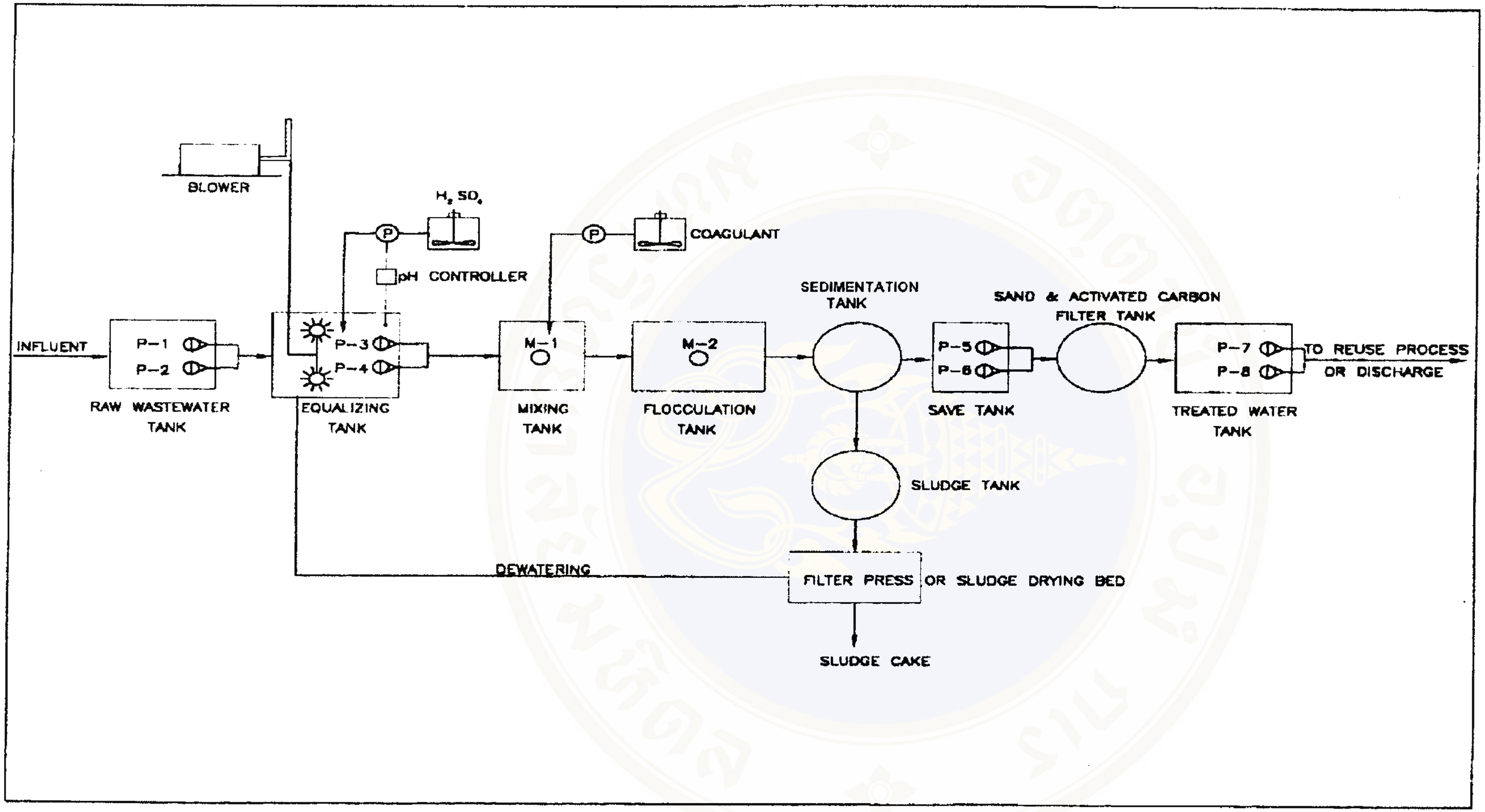


Figure 4-8: The flow diagram of preparation wastewater recycle treatment plant

demonstrated the present routine practice of the mills water consumption and disposal treatment expenses. 2) Cost of Recycle Treatment Plant and Operation, this was defined the expenses exerted from the foretell calculations. Furthermore, the plant construction was added into an account for this calculation. Consequently, 3) the cost comparison were cited and calculated as the acceptance of the Incremental Return of the project, which was resulted from the differences between the case 1) and case 2).

4.6.1 Cost of Operation for Water Consumption and Disposal Treatment

Resulted from the Table C-3 (in Appendix C), there was no civil and mechanical construction, because all the pipes and other related pumps were already adhered in the mill. Thus, solely, the pump required inducing recently and the maintenance was accounted for entirely 10 percent of the total pump cost. Groundwater was pumped with the charge per volume of 7 Bahts per cubic meter, and annually cost 2,074,800 Baht (Table D1 in Appendix D). Chemical cost (1) was the chemical consumed for treating the raw groundwater. These chemicals were costing 720,000 Baht every year, and constantly increase five percent in every five years. The electricity for pumped raw groundwater (Electricity cost (1)), was billed 42,000 Baht annually. Another electricity cost or Electricity cost (3), contrary, was the power supply for Disposal Treatment Plant applied to rotate the motor of turbine in the Activated Sludge Pond. This electricity was charged 284,360 Baht each year. Functionally, labor necessarily assigned for both pumping and discharge of the waste, annually this cost 180,000 (three labors). All of the above costs were sum up to 70,179,644 Baht in 20 years the project worth.

4.6.2 Cost of Recycle Treatment Plant and Operation.

Resulted from Table D-2 (in Appendix D) if there was a newly construction and operation of the Preparation Wastewater Recycle Plant, some cost might occurred according to the manipulations. Table C-1 to Table C-3 designed and calculated on the cost exerted. Accordingly, from the plant construction, generally, civil and mechanical engineering was required to be construct. The civil construction cost 939,385 Baht and mechanical valued 435,000 Baht. Along with the pumps, which were costed 40,000 Baht. Under the category of equipment, the pumps and mechanics need to be replaced with a decade year time. Additionally, the entirely year, each year both mechanic and pumps were costed 10m percent for maintenance.

Even though, the recycle plant was constructed, still the plant need to induce some newly groundwater to fulfill the volume of 200 m^3 (Appendix D). Since, the preparation process consumed 180 m^3 of water, while the plant was designed to recycle 160 m^3 volume of wastewater. Thus 40 m^3 of water input to the plant for the Preparation process. The extended 20 m^3 volume of water was still kept in tank for other usage. Beside this, labor was not included because the 3 labor in the water consumption plant could take in charge to function regularly, therefore, this was not brought into account. Aluminium sulfate ($Al_2(SO_4)_3$), the coagulant induced to the plant for flocculation and sedimentation. Presently, this coagulant costed 5 Baht per kilogram. Dosage was 750 mg/l and, along with, acidity of Hydrogen sulfate (H_2SO_4) to adjust the media at the pH of 7. The price of coagulant and Hydrogen sulfate (H_2SO_4) were 5 Baht per kilogram, and 4 Baht per liter, respectively, which increase 5 percent of cost in 5 years. The Electricity cost (2) was the power employed in the recycle plant to treated preparation wastewater. Each year, it costed, 168,000 Baht. Electricity cost (1) was also accounted in the recycle plant. The 40 m^3 groundwater needed to pump into the treatment, therefore, cost was exerted. The chemicals (Chemicals cost (1)) consumed for the "Soft-watering Plant" solely being accounted, because, 40 m^3 of water necessary to be treated, and costed 121,263 Baht per year. All of the above were sum to a total of 20,814,927 Baht within 20 years time (Table D-2 in the Appendix D).

4.6.3 Cost Comparison

This part was replied the result of the calculation from the actual and foretell expenses, which might generate in the mill. The result worth or judge from the comparison of costs and expenses exerted between the cases (Case 1 and Case 2). In additionally, Case 1 was the present routine practice of the mill's water consumption and disposal treatment expenses, and Case 2 was the accession of the recycle plant, operational expenses, and decreased value of both groundwater generation and discharge treatment expenses. Thus, these case expenses were compared and determined by the difference between the total expenses in the value of Incremental Return. Simply simplified, the Incremental Return was defined as the acceptance or worth of the 20 years project life.

From the Table D-3, was the result calculation of both cases. Especially, the Case 2) showed the calculation differently from the previous case or Table D-2. Since the previous was cited only the cost and expenses. Practically, if the mill induce the recycle plant, nevertheless, groundwater still has to be employ. At this circumstance, groundwater consumption was decreased. Hence, the other factors like chemical cost (1), the pumping groundwater electricity cost (electricity cost (1)), and disposal treatment cost (electricity cost (2)), were decreased too. But, there was increased expenses like labor cost, because, five labors were employed to the whole water consumption process. Then the rest categories were the increment factors added for the recycle plant to proceed. From the Capital Investment and the Cost Comparison were cited in the Table D-3.

Case 1: Consuming only the groundwater. In this case the mill consumed for dyeing preparation process was 180 m^3 and drew the ground water cost was 5 bath per cubic meter. Adhere with the pumps, size 15 kilowatts or 20 horsepower, the TDH of 10m. The draw rate was 250 cubic meter per hour, adhering two units, one unit operate and another stand-by. This all equipollents were employed for drawing the ground water. Since the water consumption for the whole mill, the electricity cost was 42,000 Baht per year. The annual maintenance in this department averages 4,200 Baht per year. Thus, caused the cost of investment or per capital investment for 20 years to operate was 70,179,644 Baht. In addition, 70,179,644 Baht, was divided by the total volume water for 20 years, and the cost per volume consumption was 11.84 Baht.

Case 2: Consuming ground water along with recycled Preparation water. For this case was necessarily to construct a newly Preparation Wastewater Recycle Treatment. From the criterion some capital investment exerted. The cost of both civil and mechanical engineering was cited in Table C-3. The Table cited the civil construction cost for Preparation wastewater recycle treatment with the total cost of 1,424,385 baht. The amount of 1,424,385 baht sum from civil construction costed 989,385 baht and mechanical cost 435,000 baht. After the construction available, this plant was able to recycle 160 cubic meter volume of water and added 40 cubic meter more of the ground water to meet the total volume of water consumption in the Preparation process. In order for the plant to proceed, coagulant and electricity cost were increasing respectively. Compared with the Case 1, which was routine proceeding, the Case 2 was reducing the total water consumption of the mill. Since the reduce caused the reduced in cost of generate and draw the ground water. Finally concluded the investment in Case 2 for 20 years of project with the operating cost of 67,615,692 baht. Which this cost divided by the volume water consumed for 20 years was the cost of water consumption per unit volume. The cost of this was 11.41 Baht per volume (Table D-3 in Appendix D).

The difference between the two cases was 2,563,952 Baht, and this may counter as "benefit". Then, took the benefit or the difference divided by 20 years, and got the amount of average payback per year. The Average Payback per Year was 128,197.59 Baht. The project incremental return, from the Table D-3, was returned within several years, or 5 years time. There was a little difference to encounter by the cost per unit volume between cases, and both were costed 11.84 Baht per cubic meter against 11.41 Baht per cubic meter, respectively between Case 1) and Case 2). Finally, the recycle plant induce to the mill was acceptable.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

As the study accomplished, the result and discussion from this study, this may concluded as stated follows:

5.1.1 Dyeing mill, the fabric-dyeing mill, dyestuff contributed the most wasteful practice among the textile industry. Especially, the commission dyeing mills were highly consumed of water, because, these mills were hired for production of dyed fabrics. In addition, these mills could not desired for the specific type of waste generated. Therefore, it is barely for these commission dyers to invested on highly equipped end-pipe treatment process. Employing some recycle possible wastewater back to the possible process of the production could solve this problem. From the review, stated that the wastewater from dyeing preparation process was able to be recycled, however, the preparation process did not consumed the highest consumption rate of the mill (approximately 20% of the total water consumption), and its wastewater was alkalinity constituted highly of the suspended solid particles. These particles were, solely, generated the highest rate of BODs and capable to be settled. The greatest volume found in the preparation process were the rinse wastewater, since, these rinses wastewater were not ranging highly polluted, and capable to be recycled. By omitting steps with highest loading parameters, thus, the rinse water contributed approximately 16% of the total volume. By applied the coagulation and sedimentation to agglomerate the whitish PVA or other sizing particles, the wastewater could be treated. The modified recycle system able to generate 16% of the total water consumption of the mill. Consequently, each day the mill could saved 16% of the groundwater generating cost and water disposal treatment cost.

5.1.2 The coagulation study discovered the three coagulants concluded different amount of dosages. The optimum dosage of Aluminium sulfate {$Al_2(SO_4)_3$}, Ferrous sulfate {$FeSO_4$}, and Ferric sulfate {$Fe_2(SO_4)_3$} were 1,176 mg/l, 2,100 mg/l, and 768 mg/l, respectively. While another study, which the media was adjusted to pH 7, then the results were 750 mg/l 850 mg/l, and 620 mg/l, respectively. From these results discovered that the unadjusted pH varied higher dosage of all coagulants, and the adjusted pH 7 were seen to be lesser. Ferric sulfate was seen to be the least amount of optimum coagulant dosage among of both adjusted and unadjusted.

5.1.3 For the recycled wastewater was generated under the amount of the optimum dosage at the adjusted pH of 7. Aluminium sulfate {$Al_2(SO_4)_3$}, Ferrous sulfate ($FeSO_4$), and Ferric sulfate {$Fe_2(SO_4)_3$} were dosed 750 mg/l, 850mg/l, and 620 mg/l, respectively. The parameters were compared between the initial treated groundwater and the recycled wastewater with three coagulants. The result revealed that all the recycled wastewater varied higher parameters than the initial treated groundwater, but pH and hardness seem to be lesser than the initial treated groundwater. For the efficiency of the recycled wastewater was tested with fabric test. The result obtained were: Aluminium sulfate {$Al_2(SO_4)_3$} recycled wastewater the dyeing preparation was effective and the gray appeared whitish; Ferrous sulfate ($FeSO_4$) recycled wastewater the dyeing preparation was effective and the gray appeared yellow; and Ferric sulfate {$Fe_2(SO_4)_3$} recycled wastewater the dyeing preparation was ineffective and the gray appeared brownish. Therefore, it can be concluded that, Aluminium sulfate {$Al_2(SO_4)_3$} was the coagulant that could be used.

5.1.4 The economic analysis accounted the modified recycle treatment plant is worthwhile than the routine water consumption plant. In order for a mill to process the recycle wastewater, the recycle treatment plant unit needed to be constructed. The construction cost was 1,374,384.62 Baht, this included the construction of both civil and mechanics. The cost of the routine water consumption and disposal treatment was 11.84 Bahts and, while, the cost of operation of the modified water consumption plant was 11.41 Bahts. Hence, the preparation wastewater recycle treatment plant is sufficiently operates than the routine water consumption plant.

5.2 Recommendations

The recommendations can be drawn for this works are:

5.2.1 The recycling plant establish in this type of mill can be applied to the similar type of mill for the cleaner production and waste minimization. More details on the disposal strategy and technology, to achieve the effectiveness of discharging the loaded wastestream.

5.2.2 More details on the recovery information on sludge, since, the sludge waste are the sizings particles. PVA was the major sizing consisted in the sludge volume, therefore, 60% of the PVA can be recovered and be reused in the weaving mill.

5.2.3 To investigate more details on the repetition of recycled wastewater, to achieve the recycle efficiency.

5.2.4 More emphasize on the recycled wastewater quality, to the achieve the dyeing preparation techniques by consuming the unblended stabilizer and sequestering. Since the chemical vender usually blended the stabilizer and sequestering with Magnesium ions (sodium silicate blended with magnesium ions), in addition, the recycle water quality was consisting the magnesium ions. Thus, if possible, in the dyeing preparation process induce the stabilizer or sodium silicate, instead of blended sodium silicate and magnesium ions. This can reduce the production expense of the mill.

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Appendix A

Table A-1: The Result of Water and Wastewater Quality

Parameters		A1	B1	B2	B3
Suspended Solids (SS)	(mg/l)	0	575	765	155
Total Dissolved Solids (TDS)	(mg/l)	0	2990	33225	3857
Turbidity	(NTU)	3.62	861	1511	522
BOD	(mg/l)	1	84	480	36
Hardness	(ppm)	174	145	2499	15
Total Iron	(mg/l)	0	0.28	0.57	0
Magnesium	(mg/l)	0	128	2499	28
pH		7.2	7	12	9

Parameters		B4	B5	B6	B7	B8
Suspended Solids (SS)	(mg/l)	20	15	13	6	5
Total Dissolved Solids (TDS)	(mg/l)	627	302	223	977	361
Turbidity	(NTU)	141	24.1	19.9	6.77	10
BOD	(mg/l)	12	15	12	77	2
Hardness	(ppm)	82	107	101	571	212
Total Iron	(mg/l)	0	0	0	0	0
Magnesium	(mg/l)	89	136	138	328	206
pH		7	7	7	3	6

Appendix B

Table B1: The result of CoagulationExperiment of Integrated wastewater as received using $Al_2(SO_4)_3$ as coagulant of pH 9.5

Categories (1liter)	$Al_2(SO_4)_3$ (mg/l)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)
Jar 0	0	540	182	1342
Jar 1	100	529	159	1135
Jar 2	200	515	142	1019
Jar 3	300	482	127	973
Jar 4	400	407	89	920
Jar 5	500	348	57	873
Jar 6	600	289	38	781
Jar 7	700	253	24	715
Jar 8	800	218	26	687
Jar 9	900	221	21	643
Jar 10	1000	185	18	628
Jar11	1100	89	12	546
Jar12	1200	23	12	378
Jar13	1300	21	12	363
Jar 14	1400	25	10	357
Jar15	1500	18	6	361

Remarks: *1. Speed of the stirrer (rpm)*

100 rpm for 3 min
40 rpm for 10 min
20 rpm for 20 min

2. settling time 5 hr.

3. initial pH = 9.5

Table B2: The result of CoagulationExperiment of Integrated wastewater as received using $Al_2(SO_4)_3$ as coagulant adjusted pH 7

Categories (1liter)	$Al_2(SO_4)_3$ (mg/l)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)
Jar 0	0	554	180	1324
Jar 1	100	457	153	1032
Jar 2	200	322	57	886
Jar 3	300	217	37	732
Jar 4	400	183	26	632
Jar 5	500	67	18	326
Jar 6	600	42	16	534
Jar 7	700	37	16	528
Jar 8	800	20	16	532
Jar 9	900	26	15	517
Jar 10	1000	25	15	517

Remarks: *1. Speed of the stirrer (rpm)*

100 rpm for 3 min
40 rpm for 10 min
20 rpm for 20 min

2. settling time 5 hr.

3. initial pH = 7

Table B3: The result of Coagulation Experiment of Integrated wastewater as received using Ferrous Sulfate (*Copperas*; $FeSO_4$) as coagulant, whereas pH 9.5

Categories (1liter)	$FeSO_4$ (mg/l)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)
Jar 0	0	540	182	1342
Jar 1	200	524	176	1351
Jar 2	400	473	127	983
Jar 3	600	459	104	927
Jar 4	800	378	86	873
Jar 5	1000	293	47	736
Jar6	1200	243	26	722
Jar 7	1400	187	21	629
Jar 8	1600	131	16	564
Jar 9	1800	84	13	386
Jar 10	2000	47	11	342
Jar 11	2200	22	11	350
Jar 12	2400	22	11	347

Remarks: *1. Speed of the stirrer(rpm)*
100 rpm for 3 min
40 rpm for 10 min
20 rpm for 20 min

2. settling time 5 hr.

3. initial pH =9.5

Table B-4: The result of Coagulation Experiment of Integrated wastewater as received using Ferrous Sulfate (Copperas; FeSO4) as coagulant, and adjusted pH 7

Categories (1liter)	$FeSO_4$ (mg/l)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)
Jar 0	0	540	182	1342
Jar 1	100	344	64	882
Jar 2	200	314	56	876
Jar 3	300	229	32	718
Jar 4	400	158	21	607
Jar 5	500	67	15	357
Jar 6	600	59	13	332
Jar 7	700	45	12	328
Jar 8	800	39	10	324
Jar 9	900	14	8	319
Jar10	1000	8	8	317

Remarks: *1. Speed of the stirrer (rpm)*
100 rpm for 3 min
40 rpm for 10 min
20 rpm for 20 min

2. settling time 5 hr.

3. initial pH = 7

Table B-5: The result of Coagulation Experiment of Integrated wastewater as received using Ferric Sulfate ($Fe_2(SO_4)_3$) as coagulant at pH 9.5

Categories (1liter)	$Fe_2(SO_4)_3$ (mg/l)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)
Jar 0	0	541	188	1382
Jar 1	100	463	107	964
Jar 2	300	369	97	895
Jar 3	500	93	21	607
Jar 4	700	41	13	438
Jar 5	900	18	11	378
Jar 6	1100	11	8	332

Table B6: The result of Coagulation Experiment of Integrated wastewater as received using Ferric Sulfate ($Fe_2(SO_4)_3$) as coagulant at adjusted pH 7

Categories (1liter)	$Fe_2(SO_4)_3$ (mg/l)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)
Jar 0	0	542	188	1382
Jar 1	150	453	145	1137
Jar 2	300	392	83	914
Jar 3	450	127	27	668
Jar 4	600	33	17	593
Jar 5	750	8	3	279
Jar 6	900	3	1	264

Remarks:

1. Speed of the stirrer (rpm)

100 rpm for 3 min

40 rpm for 10 min

20 rpm for 20 min

2. settling time 5 hr.

3. initial pH = 9.5 and 7

Appendix C

RECYCLE WASTEWATER TREATMENT CALCULATION

CONDITION

Q design				=	200	m^3/day
Operation	=	24	hr/day	=	8.3	m^3/hr
SS				=	182	mg/l
Turbidity				=	540	mg/l
BOD				=	189	mg/l
pH				=	9.5	

RAW WASTE WATER TANK

Q design				=	8.3	m^3/hr
Size of tank		wideth		=	1.0	m.
		length		=	1.5	m.
		depth of water		=	1.5	m.
		depth of tank		=	3.0	m.
Volume of tank				=	2.3	m^3
Detention time				=	16.2	min
Provide pump	=	2	(stand-by)	=	1	pump
Pump (each size)				=	8.3	m^3/hr
Capacity pump			150%	=	12.5	m^3/hr
Pump (each size)				=	12.5	m^3/hr
Total head				=	12	m
Requirement Submersible Pump (size)				=	2.2	kW
Use Submersible Pump (size)				=	2.2	kW
					#OK#	

EQUALIZING TANK

Q design				=	8.3	m^3/hr
Size of tank		wideth		=	10.0	m.
		length		=	10.0	m.
		depth of water		=	2.0	m.
		depth of tank		=	2.5	m.
Volume of tank				=	200.0	m^3
Detention time				=	24.0	hr

Provide pump	=	2	(stand-by)	=	1	pump
Capacity pump			150%	=	12.5	m^3/hr
Pump (each size)				=	12.5	m^3/hr
Total head				=	12	m
Requirement Submersible Pump (size)				=	2.2	kW
Use Submersible Pump (size)				=	2.2	kW
					#OK#	

MIXING TANK

Provide mixing tank		=	1	tank	
Q design		=	8.3	m^3/hr	
Size of tank	wideth	=	1.0	m.	
	length	=	1.0	m.	
	depth of water	=	1.0	m.	
	depth of tank	=	1.5	m.	
Volume of tank		=	1.0	m^3	
Detention time		=	7.2	min	(2-5 min)

Power mixing

from equation	G^2	=	P/mV		
or	GT	=	$(PV/m)^{1/2}/Q$		
	G	=	Mean velocity gradient		
		=	500	s^{-1}	$(250\text{-}1500\ s^{-1})$
	m	=	Dynamic viscosity		
		=	0.00114	$N.s/m^2$	
	V	=	Volume		
		=	1.00	m^3	
	T	=	Hydralic retention time (HRT)		
		=	432	s	
	Q	=	0.0023	m^3/s	
	P	=	Power mixing required		
		=	0.28	kw	
size recommended		=	0.75	kw	

Size of Turbine

Type of Turbine		Turbine mixer			
from equation	P	=	krn^3D^3		
	r	=	999.1	kg/m^3	
	k	=	6.3		
	n	=	2	rps	(120

			rpm)		
D	=	diameter of Turbine			
	=	0.18	m		

FLOCCULATION TANK

Provide flocculation tank		=	1	tank	
Q design		=	8.3	m^3/hr	
Size of tank	wideth	=	2.0	m.	
	length	=	2.0	m.	
	depth of water	=	1.5	m.	
	depth of tank	=	2.0	m.	
Volume of tank		=	6.0	m^3	
Detention time		=	43.2	min	(15-30 min)

Power mixing

from equation	G^2	=	P/mV		
or	GT	=	$(PV/m)^{1/2}/Q$		
	G	=	Mean velocity gradient		
		=	60	s^{-1}	($40\text{-}80\ s^{-1}$)
	m	=	Dynamic viscosity		
		=	0.00114	$N.s/m^2$	
	V	=	Volume		
		=	6.00	m^3	
	T	=	Hydralic retention time (HRT)		
		=	2,592	s	
	Q	=	0.0023	m^3/s	
	P	=	Power mixing required		
		=	0.02	kw	
size recommended		=	0.75	kw	#OK#

Size of Turbine

Type of Turbine		Turbine mixer			
from equation	P	=	krn^3D^3		
	r	=	999.1	kg/m^3	
	k	=	6.3		
	n	=	0.33	rps	(20 rpm)
	D	=	diameter of Turbine		
		=	0.48	m	

SEDIMENTATION TANK

Q design		=	8.3	m^3/hr	
Dimeter of tank		=	3.5	m.	
Area		=	10	m^2	
Provide		=	1	tank	
Overflow rate	Average	=	16-32	$m^3/m^2/d$	
	Peak	=	40-48	$m^3/m^2/d$	
Overflow rate		=	20.8	$m^3/m^2/d$	#OK#
depth of water		=	3.2	m	
Volume of tank		=	31	m^3	
Detention time (t)		=	3.7	hr	(2-4 hr)
Assume Sludge Volume		=	10.0	%	
Sludge Volume		=	0.8	m^3/d	

SLUDGE TANK

Q design			=	0.8	m^3/d	
Size of tank	wideth		=	1.0	m.	
	length		=	1.0	m.	
	depth of water		=	2.0	m.	
	depth of tank		=	3.0	m.	
Volume of tank			=	2.0	m^3	
Detention time			=	2.4	d	(>24 hr)
Operate 1	hr./day		=	0.8	m^3/hr	
Provide pump =	1	(stand-by)	=	0	pump	
Capacity pump		150%	=	1.3	m^3/hr	
Pump (each size)			=	1.3	m^3/hr	
Total head			=	10	m	
Consume the new Submersible Pump			=	0.75	kW	

SLUDGE DRYING BED

Q design	=	0.8	m^3/d
Design sludge drying bed	=	10	d
Volume of sludge drying bed	=	8.3	m^3
Depth of sludge	=	0.25	m
Area required	=	33	m^2

#OK#

SAVE TANK

Q design			=	8.3	m^3/hr
Size of tank	wideth		=	2.0	m.
	length		=	2.0	m.
	depth of water		=	2.5	m.
	depth of tank		=	3.0	m.
Volume of tank			=	10.0	m^3
Detention time			=	1.2	hr
Provide pump	= 2	(stand-by)	=	1	pump
Capacity pump		150%	=	12.5	m^3/hr
Pump (each size)			=	12.5	m^3/hr
Total head			=	12	m
Requirement Submersible Pump (size)			=	2.2	kW
Use Submersible Pump (size)			=	2.2	kW
				#OK#	

ANTHRACITE FILTERS TANK

Q design	=	8.3	m^3/hr	
Filter rate	=	5.0	$m^3/m^2 \cdot hr$	
Filter area require	=	1.7	m^2	
Dimeter of tank	=	1.5	m.	
Amount of Filters tank	=	1	tank	
Total area	=	1.8	m^2	(4-25 $m^3/m^2 \cdot hr$)
		#OK#		

TREATED WATER TANK

Q design			=	8.3	m^3/hr
Size of tank	wideth		=	10.0	m.
	length		=	10.0	m.
	depth of water		=	2.0	m.
	depth of tank		=	3.0	m.
Volume of tank			=	200	m^3
Detention time			=	24.0	hr
Provide pump	= 2	(stand-by)	=	1	pump
Capacity pump		150%	=	12.5	m^3/hr
Pump (each size)			=	12.5	m^3/hr
Total head			=	10	m
Requirement Submersible Pump (size)			=	2.2	kW
Use Submersible Pump (size)			=	2.2	kW
				#OK#	

CHEMICAL SYSTEM

1. Coagulant Dosage

Use			=	10	% Solution
Coagulant					
Assume maximum Coagulant dosage			=	100.0	mg/l
Maximum Coagulant feed			=	8.3	l/hr
Maximum Coagulant dosage			=	20.0	kg/d
Coagulant tank (Use 1 day)			=	200.0	l
Coagulant tank	1	tank size	=	300.0	l
Coagulant feed pump	1	pumpsize		10.0	l/hr

Table C-1: The Specification and the Cost of Civil Engineering Construction

Dyeing Preparation Wastewater Recycle Plant Project

Capital Investment

1. Civil Cost

Categories	width (m)	length (m)	high (m)	t wall (m)	t floor (m)	dia. (m)	V_{con} wall (m^3)	V_{con} floor (m^3)	V_{con} total (m^3)	Unit cost (baht)	Total Cost (baht)
1. Raw Wastewater Tank	1.00	1.50	3.00	0.20	0.15	-	2.52	0.14	2.66	5,000.00	13,275.00
2. Equalizing Tank	10.00	10.00	2.50	0.20	0.25	-	19.60	24.00	43.60	5,000.00	218,000.00
3. Fast Mixing Tank	1.00	1.00	1.50	0.10	0.15	-	0.54	0.12	0.66	5,000.00	3,300.00
4. Slow Mixing Tank	2.00	2.00	2.50	0.15	0.20	-	2.78	0.68	3.46	5,000.00	17,275.00
5. Flocdulation Tank	2.00	2.00	2.00	0.15	0.20	-	2.22	0.68	2.90	5,000.00	14,500.00
6. Sedimentation Tank	-	-	3.50	0.20	-	3.50	-	-	7.26	5,000.00	36,278.55
7. Sludge Tank	1.00	1.00	3.00	0.20	0.20	-	1.92	0.12	2.04	5,000.00	10,200.00
8. Sludge Drying Bed	5.00	10.00	2.50	0.15	0.20	-	11.03	9.40	20.43	5,000.00	102,125.00
9. Save Tank	2.00	2.00	3.00	0.15	0.20	-	3.33	0.68	4.01	5,000.00	20,050.00
10. Anthracite Filter Tank										30,000.00	30,000.00
11. Treated Water Tank	10.00	10.00	3.00	0.20	0.25	-	23.52	24.00	47.52	5,000.00	237,600.00
12. Chemical Feeding 2 sets										10,000.00	20,000.00
13. Piping System and Equipment										AR	216,781.07
Total Cost											939,384.62

urce: The Cost per capital of construction inventory in the portion of Central Commercial Division Index, Commercial Department, Commercial Ministry, December 19

Table C-2: The Specification and the Cost of Mechanical Engineering Construction

Dyeing Preparation Wastewater Recycle Plant Project

Capital Investment

2. Mechanical Cost

Categories	Amount	Unit cost (baht)	Total Cost (baht)	
1. Pump size 12.5 m^3/hr (2.2 kW) Height 12 m.	2	25,000.00	50,000.00	in RW
2. Pump size 12.5 m^3/hr (2.2 kW) height 12 □.	2	25,000.00	50,000.00	in EQ
3. Pump size 1.3 m^3/hr (0.75 kW) height 10 m.	1	20,000.00	20,000.00	in SLT
4. Pump size 12.5 m^3/hr (2.2 kW) height 12 m.	2	25,000.00	50,000.00	use in ST
4. Pump size 12.5 m^3/hr (2.2 kW) height 10 m.	2	25,000.00	50,000.00	use in TW
5. Air Blower size 3 kW	1	40,000.00	40,000.00	
6. Metering Pump size5 l/min	2	30,000.00	60,000.00	
7. pH Controller	1	15,000.00	15,000.00	
8. Motor with Turbine	4	25,000.00	100,000.00	
Total Cost			**435,000.00**	

Source : The Inventory Cost of January 1999

Table C-3: The Summerization of Cost both Civil and Mechanic for the Recycle plant

3. The Summerization of Cost

Categories	Amounts (baht)
1. Civil Cost	939,384.62
2. Mechaincal Cost	435,000.00
Total	**1,374,384.62**

Appendix D

Table D-1 The annual expense calculation of appling groundwater consumption

Yr.	Case 1): Present Expense of Water Consumption											Total cost
	Annual Cost											
	Civil	Equipment		Water Consumption Cost			Recycle Cost			Wastewater Disposal Cost		
		Mechanics	Pump (1)	Groundwater cost	Chemical Cost(1)	Electricity cost (1)	Electricity cost (2)	Chemical cost (2)	Coagulant cost	Electricity cost (3)	Labor cost	
1	-	-	800,000	2,074,800	720,000	42,000	-	-	-	284,360	180,000	4,101,160
2	-	-	80,000	2,074,800	720,000	42,000	-	-	-	284,360	180,000	3,381,160
3	-	-	80,000	2,074,800	720,000	42,000	-	-	-	284,360	180,000	3,381,160
4	-	-	80,000	2,074,800	720,000	42,000	-	-	-	284,360	180,000	3,381,160
5	-	-	80,000	2,074,800	720,000	42,000	-	-	-	284,360	180,000	3,381,160
6	-	-	80,000	2,074,800	756,000	42,000	-	-	-	284,360	180,000	3,417,160
7	-	-	80,000	2,074,800	756,000	42,000	-	-	-	284,360	180,000	3,417,160
8	-	-	80,000	2,074,800	756,000	42,000	-	-	-	284,360	180,000	3,417,160
9	-	-	80,000	2,074,800	756,000	42,000	-	-	-	284,360	180,000	3,417,160
10	-	-	80,000	2,074,800	756,000	42,000	-	-	-	284,360	180,000	3,417,160
11	-	-	800,000	2,074,800	793,800	42,000	-	-	-	284,360	180,000	4,174,960
12	-	-	80,000	2,074,800	793,800	42,000	-	-	-	284,360	180,000	3,454,960
13	-	-	80,000	2,074,800	793,800	42,000	-	-	-	284,360	180,000	3,454,960
14	-	-	80,000	2,074,800	793,800	42,000	-	-	-	284,360	180,000	3,454,960
15	-	-	80,000	2,074,800	793,800	42,000	-	-	-	284,360	180,000	3,454,960
16	-	-	80,000	2,074,800	833,490	42,000	-	-	-	284,360	180,000	3,494,650
17	-	-	80,000	2,074,800	833,490	42,000	-	-	-	284,360	180,000	3,494,650
18	-	-	80,000	2,074,800	833,490	42,000	-	-	-	284,360	180,000	3,494,650
19	-	-	80,000	2,074,800	833,490	42,000	-	-	-	284,360	180,000	3,494,650
20	-	-	80,000	2,074,800	833,490	42,000	-	-	-	284,360	180,000	3,494,650
												70,179,644

Remark:

Water consumpt per day	950	m^3
Cost of groundwater per m3	7	Baht/l
Rate of annual increase of groundwater cost	0	%
Amount of Coagulant	750	mg/l
Cost of Coagulant ($Al_2(SO_4)_3$)	5	Baht/kg
Rate of increase of Coagulant	5	% / 5years
Amount ofH_2SO_4 (concentrated)	0.17	ml/l
Cost of H_2SO_4 (concentrated)	4	Baht/l
Amount of water recycle per day	160	m^3

Table D-2 The cost calculation of Recycle Treatment Plant

Yr.	Case 2): Cost and Expense of Recycle Treatment Plant and Operation											
	Civil	Equipment		Annual Recycle Plant Operation Cost								Total Cost
				Water Consumption Cost			Recycle Cost			Wastewater Disposal Cost		
		Mechanics	Pump (1)	Groundwater cost	Chemical cost (1)	Electricity cost (1)	Electricity cost (2)	Chemical cost (2)	Coagulant cost	Electricity Cost (3)	Labor cost	
1	989,385	435,000	40,000	349,440	121,263	8,842	168,000	34,727	187,200	-	0	2,333,857
2	-	43,500	4,000	349,440	121,263	8,842	168,000	34,727	187,200	-	0	916,972
3	-	43,500	4,000	349,440	121,263	8,842	168,000	34,727	187,200	-	0	916,972
4	-	43,500	4,000	349,440	121,263	8,842	168,000	34,727	187,200	-	0	916,972
5	-	43,500	4,000	349,440	121,263	8,842	168,000	34,727	187,200	-	0	916,972
6	-	43,500	4,000	349,440	127,326	8,842	168,000	36,463	196,560	-	0	934,132
7	-	43,500	4,000	349,440	127,326	8,842	168,000	36,463	196,560	-	0	934,132
8	-	43,500	4,000	349,440	127,326	8,842	168,000	36,463	196,560	-	0	934,132
9	-	43,500	4,000	349,440	127,326	8,842	168,000	36,463	196,560	-	0	934,132
10	-	43,500	4,000	349,440	127,326	8,842	168,000	36,463	196,560	-	0	934,132
11	98,939	435,000	40,000	349,440	133,693	8,842	168,000	38,286	206,388	-	0	1,478,588
12	-	43,500	4,000	349,440	133,693	8,842	168,000	38,286	206,388	-	0	952,149
13	-	43,500	4,000	349,440	133,693	8,842	168,000	38,286	206,388	-	0	952,149
14	-	43,500	4,000	349,440	133,693	8,842	168,000	38,286	206,388	-	0	952,149
15	-	43,500	4,000	349,440	133,693	8,842	168,000	38,286	206,388	-	0	952,149
16	-	43,500	4,000	349,440	140,377	8,842	168,000	40,201	216,707	-	0	971,068
17	-	43,500	4,000	349,440	140,377	8,842	168,000	40,201	216,707	-	0	971,068
18	-	43,500	4,000	349,440	140,377	8,842	168,000	40,201	216,707	-	0	971,068
19	-	43,500	4,000	349,440	140,377	8,842	168,000	40,201	216,707	-	0	971,068
20	-	43,500	4,000	349,440	140,377	8,842	168,000	40,201	216,707	-	0	971,068
												20,814,927

Remark:	Water consumpt per day	950	m^3
	Cost of groundwater per m3	7	Baht/l
	Rate of annual increase of groundwater cost	0	%
	Amount of Coagulant	750	mg/l
	Cost of Coagulant ($Al_2(SO_4)_3$)	5	Baht/kg
	Rate of increase of Coagulant	5	% / 5years
	Amount of H_2SO_4 (concentrated)	0.17	ml/l
	Cost of H_2SO_4 (concentrated)	4	Baht/l
	Amount of water reuse per day	160	m^3

Table D-3 The Cost of operation and Cost Comparison with Capital Investment

The Cost Comparison of both Cases in Consideration of 20 years

Case 1): Present Expense of Water Consumption

Yr.	Equipment	Annual cost					Total cost
	Pump (1)	Groundwater cost	Electricity cost (1)	Chemical Cost	Electricity cost (2)	Labor cost	
1	800,000	2,074,800	42,000	720,000	284,360	180,000	4,101,160
2	80,000	2,074,800	42,000	720,000	284,360	180,000	3,381,160
3	80,000	2,074,800	42,000	720,000	284,360	180,000	3,381,160
4	80,000	2,074,800	42,000	720,000	284,360	180,000	3,381,160
5	80,000	2,074,800	42,000	720,000	284,360	180,000	3,381,160
6	80,000	2,074,800	42,000	756,000	284,360	180,000	3,417,160
7	80,000	2,074,800	42,000	756,000	284,360	180,000	3,417,160
8	80,000	2,074,800	42,000	756,000	284,360	180,000	3,417,160
9	80,000	2,074,800	42,000	756,000	284,360	180,000	3,417,160
10	80,000	2,074,800	42,000	756,000	284,360	180,000	3,417,160
11	800,000	2,074,800	42,000	793,800	284,360	180,000	4,174,960
12	80,000	2,074,800	42,000	793,800	284,360	180,000	3,454,960
13	80,000	2,074,800	42,000	793,800	284,360	180,000	3,454,960
14	80,000	2,074,800	42,000	793,800	284,360	180,000	3,454,960
15	80,000	2,074,800	42,000	793,800	284,360	180,000	3,454,960
16	80,000	2,074,800	42,000	833,490	284,360	180,000	3,494,650
17	80,000	2,074,800	42,000	833,490	284,360	180,000	3,494,650
18	80,000	2,074,800	42,000	833,490	284,360	180,000	3,494,650
19	80,000	2,074,800	42,000	833,490	284,360	180,000	3,494,650
20	80,000	2,074,800	42,000	833,490	284,360	180,000	3,494,650
							70,179,644

Case 2): Operational expense of consuming groundwateralong with recycled water

Yr.	Civil	Equipment		Annual operation cost							Total cost	Incremental
		Mechanics	Pump (1)	Groundwater cost	Chemical cost (1)	Coagulant cost	Chemical cost (2)	Electricity cost (1) + (3)	Electricity cost (2)	Labor cost		Return
1	989,385	435,000	40,000	1,725,360	598,737	187,200	34,727	210,000	236,468	180,000	4,636,876	-535,717
2	-	43,500	4,000	1,725,360	598,737	187,200	34,727	210,000	236,468	180,000	3,219,991	-374,548
3	-	43,500	4,000	1,725,360	598,737	187,200	34,727	210,000	236,468	180,000	3,219,991	-213,380
4	-	43,500	4,000	1,725,360	598,737	187,200	34,727	210,000	236,468	180,000	3,219,991	-52,212
5	-	43,500	4,000	1,725,360	598,737	187,200	34,727	210,000	236,468	180,000	3,219,991	108,957
6	-	43,500	4,000	1,725,360	628,674	196,560	36,463	210,000	236,468	180,000	3,261,025	265,092
7	-	43,500	4,000	1,725,360	628,674	196,560	36,463	210,000	236,468	180,000	3,261,025	421,227
8	-	43,500	4,000	1,725,360	628,674	196,560	36,463	210,000	236,468	180,000	3,261,025	577,362
9	-	43,500	4,000	1,725,360	628,674	196,560	36,463	210,000	236,468	180,000	3,261,025	733,497
10	-	43,500	4,000	1,725,360	628,674	196,560	36,463	210,000	236,468	180,000	3,261,025	889,633
11	98,939	435,000	40,000	1,725,360	660,107	206,388	38,286	210,000	236,468	180,000	3,830,548	1,234,044
12	-	43,500	4,000	1,725,360	660,107	206,388	38,286	210,000	236,468	180,000	3,304,109	1,384,895
13	-	43,500	4,000	1,725,360	660,107	206,388	38,286	210,000	236,468	180,000	3,304,109	1,535,745
14	-	43,500	4,000	1,725,360	660,107	206,388	38,286	210,000	236,468	180,000	3,304,109	1,686,595
15	-	43,500	4,000	1,725,360	660,107	206,388	38,286	210,000	236,468	180,000	3,304,109	1,837,446
16	-	43,500	4,000	1,725,360	693,113	216,707	40,201	210,000	236,468	180,000	3,349,348	1,982,747
17	-	43,500	4,000	1,725,360	693,113	216,707	40,201	210,000	236,468	180,000	3,349,348	2,128,048
18	-	43,500	4,000	1,725,360	693,113	216,707	40,201	210,000	236,468	180,000	3,349,348	2,273,349
19	-	43,500	4,000	1,725,360	693,113	216,707	40,201	210,000	236,468	180,000	3,349,348	2,418,651
20	-	43,500	4,000	1,725,360	693,113	216,707	40,201	210,000	236,468	180,000	3,349,348	2,563,952
											67,615,692	

Case1	Case 2	Differences	Average payback per year
70,179,644	67,615,692	2,563,952	128,197.59

Remarks:					
Water consumpt per day	950	m^3	Amount of Coagulant	750	mg/l
Amount of water reuse per day	160	m^3	Cost of Coagulant	5	Baht/kg
Cost of groundwater per m^3	7	Baht/l	Rate of increase of Coagulant	5	% / 5years
Rate of annual increase of groundwater cost	0	%	Amount of H_2SO_4 (conc.)	0.17	ml/l
			Cost of H_2SO_4 (conc.)	4	Baht/l

BIOGRAPHY

NAME Mr. Somkiat Thitipanont

DATE OF BIRTH May 24, 1970

PLACE OF BIRTH Phachinburi, Thailand

INSTITUTIONS ATTENDED

Mahidol University, 1990-1994

Bachelor of Science (Biology)

(International Student Degree Program or the former International College)

Mahidol University, 1994-2000

Master of Science (Technology of Environmental Management)