WOOL-SCOURING WASTEWATER TREATMENT AT LIU-TU INDUSTRIAL DISTRICT IN TAIWAN, R.O.C.

by

CHIANG-PI HSIAO

Diploma in Civil Engineering
Taipei Institute of Technology
Taiwan, China, 1961

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

Approved by

Lawrence A. Schmid
Major Professor

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to Dr. Lawrence A. Schmid, my major advisor, for his guidance and continuous interest in my study. I am grateful to the other members of my supervisory committee: Dr. Jerome J. Zovne and Dr. Jason Carl Annis for their advice and help.

I also wish to express my appreciation to Dr. Robert R. Snell, Head of the Civil Engineering Department, who made my graduate study possible here at Kansas State University.

Grateful acknowledgment is made for the financial support received from the Taiwan Provincial Government, the Republic of China.

Last, but certainly not least, I would like to express my heartful thanks to my wife for her encouragement and her care to our family in Taiwan during my study in the U.S.A.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

CONTENTS

CHAPTER I

INTRODUCTION

1. Objective of the Report

The objective of this report was to determine the most pratical means to improve the Liu-Tu Industrial District Wastewater Treatment Plant in Taiwan, the Republic of China. The present design loading are 3,000 cubicmeters per day, CMD (0.8 million gallons per day, MGD) of average daily flow, 500 mg/l of five-day BOD, 400 mg/l of suspended solids, and 50 mg/l of grease. The basic data in 1971 were selected to analyze the actual inflow of the plant. According to the analysis of the data in 1971, the average daily flow of raw wastewater to the plant had increased to 4890 CMD. Other loadings were 1211 mg/l of five-day BOD, 924 mg/l of suspended solids, and 821 mg/l of grease. It is obvious that the present conditions need to be improved and the wastewater treatment plant needs to be upgraded. The overloaded conditions are caused by wool scouring wastes. This problem can be corrected by industrial pretreatment and plant upgrading. The report was divided into two major parts. The first part covers wool-scouring wastewater pretreatment in the woolen mills. The second part covers the recommendations for the Liu-Tu Wastewater Treatment Plant.

2. Basic Data

The report was initiated by the collection of all available basic data provided by the Liu-Tu Industrial District Water Works. Most of the data are incomplete and insufficient except those data of 1971. The monthly average data in 1971 were obtained by averaging about eight samples in a month. Since the data of several months are't reasonable, only those data of January, April, May, June, November, and December in 1971 were selected for the overall yearly average data.

CHAPTER II

EXISTING FACILITIES

1. Introduction

The District is located at Liu-Tu, about eight kilometers to the southeast of Keelung City and twenty kilometers to the northeast of Taipei, the temporary capital of the Republic of China. The Liu-Tu Industrial District covers a total area of 54.5 hectares and is bordered on its northeast, north, and west by Keelung River which is a tributary of Tanshui River, the largest river in the northern Taiwan. The District was constructed in 1962. There are three systems of sanitary facilities in the District, water supply, sewage & industrial wastewater disposal, and storm water drainage. The wastewater treatment plant was built at the same time that the District was constructed. Because the types of industry to be incorporated in the District were not known, the design work was adopted by estimating the flow with probable values of 5-day BOD and suspended solids. The type of the treatment plant is secondary biological using the trickling filter. The actual concentrations of raw wastewater which are much higher than those expected, have destroyed the functions of the process. The pores of media in the trickling filter were clogged. In order to improve the ruined condition, part of the process was changed and the media in the trickling filter was replaced by larger stones in 1970.

2. Existing Facilities and Design Functions

(1) Basic Design Data

Average daily flow	: 3,000 CMD (0.8 MGD)
Maximum daily flow	: 4,560 CMD (1.2 MGD)
Charateristics of sewage at the design flow factor	: 3,800 CMD (1.0 MGD)
5-day BOD	: 500 mg/l
Suspended solids	: 400 mg/l
Grease	: 50 mg/l

(2) Industrial Waste Ordinance

The biological filtration type treatment plant was designed by estimating the loadings. Certain substances that may be present in industrial wastes which may adversely affect the proper function of the treatment plant had to be excluded either in whole or in part. In some cases a limited quantity was permissible, and this was based either on the individual industrial establishment or on concentration of the substance at the treatment plant from the entire system. The following ordinance was supported for the protection of the plant.

It was suggested that the following substances be excluded:

Oil, grease, or other substances that will solidfy or become viscous in the sewer;

Gasoline or similar liquids or gases that are flammable or explosive;

Substances that tend to settle out in sewers and cause stoppage or obstruction to flow;

Liquids that are corrosive, highly acid, or highly alkaline (pH below 5 or above 9);

Liquids with a temperature greater than 65°C;

Toxic or poisonous substances;

Iron, zinc, chromium, copper, and similar toxic material that will have an average daily concentration greater than the following quantities, or a maximum instantaneous concentration three times the following quantities in the sewage as it arrives at the proper treatment plant:

Iron	:	15 mg/l
Chromium	:	5 mg/l
Copper	:	3 mg/l
Zinc	:	2 mg/l
Cyanide	:	1 mg/l
Chlorine demand	:	30 mg/l

It was also suggested that the following substances be omitted or subjected to special review. Certain pretreatment or recovery before admission to the proposed sewers may be required:

High colored wastes;

Oil producing wastes;

Pulp, paper and paperboard wastes;

Extremely heavy BOD wastes that will have an average daily concentration greater than 500 mg/l or a maximum instantaneous concentration greater than 1,500 mg/l;

(3) Type of Plant

The minimum flow for Keelung River at the treatment plant site, which is expected to occur once-in-20 years after deducting the possible future water requirments, is probably from 40,000 to 50,000 CMD. The estimation of the ultimate plant capacity is 6,000 CMD. The dilution available will be 6.7 : 1 to 8.3 : 1. According to the recommendations of Royal Commission on Sewage Disposal of United Kingdom, the complete biological treatment using trickling filters was selected.

(4) Construction Items

a) Raw Sewage Pumping Station

Three sets of identical 5 HP motor driven vertical non-clog raw sewagepumps were installed to pump the raw sewage from a wet well into the preaeration basin.

b) Bar Rack

A dimension of 3.2M X 0.66M X 0.60M having 2.54CM clear opening bar rack was constructed before a Parshall flume.

c) Parshall Flume

The flow meter setting on the Parshall flume has a flow range of 1,500 to 22,000 CMD.

d) Preaeration Basin

Having dimensions of 7.8M X 4.8M X 3.00M with a unit of aerated sand and grit chamber was constructed. The detention time is 45 minutes at design flow. There are two sets of identical 7.5 HP motor driven rotary positive displacement blowers each with an inlet volume of 200 cfm.

e) Lagoons

Three lagoons with each an area of 3,500 M^2, originally designed for the last unit of the plant. The process has been changed since 1970. Waste is delivered from a preaeration basin into lagoon 1 through lagoon 2 and then pumped from lagoon 2 to the primary clarifier in order to reduce grease concentration. The effective depth of the lagoons is about one meter. The storage capacity of two lagoons is 9,000-9,500 M^3 corresponding to two days of detention time.

f) Primary Clarifier

Dimension : 13.71 M in diameter, 2.4 M in side water depth with a floor slop of 1:12

Overflow rate : 25.7 CMD/M^2 (630 GPD/Ft^2)

Weir loading : 88.0 CMD/M^2 (7,060 GPD/Ft^2)

Detention period : 2.29 hours

Expected BOD removal : 55%

BOD to trickling filter : 169 mg/l

A skimming device is provided in the clarifier for collecting the surface scum. Sludge is removed by scraper to a center pit for discharging to pumps.

g) Trickling Filter

Dimension : 27.5 M in diameter and 2.25 M in rock depth

Rock size : 6 - 10 CM (2.5 - 4.0 inches)

Hydraulic loading : 6,000 CMD/ha. (4.0 MGD/acre)

BOD loading : 42.5 Kgs/1,000 M^3(12 lbs/1,000 Ft^3)

Expected BOD removal : 85.5% in conjunction with secondary clarifier

Effluent of BOD : 24.5 mg/l

h) Secondary Clarifier

Dimension : the same as the primary clarifier

Overflow rate : 30 CMD/M^2 (733 GPD/Ft^2)

Weir loading : 103 CMD/M (825 GPD/Ft)

Detention period : 1.95 hours

i) Sludge Digestion Tank

Type : uncovered sludge digestion tank

Dimension : 18 M in diameter and 6.1 M in wall height, hopper bottom has a side slope of 5:1

Loading : 0.11 M^3 (4 Ft^3) per capita on population equivalent basis

Two sets of the identical 2 HP motor driven vertical non-clog pedestal mounted sludge pumps were installed to transfer or recirculate sludge.

j) Sludge Drying Beds

Four uncovered drying beds were constructed. The dimension of each bed is 12 M X 24 M. These four sludge beds are designed at 0.06 M^2 (0.66 Ft^2) per capita on population equivalent basis.

k) Chlorination

The feeding range of chlorinator is 3.5 to 70 Kgs (7.5 to 150 lbs) of liquid chlorine per 24 hours.

A schematic flow diagram indicating the proposed sewage treatment plant is shown in Fig.1.

3. Existing Wastewater Flow and Strength

It has been mentioned that the data of 1971 were selected for the basic standard to evaluate the existing facilities.

According to the waste statistics of 1971 by the Liu-Tu Industrial District Water Works, there were about 40 factories including 10,000 workers and employees in the District, and about 2,000 residents living in the neighborhood. Three factories, Liang-Yu Synthetic Textile Mill, Chungho Wool-Scouring Mill, and Lihua Wool-Scouring Mill in the District are the major sources of wastewater discharged into the wastewater treatment plant. The wastewater flow of those three factories was 56.3 % of the total amount. Because of the high strength of their wastes, the processing functions of the wastewater treatment plant have been ruined. The wastewater of the other factories are not considered as industrial wastes. The domestic wastewater of the residents in the neighborhood of the District is discharged into the plant. The monthly and yearly average data of wastes are listed in table 1 to table 9 of the Appendix 1.

(1) Wastewater Flow

The daily flow of the treatment plant was 4880 CMD calculated by averaging the average daily flow of the twelve months in 1971 shown as table 9. The daily flow averaged by seven months' data as table 8 was 4890 CMD which is very close to the twelve months' average daily flow. The following ratio of wastewater flow of three factories to the total amount of wastewater can be adopted from the data of 1971.

Lihua Wool-Scouring Mill	19.6 %
Chungho Wool-Scouring Mill	7.6 %
Liangyu Synthetic Textile Mill	29.1 %

There are no available data of sewage flow per capita which can be referred to in Taiwan. The data must be estimated. According to a study of data reported by 73 cities in 27 states in the United States[1], the following criteria are adopted.

Domestic sewage for low-cost housing	265 liters/capita/day
Employees of factories including cafeteria waste	80 liters/capita/day

The component of waste flow of residents and employees in the District in 1971 are calculated as follows.

	Daily flow	Ratio to total amount
Domestic sewage of residents	530 CMD	10.8 %
Employees of factories	800 CMD	16.4 %

The rest of the wastewater, about 16.5 % of the total, is a relatively clean waste such as cooling water and boiling water. It is assumed that there are no pollutants in this part of the waste.

(2) Wastewater Quality

The following concentrations are selected for calculating the loading of the treatment plant.

	BOD mg/l	Suspended solids mg/l	Grease mg/l
Lihua Wool-Scouring Mill*	3575	3052	3199
Chungho Wool-Scouring Mill*	2539	2333	2246
Liangyu Synthetic Textile Mill*	1280	143	115
Domestic Waste (including employees in the factory)	200	200	20

* : Yearly average of 1971

For domestic waste, the sewage strength of BOD and suspended solids were recommended by Engineering-Science, Inc. in the U.S. and China Engineering Consultants, Inc. in Taiwan in the report of Taipei Area Sewage Project in 1974. For the strength of grease, the medium value of typical sanitary chemical analysis of sewage[2] in the "Sewerage and Sewage Treatment" by Harold E. Bobbitt is used.

(3) Summary of Characteristic of Wastewaters

	BOD mg/l	Suspended solids mg/l	Grease mg/l	Ratio to total amount of waste
Lihua Mill	3575	3052	3199	19.6%
Chungho Mill	2539	2333	2246	7.6%
Liangyu Mill	1280	143	115	29.1%
Domestic Waste	200	200	20	27.2%

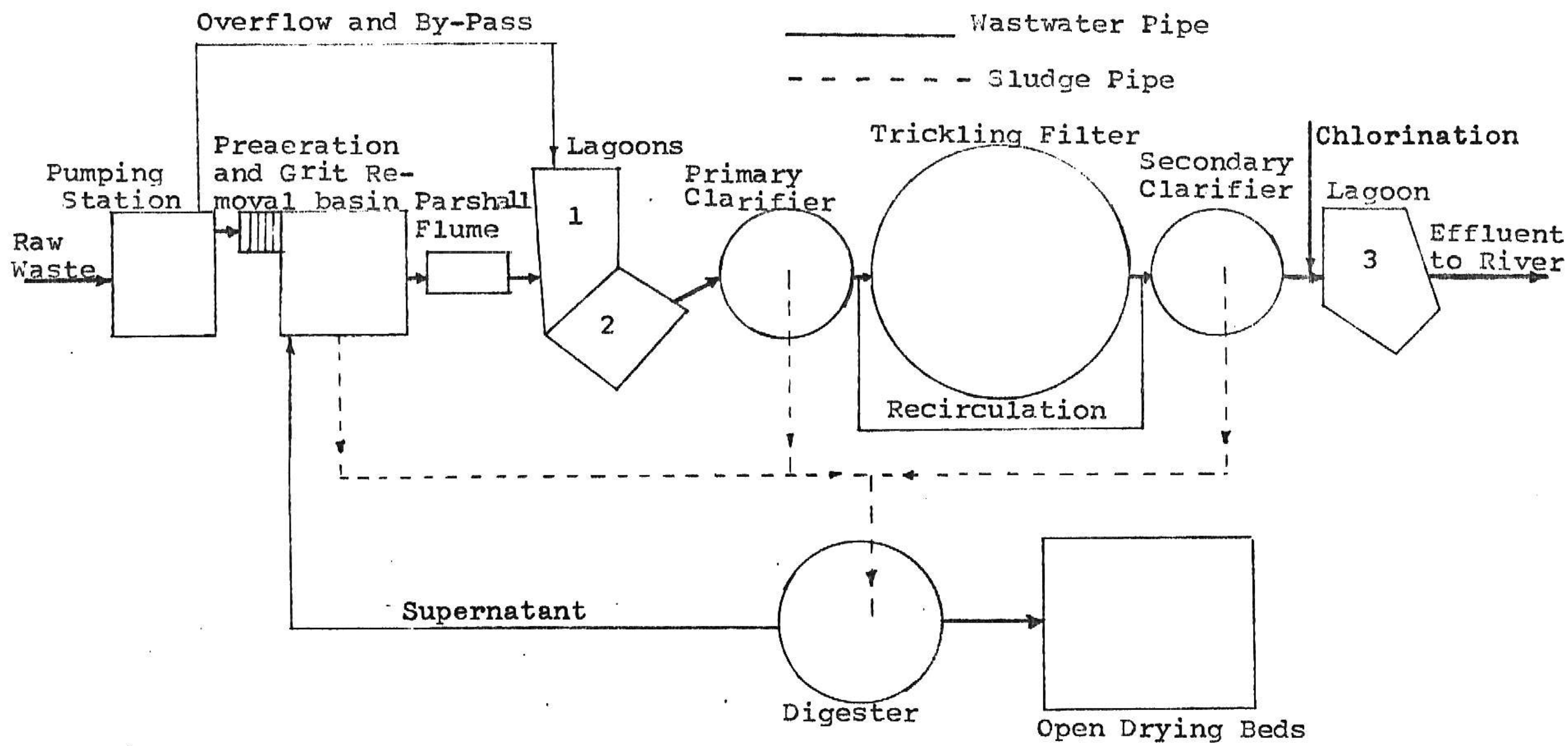


Fig. 1 EXISTING FLOW DIAGRAM OF LIU-TU WASTEWATER TREATMENT PLANT

CHAPTER III

PRETREATMENT OF WOOL-SCOURING WASTEWATERS

The industrial waste ordinance of the Liu-Tu Industrial District has never been enforced. For normal operations of the plant to occur, the ordinance must be enforced and pretreatment must be required. Some methods available for pretreatment of the wool-scouring wastewaters are as follows.

1. Methods of Scouring

There are several methods of wool scouring that are used and depending upon which is used the characteristic of the wastewater produced will be different.

(1) Freezing Process[3]

The freezing process for removal of dirt and grease consists of passing of wool, after dusting, through a low temperature chamber in which the moisture is frozen and the grease solidified. After freezing the dirt and fibers are separated mechanically, and the amount of the organic matter to be removed by subsequent washing of the fibers thus reduced. The method has not been generally acceptable as the quality of the wool after this treatment has not been considered satisfactory.

(2) Solvent Scouring

After dusting and opening raw wool, solvent is used to remove grease and then scouring the wool in the slight soap and soda wash. The used solvent is redistilled and the grease recovered. 80% of grease and 25-40% of the BOD can be removed by using the solvent process.

(3) Detergent Scouring

In this method the wool is first subjected to opening and dusting. Considerable dirt amounting to 5-15% of the total impurities is removed in this step. The opened and dusted wool is fed into a scouring machine and conveyed by moving rakes through two to five bowls containing a warm soap and soda solution maintained at 120-130^{o}F. After rinsing the wool may be bleached and carbonized before going to subsequent dyeing and finishing operations.

This is a common method used almost entirely in the U.S. and other countries. High concentrations of grease and BOD are contained in the wool scouring liquors. Several methods of wool-scouring wastewater treatment for the detergent scouring method are presented in this chapter.

2 Characteristics of Wool-Scouring Wastewater

The quantity of wastewater obtained from wool processing depends on a number of factors, such as the degree of purity of the raw material, the kind and quality of the woven fibers produced, and the kind and quality of the detergents. On the average, producing 1 Kg of the washed wool will cause 100 liters of waste.[3,4] (range : 80 to 120 liters)(100 lbs of wool produces 100 to 155 gallons of wastewater) The wool-scouring wastes contain the detergents and alkalies used for cleaning and the waxes, grease, sand, dung, blood, urea, sweat, and potassium salts or organic acids readily soluble in the water. The actual wool- fiber content in " grease wool" as taken from the sheep's back, average only 40%, the remaining 60% is composed of natural impurities.[5]

Most of grease is emulsified by the detergents and complex proteins. The remaining part of the grease stays suspended in the waste. The grease removed by the centrifuges is the part that suspends in the wastes. The rest of the grease, about 50 to 80% is still emulsified . Because of this emulsion, The grease and BOD cannot be removed by gravity sedimentation without chemicals. The wastes are basic, pH value of 8-11. The grease in wastes will decompose upon anaerobic conditions and produce H_2S gas and nuisance odors.

The average composition of wastes from the wool industry is given as follows.[6]

pH	strongly alkaline, 8-11
Suspended solids (at 105°C)	
total mg/l	10,000 - 20,000
volatile mg/l	7,500 - 15,000
Dry residue (at 105°C) mg/l	5,000 - 10,000
Volatile matter mg/l	1,500 - 3,000
Grease mg/l	6,000 - 12,000
BOD_5 mg/l	4,000 - 15,000

Reviewing the above data, it is obvious that the high concentration of grease in the wastes causes high concentrations of suspended solids and BOD. Therefore, it may be concluded that the main problem of the wool-scouring wastewater treatment is the removal of the grease.

Fats(grease) are esters of the trihydroxy, glycerol.[7] The term grease applied to a wide variety of organic substances that are extracted from aqueous solution or suspension by hexane.

It was mentioned that not all the grease is removed from wastes by primary settling units without chemicals or other treatment. Appreciable amounts remain in a finely divided emlsified form. If the grease treated by subsequent biological attack in secondary treatment units, the emulsifying agents are usually destroyed, and the finely divided grease particles become free to coalesce into larger particles. The larger particles of grease give a minimum of surface for bacterial action. Both trickling filters and the activated sludge process are adversely affected by unreasonable amounts of grease which seems to coat the biological forms sufficiently to interfere with oxygen transfer from the liquid to the interior of the living cells.

3. Effect of the Wastes upon Sewers and Treatment Plant

Wool-scouring wastewaters discharged into public sewers damage the brickwork or concrete unless they are discharged in relatively small amounts. Sulfides have a particularly harmful effect on concrete. Corrosion is also caused by sulfates at concentrations of over 300 mg/l and by fatty acids from the splitting of greases and soaps. Greases in the wastes also clog inside the sewer pipes. The pores of the media in the trickling filters are also clogged by high concentration of the grease in wastes. Because of their deleterious effect on sewage treatment processes, the proportion of wool wastes in domestic(or combined) sewage treatment system should be only 1-2%.[8] If large amounts are present, they should be subjected to preliminary physical and chemical treatment.

Discharge of crude wool wastes into the rivers often disturbs very seriously the biological state because of their alkalinity and very high grease concentration. Dissolved oxygen in the river is consumed very rapidly.

4. Usages and Value of the Recovered Greases

The grease recovered from wool-scouring wastewaters can be used as a material in soaps, lubricants, anti-corrosive oil, and cosmetics. A plant has been erected at Darlington, England, to treat 180,000 gal/WK (6,800 M^3/WK) of mixed botany and crossbred scour liquor.[9] So far, the work indicates that a substantial proportion of the cost of operation can be met by a more complete recovery of lanoline from the scour. The basic of the treatment process is calcium chloride(brine)and a sodium carbonate which is vacuum filtered. The grease removal is in the range of 99 to 100 percent, suspended solids removal after vacuum filtration is in the range of 80 to 97 percent, and BOD removal is 82 to 87 percent. The grease concentration is 18 to 25 percent.

In Russian investigation, the possibility of using wool industrial wastewaters, containing chromium, for irrigation purposes has been investigated both in laboratory experiments and in the field.[10] It has been determined that concentrations of more than 0.1 mg/l of trivalent or hexavalent chromium per 100 mg of soil inhibit nitrification. Irrigation of soil with wastewaters containing chromium caused a 2 to 10-fold increase in concentration of chromium in the soil down to a depth of one meter. Vegetables grown on soil irrigated with the wastewaters containing chromium had 3 to 10 times more than those grown on soil irrigated with water devoid of chromium.

5. Methods of Wool-Scouring Wastewater Treatment

The wastes constitute a highly polluting material consisting of an emulsion of dirt and bacteria in the water, with soaps and complex proteins as emulsifying agents. The concentration of grease is too high to be treated by biological processes such as activated sludge and trickling filter without pretreatment. There are several methods of treating wool-scouring wastewaters. Among these methods, centrifuging and diffusing air, are less effective in recovering a grease and in producing a good effluent, but under some conditions they may be more economical.[4]

(1) Centrifuging Method

The wastes are treated in a preliminary centrifuge where the large solid particles are seperated, and then heated in a special tank to about 85-90°C, from where they flow to smaller centrifuges where greases are seperated, Where centrifuges are employed, most of the greases removed is that in relatively free suspension. The most effective grease removal by centrifuges occurs when grease is in range of 9,000 to 11,000 mg/l.[6]

About 45 to 50% of the grease can be recovered in that range. In general, there is still 50 to 80% of grease remaining in the centrifuging effluent.

Centrifuges also can be used to recover the grease from the sludge which is produced in chemical coagulation.

(2) Acid Cracking Process

Acid cracking with sulfuric acid breaks the emulsion and precipitates the grease, after which it is drawn off to be dischared onto drying beds. After drying, the greasy sludge is filter-pressed under heat and may be further refined. Using this process, sufficient sulfuric acid is needed to neutralize the alkalies, to precipitate the grease and to give an excess mineral acidity of about 1,000 mg/l, or in the pH range of 3-4. The optimum pH range will be 3.2 ± 0.3.[11] On quiescent sedimentation, colloidal greases and soaps rise to the top as a scum or settle as a sludge, carrying with them other finely suspended matters. On the average, 87.5% of suspended solids, 77% of grease, and 50% of BOD can be removed by this process. There are many wool scouring mills employing this process in the U.S. and England. In the Soviet Union 3-5% sulfuric acid is used, after adding the acid, the wastes are heated to 40-45°C and then a similar procedure is followed.

Because of the high cost of sulfuric acid and the ajustment of the low pH effluent, several kinds of coagulants have been used to replace sulfuric acid.

(3) Calcium Hypochlorite Process

The process was developed by the Fields Point Mfg. Corp. of Providence. The treatment of wastes by this process consists essentially of adding to the warm settled wastes sufficient calcium hypochlorite $Ca(OCl)_2$ to reduce the pH to about 7.5 causing coagulation and separation of the wool grease and other colloidal and suspended solids. After eight hours of quiescent sedimentation, the clarified liquor is drawn to waste. The remaining sludge and scum are thoroughly mixed by agitation, and sulfuric acid is added until the pH is reduced to between 4 and 5. The treated sludge is thereby reduced about 50% in volume. The concentrated sludge is heated by steam to 90°C and is pressed in plates as described under treatment by sulfuric cracking.

Calcium ion concentration in the coagulation process is an important factor.[3,8] Free chlorine is also helpful for coagulation. For example, hydrated lime or quicklime can be used for a coagulatant, but it can't separate grease from wastes because less calcium ion existed.

The process can remove up to 96% of suspended solids, 86% of grease, and 42% of BOD.

(4) Calcium Chloride-Carbonation Process[8]

The process(as Fig.2)consists of two stages, acidification with CO_2 of the wastes and additional coagulation. The treatment is carried out in two communicating vertical tanks. The wastes flow upwards in the first tank and downwards in the second tank. They are acidified with carbon dioxide flue gases. The coagulant

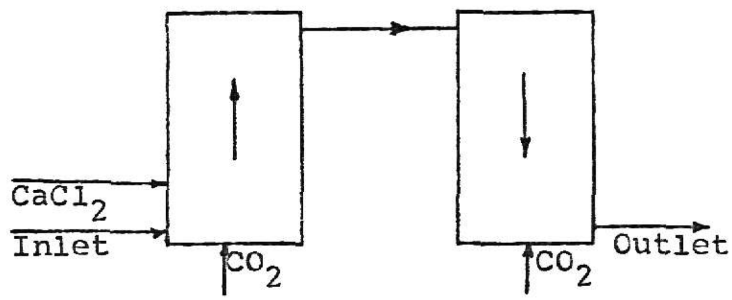


Fig. 2 Apparatus for combined treatment of scouring wastes

$CaCl_2$ is added to the first tank. The flue gases are passed through both tanks from below in large excess, about 2-3 times greater than is required theoretically for reaction with carbonates and hydroxides. At the same time fine bubbles of air are passed through the wastes. The sludge formed in the tanks dries quickly, it is filtered off on filters and after further acidification with sulfuric acid, the grease can be processed out of the sludge.

The main purpose for adding CO_2 is to reduce the requirement of calcium chloride. Adding CO_2 to reduce pH value to 8, 20 to 50% of calcium chloride can be saved.

The following data are derived by Joseph A. McCarthy, Massachusetts department of Public Health. From the test data, it is easy to find that when the added coagulant reaches the extent that suspended solids has been removed, it is not economical to add more coagulant. Biological methods such as high-rate trickling filters may be used economically to remove the dissolved or emulsified solids and BOD.

Results of Treatment of a Strong Wool Scouring Waste with $CaCl_2$ and CO_2[8]

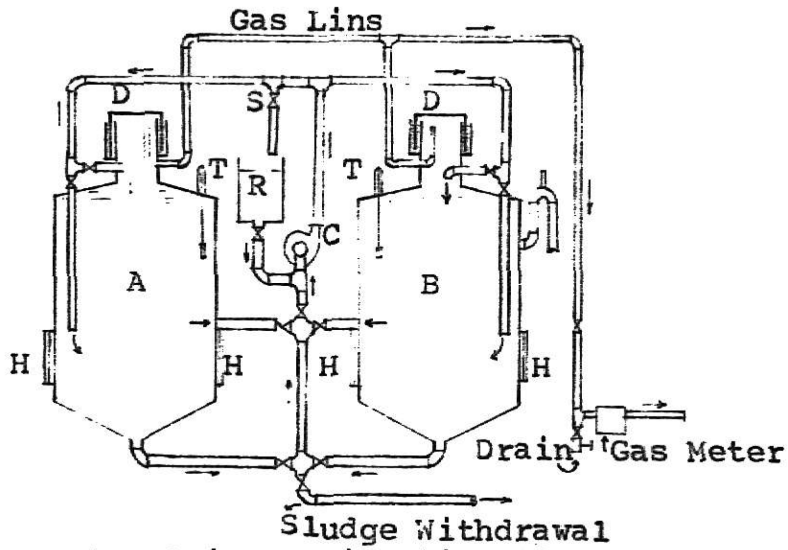
	pH	Sludge after 2 hr. settling % by volume	Suspended solids Total mg/l	Suspended solids Volatile mg/l	Grease mg/l	BOD mg/l
Untreated waste	9.5	-	5,640	3,820	11,500	10,700
Supernatant after 1.25% $CaCl_2$	7.6	26	320	260	1,130	3,000
Reduction(%)	-	-	94	93	90	72
Supernatant after carbonation plus 1.25% $CaCl_2$	7.3	26	30	21	370	2,100
Reduction(%)	-	-	99	99	97	80
Supernatant after 1.6% $CaCl_2$	7.3	26	45	25	360	2,000
Reduction(%)	-	-	99	99	91	81

The average reduction using this process may be 98% of suspended solids, 90% of grease, and over 70% of BOD.

(5) Anaerobic Digestion Process[12,13,14]

The process was investigated by M.T. Singleton, Wiedeman and Singleton, consulting Engineers in 1948. The process is given as Fig.3.

It is a controlled digestion method. That grease and soaps could be completely digested to form methane and carbon dioxide. Gas yield will be pratically proportional to grease content. A pilot plant study was conducted by M.T. Singleton. Two 500 gallons tanks were provided, equipped with hopper bottoms, gas collection domes and a small gas meter. Heat was provided by electric heaters. First, 250 gallons of digested sludge was



A : Primary Digestion 500 GAL.
B : Secondary Digestion 500 GAL.
C : Recirculation Pump
D : Removable Liquid Seal Gas Domes
H : Strap on Electric Tank Heaters
R : Raw Waste Feed
S : Sampling Line & Raw Feed Flushing
T : Stem Thermometers

Fig. 3 Diagrammatic Layout of Pilot Plant for Digestion of Wool Scouring Wastewaters

obtained from the city sewage plant and placed in the primary digester, and then both tanks were filled with water. Temperaure was raised to 95°F. Five gallons of wool-scouring wastewater(average volatile solids 28,000 mg/l) was added the first day and daily volume increaseed by increments over a 2-week period until the feed was 36 GPD, which is equivalent to 0.06 lbs of total volatile solids per cubic foot of total digester capacity per day. 36 GPD of waste was fed for eight days more, at which time there was a sudden rise in the volatile acid content to about 4,000 mg/l. The feed was reduced to about 15

GPD through the following week, but the volatile solids content increased to about 5,000 mg/l. City water was added to the primary digester for diluting purpose. This had the effect of reducing the volatile acid content to below 2,000 mg/l, and no further trouble was experienced in controlling the volatile acid content during the experiment. From the pilot test, the following data were anticipated for designing.

Total displacement capacity for two tanks	: 20 days of waste
Volatile solids loading	: 0.1 $lbs/ft^3/day$
Volatile acid content	: below 2,000 mg/l
Volatile solids removal	: 65%
Grease removal	: 90%
Gas produced	: 8.6-10.2 ft^3/lb of volatile matters

The advantage of this process is the relatively low construction cost, low operation and maintenance costs and gas product. Lanolin is not produced.

(6) Miscellaneous

a)[15] Aluminium salt can be used instead of sulfuric acid for coagulating the grease. Varel Mills, Inc. at West Virginia, the plant was originally designed for 1 MGD flow, with the expection that alum, lime, and chlorine would affect satisfactory treatment. This expection has proved largely true. However, during some operating periods it has been found economical to add clay. As analysis showed the following reduction for a typical run; BOD 93%(300 to 20 mg/l), total solids 64%(1,530 to 550 mg/l), volatile solids 81%(780 to 150 mg/l), suspended solids 90% (300 to 30 mg/l), volatile suspended solids 91%(179 to 16 mg/l).

b)[16] Franclin, Colville and Bowers reviewed two years operation of the waste treatment plant at a large England woolen mill for recovery of grease by use of $CaCl_2$. The mixed wastes were sceened and treated with a hydrocyclone to remove suspended solids, then centrifuged to recover the neutral wool grease for cracking with $CaCl_2$ and finely filtered.

c)[17] Methods examined in detail at the Wool Industry Research Association for the treatment of effluents such as these have included electrophoresis, dialysis, reverse osmosis, and distillation. These studies have resulted in the development of the Traflo-W process. The process essentially entails chemical coagulation of impurities, followed by vacuum filtration. As its optimum, it is capable removing 100 percent of the suspended solids and grease and of reducing the BOD by at least 80 percent. The process is shown in Fig.4.

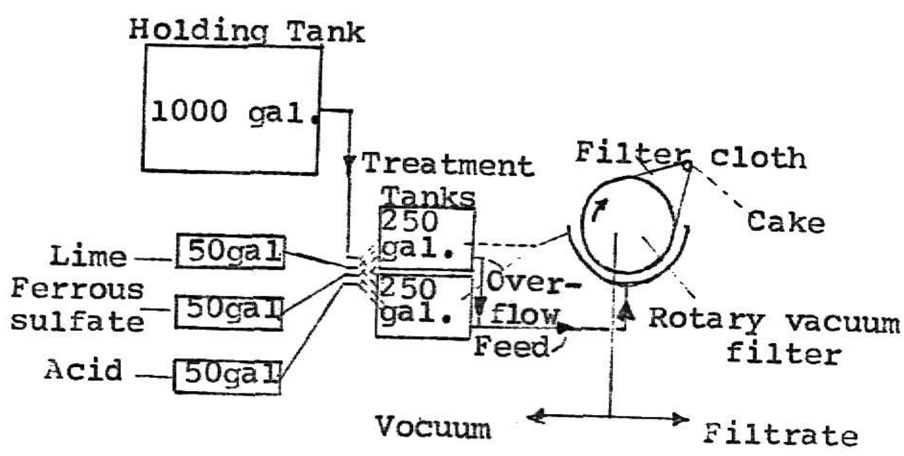


Fig. 4 Outline of Mill-based Pilot-scale Plant for Treatment of Piece-scouring Effluent

6. Effluent Limitations and Guidelines of Wool-Scouring Wastewaters by EPA of the U.S.[18]

The effluent limitations and guidelines of wool-scouring wastes are in the subpart of the textile mills point source category which were issued in the Federal Register(Title 40, Part 404) on April 4, July 5, and August 21 in 1974. They are arranged as follows.

a) Effluent limitations guidelines representing the degree of effluent reduction attainable by the application of the best practicable control technology currently available.

Effluent characteristic	Effluent limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not excess
Metric units Kg/KKg of product		
BOD	10.6	5.3
TSS	32.2	16.1
COD	138.0	69.0
Grease	7.2	3.6
Total chromium	0.10	0.05
Phenol	0.10	0.05
Sulfide	0.20	0.10
pH	6.0-9.0	
Color	-	-
Fecal	-	-

b) Effluent limitatioms guidelines representing the degree of effluent reduction attainable by the application of the best available technology economically achievable.

Effluent characteristic	Effluent limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not excess
	Metric units Kg/KKg of product	
BOD	4.8	2.4
TSS	4.0	2.0
COD	36.0	18.0
Grease	2.0	1.0
Total chromium	0.10	0.05
Phenol	0.10	0.05
Sulfide	0.20	0.10
pH	6.0-9.0	
Color	less than 600 APHA	
Fecal	less than 400/100 ml	

c) Standard of performance for new sources

Effluent characteristic	Effluent limitations	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not excess
	Metric units Kg/KKg of product	
BOD	10.6	5.3
TSS	32.2	16.1
COD	138.0	69.0
Grease	7.2	3.6
Total chromium	0.10	0.05
Phenol	0.10	0.05
Sulfide	0.20	0.10
pH	6.0-9.0	
Color	-	-
Fecal	-	-

For the grease, as an incompatible pollutant introduced into a public owned treatment works, its pretreatment standard shall be standard of performance for new source. The effluent limitations guidelines for COD, total chromium, phenol, sulfide, and oil and grease set above shall apply for pretreatment standards of existing sources.

The limitations set by EPA are based on the Amendments of the Federal Water Pollution Control Act in 1972. The Acts require to restore and maintain the chemical, physical, and biological integrity of the nation's waters by 1977. The intent is that the nation's waters can be used for the purposes of water supply, aquatic life and second class recreations on the water before 1977. The limitations of the section a) need to meet the target of 1977. The Acts also require that the 1983 target is to reach the standard that nation's waters can be used for water supply, aquatic life, and people can recreate on and in the water. The limitations of the section b) may be adopted for the target of 1983.

7. Further Treatment of Wool-Scouring Wastewaters

After treatment using the methods mentioned above, a relatively high concentration of pollutants is still left in the effluent. For instance, the removal efficiencies are 97% of grease and 80% of BOD, if calcium-carbonation process is employed. There are about 180 to 420 mg/l of grease and 800 to 3,000 mg/l of BOD leaving in the effluent. Assuming 1 Kg of washed wool causes 100 liters of wastes, the effluent limitations of grease and BOD regulated by EPA, can be calculated as follows.

Grease : $3.6\ Kg/KKg \times 10^6\ mg/Kg \times 1/1000 \times 1/100\ KKg/l.$

$= 36\ mg/l$

BOD : $5.3\ Kg/KKg \times 10^6\ mg/Kg \times 1/1000 \times 1/100\ KKg/l.$

$= 53\ mg/l$

It is obvious that the effluent of wastes pretreated by the calcium-carbonation process needs further treatment. It is not practical or economical to remove more pollutants by adding more chemical coagulants. After pretreatment of chemical or other methods, the wastes can be treated in admixture with domestic sewage by activated sludge or trickling filter process. For wool-dyeing wastes treatment, trickling filter is better than activated sludge process.[6] In general, the ratio of wool wastes to sewage shall not be beyond 1:10.[6]

CHAPTER IV

RECOMMENDATIONS FOR LIU-TU WASTEWATER TREATMENT PLANT

1. Analysis of the Plant Functions

a) Lagoons

The removal efficiencies of lagoons for BOD, suspended solids, and grease were 18.7%, 51.3%, 25.9% respectively in 1971. The detention time of waste in the lagoons with 6,000 M^3 in surface area and a 1.5 M depth was about two days. A field test was made by Liu-Tu Industrial District Water Works in 1972. The following are the results.

Depth of lagoons	3 M
Detention time	5 days
Grease removal	40%
BOD removal	35%
Suspended solids removal	55%

b) Trickling Filter Process

The removal efficiencies of the trickling filter for treating only 2,000 CMD of existing waste are limited. only 22.6% of BOD, 14.1% of suspended solids, and 19.2% of grease were removed by trickling filter and secondary clarifier in 1971. One reason for the limited trickling filter effectiveness is the high concentration of grease. Ronald E. Bartlett suggested that typical consent conditions for the discharge of industrial wastes to a public sewer for oil and grease is less than 100 mg/l.[19] Assuming 1 Kg of washed wool which causes 100 liters of waste, the pretreatment standard of grease will be 36 mg/l according to the EPA guidelines. Thus, it may be concluded that the permissible concentration of grease, 50 mg/l, of the Liu-Tu Industrial District Wastewater Treatment Plant is reasonable.

On the average, a waste of 940 mg/l of BOD, 348 mg/l of suspended solids, and 551 mg/l of grease was pumped into the trickling filter in 1971. The strength of waste was too high to be treated. It is evident that some of the industrial wastes must be pretreated before discharging to the plant.

c) The average daily flow of 1971 had exceeded the design capacity. The average daily flow was 4890 CMD, and maximum daily flow was up to 6,100 CMD. Compared with the design capacity of 3,800 CMD, some of the facilities must be extended.

d) Since the available data are not complete, more detailed analysis is impossible and exceeds the scope of this report.

e) Calculation of Pretreatment Standards

Pretreatment standards of wool-scouring waste must be set since grease has become a main problem for the plant. Assume the lagoons will be enlarged to the capacity of 30,000 M^3(surface area : 10,000 M^2, depth : 3 M), and the raw waste will be stored in the lagoons for five days before the pre-aeration process. The limitation of grease for raw waste discharged into the plant will be.

$$\frac{50 \text{ mg/l}}{0.6} = 83 \text{ mg/l}$$

The concentration of grease contributed by Liangyu Synthetic Textile Mill and domestic sewage will be.

$$115 \times 0.291 + 20 \times 0.272 = 39 \text{ mg/l}$$

Thus, the limitation of grease for wool-scouring mills will be.

$$\frac{83 - 39}{0.196+0.076} = 162 \text{ mg/l}$$

The grease removal of wool-scouring mill for pretreatment must be.

Lihua Wool-Scouring Mill $\frac{3199 - 162}{3199} = 95\%$

Chungho Wool-Scouring Mill $\frac{2246 - 162}{2246} = 93\%$

In order to obtain the expected removal efficiency, calcium chloride-carbonation process is recommended for pretreatment. Using this process, 80% BOD and 99% suspended solids removal can be expected.

Check for BOD loading:

Lihua Wool-Scouring Mill $3575 \times (1 - 0.8) = 715$ mg/l

Chungho Wool-Scouring Mill $2539 \times (1 - 0.8) = 508$ mg/l

The BOD of raw waste discharged into the plant will be.

$$715 \times 0.196 + 508 \times 0.076 + 1280 \times 0.291 + 200 \times 0.272$$
$$= 606 \text{ mg/l}$$

The enlarged lagoons will reduce 35% of BOD, so that the BOd loading before preaeration basin will be.

$$606 \times (1 - 0.35) = 394 \text{ mg/l}$$

The BOD loading will be under the 500 mg/l design loading.

Check for suspended solids:

Lihua Wool-Scouring Mill 3052 X (1 - 0.99) = 31 mg/l

Chungho Wool-Scouring Mill 2333 X (1 - 0.99) = 23 mg/l

The suspended solids of raw waste discharged into the plant will be.

31 X 0.196 + 23 X 0.076 + 143 X 0.291 + 200 X 0.272

= 104 mg/l

The enlarged lagoons will reduce 55% of suspended solids. So that the suspended solids loading before the preaeration basin will be.

104 X (1 - 0.55) = 47 mg/l

The suspended solids loading is less than 400 mg/l design loading.

2. Recommendations

Because the data were neither complete nor sufficient, more detailed recommendation is impossible and exceeds the scope of this report. Based on the statements described in the report, the following conclusions and recommendations can be made. (flow diagram shown as Fig.5)

a) The Liu-Tu Industrial District Wastewater Treatment Plant was designed to provide a biological filtration type treatment for a flow of 3,800 CMD. A provision has been considered for doubling the design flow up to 7,600 CMD. The average daily flow had reached 4890 CMD, and the maximum monthly flow had been up to 6,100 CMD in 1971. Another trickling filter needs to be constructed. A two-stage filtration system[20] is recommended to upgrade the efficiency of plant performance.

b) Some of the existing process must be changed. A primary sedimentation basin should be added before waste is discharged into the lagoons. Three lagoons with a total surface area of 10,000 M^2 and a depth of 3 M should be connected by set up for a five days detention time. Raw waste will be first pumped through primary sedimentation basins to lagoons, and then discharged into the preaeration basin followed by the original process.

c) The existing drying beds in the Plant are open style. On the average, rain days occur about half of the time. Therefore the beds need to be enclosed. Sandbeds can be covered and enclosed by glass.[21] Glass enclosures protect the drying sludge from rain, control odors and insects, reduce the drying period during cold weather, and can improve the appearance of the plant. Good ventilation is also important to control humidity and optimize the evaporation rate.

d) The following pretreatment standards must be set for wool-scouring mills.

BOD	1,200 mg/l
Grease	162 mg/l

The pretreatment method of calcium chlorite-carbonation is suggested to meet the requirement.

e) Although the BOD concentration of the waste of Liangyu Textile Mill is relatively high, based on the data of 1971, it will be permitted to discharge into the wastewater treatment plant without pretreatment. Dying waste discharged from the mill may cause problems for the wastewater treatment plant. Since no quantitive data are available to evaluate the effects of these wastes, it is impossible to make further suggestion in this report. Color removal can be done only at great cost in most instances. Among the various means, the most simple and efficient one is to segregate the high color wastes.[17] (e.g. dispose of them separately in landfill, ocean, or incinerator) This method can possibly produce enough color removal to satisfy the requirements. Otherwise the wastewater may be treated with chlorine, ozone, hydrogen peroxide, potassium permanganate, sodium bisulfite, or chemical coagulation with the common coagulants. If adequate removal is not applicible, the treated effluent may be further treated by passage through a granular activated-carbon adsoption system.[22]

f) The recommendations are made upon the 1971 conditions. Any individual factory that intends to change its process of production which will cause the change of the waste both in quantity and quality, must get permission from the wastewater treatment plant in advance.

g) There is no effluent standard for secondary treatment yet in Taiwan. The effluent quality for secondary treatment of the U.S. regulated by EPA[23] can be referred to by the Liu-Tu Wastewater Treatment Plant for evaluation of treatment efficiency. All requirements for each parameter of secondary treatment effluent of the U.S. shall be achieved as follows.

	BOD	Suspended solids	Fecal coliform bacteria	pH
Average value of 30 consecutive days	30 mg/l	30 mg/l	200/100 ml	6-9
Average value of 7 consecutive days	45 mg/l	45 mg/l	400/100 ml	
Average removal of 30 consecutive days	85%	85%		

h) Comparison of flow and strength of influent is as the following table.

	Flow CMD	BOD mg/l	Suspended solids mg/l	Grease mg/l
1. Original design data	4,890	500	400	50
2. Average data of 1971	4,890	1,211	924	821
3. After recommended pretreatment in woolen mills, based on 1971 data	4,890	621	104	83
4. After item 3 plus enlarged lagoons, based on 1971 data	4,890	404	47	50

Design calculation to determine the adequacy of sizing of operational unites are presented in the Appendix II. The recommended final flow diagram is shown in Fig.5.

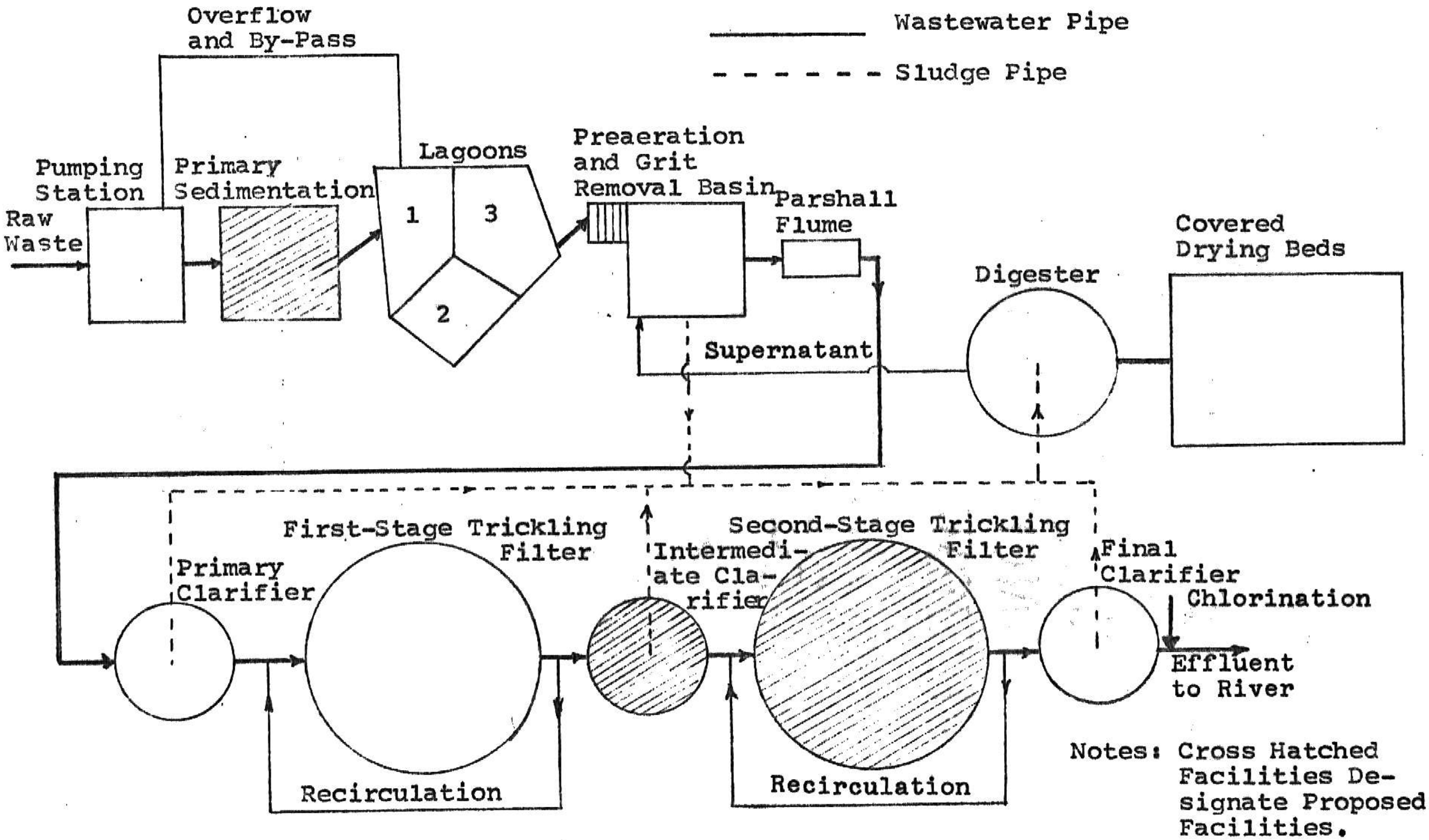


Fig.5 RECOMMENDED FLOW DIAGRAM OF LIU-TU WASTEWATER TREATMENT PLANT

Appendix I

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 1

Monthly Average in January in 1971

Sampling Date : January 6, 7, 8, 12, 13, 14, 15,

Sample		Individual Manufacturer Eff.			Wastewater Treatment Plant			
		I	II	III	IV	V	VI	VII
Temperature	C°	32.4	29.0	26.47	23.54	22.31	22.3	21.2
pH Value		7.67	7.98	6.50	6.35	6.78	6.94	7.13
Alkalinity	mg/l	1157	791	56	177	409	438	458
Acidity	mg/l	70	19	36	119	170	141	110
Suspended Solids	mg/l	3664	2133	199	848	360	333	364
Volatile Solids	mg/l	2623	1728	179	601	328	307	332
Total Solids	mg/l	8858	5263	1027	2210	1700	1650	1584
Settleable Solids	ml/l	2.67	1.84	0.15	5.07	0.84	0.24	1.90
Chloride	mg/l	76	71	34	152	75	73	69
Grease	mg/l	3875	2066	81	554	507	488	412
BOD	mg/l	3800	2648	638	996	1026	956	850
COD	mg/l	12981	7723	2812	2917	2721	2661	2155
Phosphate	mg/l						14.00	
Appearance Color								
Estimated Amount of Waste	CMD	900	330	1120	4000	4000	2000	2000
Rario to Total Amount of Waste	%	22.4	8.2	28	100	100	50	50
Remark								

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

Appendix I

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 2

Monthly Average in February in 1971

Sampling Date : Feb. 4, 5, 10, 18, 19, 24, 25, 26,

Sample		Individual Manufacturer Eff.			Wastewater Treatment Plant			
		I	II	III	IV	V	VI	VII
Temperature	C°	33.0	30.6	27.7	23.8	22.6	22.5	21.2
pH Value		7.23	8.23	6.04	6.55	6.86	7.00	7.35
Alkalinity	mg/l	734	897	66	251	480	490	500
Acidity	mg/l	124	6.5	240	78	126	125	75
Suspended Solids	mg/l	2355	2183	117	962	719	425	398
Volatile Solids	mg/l	1846	1748	114	744	625	379	378
Total Solids	mg/l	6990	6080	981	2536	2385	2022	2125
Settleable Solids	ml/l	0.86	1.42	0.36	2.41	0.56	0.15	1.77
Chloride	mg/l	73	61	19	159	80	78	74
Grease	mg/l	3209	2653	107	885	879	714	560
BOD	mg/l	2721	2312	1104	1115	1138	996	842
COD	mg/l	9851	8252	2487	3539	3274	2900	2378
Phosphate	mg/l						3.94	
Appearance Color								
Estimated Amount of Waste	CMD	1080	350	1380	4530	4530	2000	2000
Rario to Total Amount of Waste	%	24.0	7.7	30.5	100	100	44.2	44.2
Remark								

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 3

Monthly Average in April in 1971

Sampling Date : April 14, 15, 16, 21, 22, 23, 27, 28,

Sample	Individual Manufacturer Eff.			Wastewater Treatment Plant			
	I	II	III	IV	V	VI	VII
Temperature C°	34.12	32.18	30.30	28.78	27.18	27.80	26.00
pH Value	6.81	7.73	5.42	7.10	7.02	6.69	7.25
Alkalinity mg/l	999	793	74	425	593	620	590
Acidity mg/l	135	38	76	62	107	95	70
Suspended Solids mg/l	2490	2069	334	874	691	396	345
Volatile Solids mg/l	1954	1571	208	646	575	360	326
Total Solids mg/l	7458	5052	757	2690	2382	2064	1935
Settleable Solids ml/l	2.01	3.91	1.01	2.96	0.64	0.37	0.45
Chloride mg/l	67	53	18	118	79	87	86
Grease mg/l	3219	2377	139	978	876	749	676
BOD mg/l	3637	2565	747	1580	1260	1210	866
COD mg/l	11021	7647	1705	3855	3519	3144	2702
Phosphate mg/l						5.00	
Appearance Color							
Estimated Amount of Waste CMD	930	270	1450	4370	4370	2000	2000
Rario to Total Amount of Waste %	21.3	6.2	33.3	100	100	45.7	45.7
Remark							

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 4

Monthly Average in May in 1971

Sampling Date : May 12, 17, 18, 19, 21, 24, 26, 28,

Sample		Individual Manufacturer Eff.			Wastewater Treatment Plant			
		I	II	III	IV	V	VI	VII
Temperature	C°	37.25	34.20	35.10	31.90	30.28	30.20	29.57
pH Value		7.66	8.50	5.85	7.15	7.09	7.10	7.50
Alkalinity	mg/l	1263	1001	37	450	640	645	637
Acidity	mg/l	101	7	99	61	117	101	88
Suspended Solids	mg/l	2983	1739	103	1057	354	334	262
Volatile Solids	mg/l	2318	1447	101	823	343	325	258
Total Solids	mg/l	8317	5021	663	3901	2061	2102	1823
Settleable Solids	ml/l	3.29	1.33	0.11	1.95	0.28	0.29	0.34
Chloride	mg/l	90	68	30	723	814	85	91
Grease	mg/l	3384	1979	82	958	582	566	408
BOD	mg/l	3783	2544	566	1337	980	949	693
COD	mg/l	13141	7213	3173	4264	3052	3003	2239
Phosphate	mg/l						3.06	
Appearance Color								
Estimated Amount of Waste	CMD	910	350	1380	4580	4580	2000	2000
Rario to Total Amount of Waste	%	19.8	7.7	30.2	100	100	43.7	43.7
Remark								

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

Appendix I

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 5

Monthly Average in June in 1971

Sampling Date : June 15, 16, 17, 18, 21, 22, 23, 25,

Sample		Individual Manufacturer Eff.			Wastewater Treatment Plant			
		I	II	III	IV	V	VI	VII
Temperature	C°	37.84	36.95	37.88	34.76	33.48	33.43	32.73
pH Value		7.73	7.81	6.71	7.09	7.28	7.25	7.46
Alkalinity	mg/l	1088	500	50	347	637	642	510
Acidity	mg/l	62	45	49	60	92	91	72
Suspended Solids	mg/l	2150	1348	134	888	383	356	166
Volatile Solids	mg/l	1679	1138	123	703	334	316	164
Total Solids	mg/l	7133	3683	860	2200	1742	1730	1503
Settleable Solids	ml/l	2.64	1.49	0.18	2.74	0.86	0.67	0.51
Chloride	mg/l	85	58	22	108	88	88	82
Grease	mg/l	3230	1721	90	825	522	504	341
BOD	mg/l	3575	1706	2407	1008	842	812	589
COD	mg/l	11460	5519	4927	3598	2615	2605	1807
Phosphate	mg/l						5.75	
Appearance Color								
Estimated Amount of Waste	CMD	740	370	1440	4860	4860	2000	2000
Rario to Total Amount of Waste	%	15.2	7.6	29.7	100	100	41.2	41.2
Remark								

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

Appendix I

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 6

Monthly Average in November in 1971

Sampling Date : Nov. 15, 16, 23, 24, 25, 26,

Sample		Individual Manufacturer Eff.			Wastewater Treatment Plant			
		I	II	III	IV	V	VI	VII
Temperature	C°	31.72	35.01	30.21	28.17	23.67	23.68	22.65
pH Value		6.83	8.46	6.49	7.15	7.34	7.25	7.65
Alkalinity	mg/l	663	666	48	217	297	305	322
Acidity	mg/l	492	32	42	77	101	105	94
Suspended Solids	mg/l	3963	3074	33	1026	275	248	319
Volatile Solids	mg/l	3146	2764	32	910	270	246	316
Total Solids	mg/l	8084	6559	595	2241	1348	1317	1164
Settleable Solids	ml/l	3.11	1.94	0.05	1.34	0.19	0.35	1.06
Chloride	mg/l	98	84	23	59	91	89	78
Grease	mg/l	2544	2273	169	740	319	325	292
BOD	mg/l	3584	3013	1419	1040	762	762	573
COD	mg/l	12307	10993	2525	3734	2101	2067	1851
Phosphate	mg/l						3.92	
Appearance Color								
Estimated Amount of Waste	CMD	1040	440	1560	5780	5780	2000	2000
Rario to Total Amount of Waste	%	18.0	7.7	27.0	100	100	34.6	34.6
Remark								

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

Appendix I

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 7

Monthly Average in December in 1971

Sampling Date : Dec. 14. 15, 17, 22, 24, 30,

Sample		Individual Manufacturer Eff.			Wastewater Treatment Plant			
		I	II	III	IV	V	VI	VII
Temperature	C°	30.08	34.56	31.78	27.40	24.88	25.00	23.46
pH Value		7.07	8.46	7.23	7.32	7.30	7.30	7.62
Alkalinity	mg/l	865	753	68	315	509	520	502
Acidity	mg/l	197	32	28	58	140	135	120
Suspended Solids	mg/l	3758	3787	80	812	368	344	238
Volatile Solids	mg/l	3125	3263	72	706	333	298	213
Total Solids	mg/l	7719	6658	1092	3132	1913	1968	1704
Settleable Solids	ml/l	2.06	2.31	0.06	1.61	0.30	0.48	1.09
Chloride	mg/l	100	84	31	84	118	113	89
Grease	mg/l	2935	2650	137	807	576	512	433
BOD	mg/l	3923	2987	2079	1407	887	895	682
COD	mg/l	14000	11411	3900	6126	2757	3010	2335
Phosphate	mg/l						4.33	
Appearance Color								
Estimated Amount of Waste	CMD	1130	490	1630	6100	6100	2000	2000
Rario to Total Amount of Waste	%	18.4	8.1	26.6	100	100	32.7	32.7
Remark								

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

Appendix I

LIU-TU INDUSTRIAL DISTRICT WATER WORKS
SEWAGE EXAMINATION REPORT

Table 8

Monthly Average in 1971

Sampling Date : January, February, April, May, June, November, December,

Sample		Individual Manufacturer Eff.			Wastewater Treatment Plant			
		I	II	III	IV	V	VI	VII
Temperature	C°	33.88	33.21	31.35	28.34	26.34	26.42	25.26
pH Value		7.29	8.17	6.32	6.96	7.10	7.11	7.42
Alkalinity	mg/l	967	772	81	312	509	523	502
Acidity	mg/l	169	26	81	74	122	113	90
Suspended Solids	mg/l	3052	2333	143	924	450 51.3%	348 62.3%	299 67.6%*
Volatile Solids	mg/l	2387	1951	118	733	401 45.3%	319 56.5%	284 61.3%*
Total Solids	mg/l	7794	5474	854	2701	1933 28.4%	1836 32.0%	1691 37.4%*
Settleable Solids	ml/l	2.38	2.04	0.27	2.58	0.52 79.8%	0.36 86.0%	1.02 60.6%*
Chloride	mg/l	85	68	25	200	192 4.0%	88 56.0%	81 59.4%*
Grease	mg/l	3199	2246	115	821	609 25.9%	551 32.9%	445 45.7%*
BOD	mg/l	3575	2539	1280	1211	985 18.7%	940 22.4%	728 39.9%*
COD	mg/l	12109	8394	3076	4005	2863 28.5%	2770 30.8%	2210 44.8%*
Phosphate	mg/l						5.71	
Appearance Color								
Estimated Amount of Waste	CMD	960	370	1430	4890	4890	2000	2000
Rario to Total Amount of Waste	%	19.6	7.6	29.1	100	100	40.9	40.9

Remark * :Removal efficiency

I : Tihua Wool-Scouring Mill, II : Chungho Wool-Scouring Mill, III : Liangyu Synthetic Textile Mill, IV : Influent at Parshall Flume, V : Lagoon 2, VI : Primary Clarifier, VII : Effluent at Secondary Clarifier.

Table 9

Wastewater Flow of the Liu-Tu Wastewater Treatment Plant in 1971

Month	Average Daily Flow CMD	Ratio to Total Average
January	4,000	0.82
February	4,530	0.92
March	4,370	0.90
April	4,370	0.90
May	4,580	0.94
June	4,860	1
July	4,830	0.99
August	5,300	1.09
September	4,580	0.94
October	5,280	1.08
November	5,780	1.18
December	6,100	1.25
Total Average	4,880	

Appendix II

Design Calculations

Check for BOD Loadings

Preaeration Tank

Capacity = 7.8M x 4.8M x 3M = $112M^3$

Retention Time = $\frac{112}{4890}$ = 0.023 days = 33 Min.

Existing air pumps of each with an inlet volume

200 ft^3 per min. = 5.67 M^3 per min.

Assume 8% of air transfer rate, 21% of O_2 in air by volume. Kgs of O_2 transfer per M^3 of wastewater;

5.67 x 33 x 0.08 x 0.21/112 = 0.028 M^3 Of O_2/M^3 of waste

Assuming the average temperature 25^oC

1 mole of O_2 at 25^oC at 1 atm is

22.4 liters x $\frac{298}{273}$ = 24.45 liters

Thus

$$\frac{32\ g}{24.45\ liters} \times \frac{1\ Kg}{1000\ g} \times \frac{1000\ liters}{1\ M^3}$$

= 1.31 Kgs/M^3 of O_2

BOD_5 removed by preaeration tank;

0.028 M^3 of O_2 / M^3 of waste x 1.31 Kgs/M^3 of O_2

= 0.0368 Kgs of O_2/M^3 of waste

= 37 mg/1

Rate of BOD removal

$\frac{37}{404}$ = 9.2 %

Primary Clarifier

BOD_5 to primary clarifier 404 - 37 = 367 mg/1

Retention Time 2.29 x $\frac{3800}{4890}$ = 1.8 hrs.

According to the record of performance of sedimentation introduced by H.J.H. Hodgson,[24] 30 % of BOD_5 removal in the primary tank can be expected. Thus,

BOD_5 to trickling filter 367 x (1 - 0.3) = 257 mg/l

Trickling Filters (two-stage type)

First Stage

$$\text{Media volume} = \left(\frac{27.5}{2}\right)^2 (3.1416)\ (2.25)\ (3.28)^3$$

$$= 47{,}144\ ft^3$$

$$BOD_5\ \text{lbs/day} = 257\ \text{mg/l} \times 4890\ M^3 \times \frac{Kg}{10^6 mg} \times \frac{1000\ \text{liters}}{M^3}$$

$$\times\ 2.204\ \text{lbs/Kg}$$

$$= 2770\ \text{lbs/day}$$

$$\frac{2770}{47140} = 59\ \text{lbs}\ BOD_5/\text{day}/1000\ ft^3$$

Using National Reseach Council (NRC) Equations[25]

BOD_5 removal Efficiency of firt stage

$$E_1 = \frac{100}{1 + 0.0085\left(\frac{W}{VF}\right)^{1/2}}$$

R = 1/6 = 0.167 ......recirculation rate

$$F = \frac{1+R}{(1+0.1R)^2} = \frac{1+0.167}{(1+0.1 \times 0.167)^2} = 1.13$$

$$W = 2770\ \text{lbs}\ BOD_5/\text{day}$$

$$V = \left(\frac{27.5}{2}\right)^2 (3.1416)\ (2.25) = 1336\ M^3$$

$$= 1.0816\ \text{ft-acre}$$

$$E_1 = \frac{100}{1 + 0.0085\left(\frac{2770}{1.0816 \times 1.13}\right)^{1/2}}$$

$$= 71\ \%$$

Second Stage

$$W' = 257(1-0.71)\ \text{mg/l} \times 4890\ M^3/\text{day} \times \frac{\text{Kgs}}{10^6\ \text{mg}}$$

$$\times \frac{2.204\ \text{lbs}}{\text{Kg}} \times \frac{1000\ \text{liters}}{M^3}$$

$$= 803\ \text{lbs/day}$$

BOD_5 removal efficiency

$$E_2 = \frac{100}{1 + \frac{0.0085}{1-E_1}\left(\frac{W'}{VF}\right)^{1/2}}$$

$$= 57\ \%$$

BOD_5 of Effluent

$$257(1-0.71)(1-0.57) = 32\ \text{mg/l}$$

Check for Sludge

Removing 1 Kg of BOD will produce 0.1 to 0.48 Kgs of solids. Assume that 1 Kg of BOD_5 removed produces 0.3 Kgs of solids and 30 % of suspended solids is non-biolodgradable.

Primary Clarifier

Kgs of BOD removed per day (including preaeration tank)

$$404 - 257 = 147\ \text{mg/l} \quad (36\ \%)$$

$$147\ \text{mg/l} \times 4890\ M^3/\text{day} \times \frac{\text{Kg}}{10^6\ \text{mg}} \times \frac{1000\ \text{liters}}{M^3}$$

$$= 719\ \text{Kgs of } BOD_5/\text{day}$$

Kgs of solids produced per day (assuming 36% S.S. removal)

$$719 \times 0.3 + 47\ \text{mg/l} \times 0.3 \times 0.36 \times 4890\ M^3/\text{day}$$

$$\times \frac{1\ \text{Kg}}{10^6\ \text{mg}} \times \frac{1000\ \text{liters}}{M^3}$$

$$= 241\ \text{Kgs/day}$$

Intermediate Clarifier

Kgs of BOD removed per day

$$257 \times 0.71 = 182 \text{ mg/l} \left(\frac{182}{404} = 45\ \%\right)$$

$$182 \times 4890 \times 1000/10^6 = 890 \text{ Kgs of } BOD_5/\text{day}$$

Kgs of solids produced per day (assuming 45 % S.S. removal)

$$890 \times 0.3 + 47 \times 0.3 \times 0.45 \times 4890 \times 1000/10^6$$

$$= 298 \text{ Kgs/day}$$

Final Clarifier

Kgs of BOD removed per day

$$257(1-0.71)(0.57) = 43 \text{ mg/l} \left(\frac{43}{404} = 11\ \%\right)$$

Kgs of solids produced per day (assuming 11 % S.S. removal)

$$43 \times 4890 \times 1000/10^6 \times 0.3 + 47 \times 0.3 \times 0.11$$

$$\times 4890 \times 1000/10^6$$

$$= 71 \text{ Kgs/day}$$

Total Sludge

$$241 + 298 + 71 = 610 \text{ Kgs/day}$$

Check for Digestion Tank

Assuming 2 % of sludge concentration

$$20{,}000 \text{ mg/l} = 20 \text{ Kgs/M}^3$$

$$\frac{610 \text{ Kgs/day}}{20 \text{ Kgs/}_{M}3} = 30.5 \text{ M}^3\text{/day of sludge}$$

Capacity of existing digestion tank

$$\left(\frac{18}{2}\right)^2 (3.1416)\left(6.1 + \frac{1.8}{2}\right) = 1781 \text{ M}^3$$

Detention time will be

$$\frac{1781}{30.5} = 58.4 \text{ days}$$

Equivalent population of BOD_5 parameter

0.2 lbs BOD/capita/day is used

0.2/2.2048 = 0.091 Kgs/capita/day

$404 \text{ mg/l} \times 4890 \times 1000/10^6 = 1975$ Kgs/day of BOD in influent

$$\frac{1975}{0.091} = 21700 \text{ persons}$$

$$\frac{1781\ M^3}{21700} = 0.082\ M^3/\text{capita} \doteqdot 3\ ft^3/\text{capita}$$

Babbitt introduced some basic design factors in sludge digestion of several states in the U.S. that the range of the factor is 3 - 4.5 ft^3/capita. Among the factors, Florida and Texas use 3 ft^3/capita. Since the temperature in Taiwan is approximately same as in Taxas or Florida, the 3 ft^3/capita of digestion tank loading can be adopted in the Liu-Tu plant. No additional digestion tank is recommended.

Appendix III

References

1. Eckenfelder, W. Wesley, "Water Quality Engineering for Praticing Engineers" Barnes & Noble Inc., 1970, pp. 58-62.
2. Babbitt, Harold E. "Sewerage and Sewage Treatment" John Wiley & Sons, Inc., New York, 1953, pp. 312.
3. Coburn, Stuart E. "Comparison of Methods for Treatment of Wool Scouring Wastes", Journal Water Pollution Control Federation (JWPF), Jan. 1949, pp. 84-90.
4. Babbitt, Harold E. & Bauman, E. Robert. "Industrial Waste Disposal fpr Sewerage and Sewage Treatment", 1958, pp. 670-71.
5. Metcalf & Eddy, Inc., Engineers, Boston, Mass., "Sources and Strengths of Textile Wastewaters", in "Wastewater Treatment Systems, Upgrading Textile Operations to Reduce Pollution 2" of U.S. EPA Technology Transfer Seminar Publication in 1974.
6. Koziorowki, B. & Kucharski, J. "Industrial Waste Disposal", 1972, Poland, pp. 280-302.
7. Sawyer, Clair N. & McCarty, Perry L. "Chemistry for Sanitary Engineers", McCraw-Hill Book Company,1967 Edition, pp. 137-40.
8. McCarthy, Joseph A. "A Method for Treatment of Wool Scouring Wastes" JWPF, Jan. 1949, pp. 75-84.
9. Literature Review, LWPF, June 1964, pp. 689.

10. Literature Review, JWPF, June 1959, pp. 633-34.

11. Hill, K.V. Reviews and Abstracts, JWPF, June 1941, pp. 624.

12. Singleton, M.T. "Experiments on Anaerobic Digestion of Wool Scouring Wastes" JWPF, March 1949, pp. 286-293.

13. Literature Review, JWPF, June 1964, pp. 689.

14. Literature Review, JWPF, June 1960, pp. 567-68.

15. Goode, Wendell B. "Waste-Treatment Cost Need Not Be Excessive" Textile World, Jan. 1950, JWPF, 1951, pp. 122.

16. Alspaugh, T.A. "Literature Review" JWPF, 1965, pp. 764.

17. Day, Willian J. Davis and Floyd Engineers, Inc., "Panel Discussion on Sustitution Processes and Materials" in "In-Plant Control of Pollution, Upgrading Textile Operations to Reduce Pollution 1" of U.S. EPA Technology Transfer Seminar Publication. Oct. 1974.

18. U.S. Federal Register, April 4, (pp. 12263) July 5 (pp. 24736, and pp. 24750), August 21 (pp. 30134) in 1974.

19. Bartlett, Ronald E. "Wastewater Treatment" London, Applied Science Publishers LTD., 1971, pp. 183-84.

20. U.S. EPA Tecgnology Transfer, "Process Design Manual for Upgrading Existing Wastewater Treatment Plants" Originally Prepared by Roy E. Weston, Inc. in 1971 and Revised by Metcalf & Eddy, Inc. in 1974, pp. 4-1 - 4-48.

21. The Firm of Black, Crow and Eidsness, Gainesville, Florida, "Process Design Manual for Sludge Treatment and Disposal" of EPA Technology Transfer in Oct. 1974.

22. Metcalf & Eddy, Inc. Engineers, Boston, Mass. "Experience with Granular Activated Carbon in Treatment of Textile Industry Wastewaters" in "Wastewater Treatment Systems, Upgrading Textile Operations to Reduce Pollution 2" of EPA Technology Transfer Seminar Publication" in Oct. 1974.

23. U.S. Federal Register, August, 1973. (pp. 22298)

24. Babbitt, Harold E. "Sewerage and Sewage Treatment" New York, John Wiley & Sons, Inc. in 1953, pp. 377.

25. U.S. EPA Technology Transfer, "Process Design Manual for Upgrading Existing Wastewater Treatment Plants" Originally Prepared by Roy E. Weston, Inc. in 1971 and Revised by Wetcalf & Eddy, Inc. in 1974, pp.4-5

26. Babbitt, Havold E. "Sewerage and Sewage Treatment" New York, John Wiley & Sons, Inc. in 1953, pp. 519.

WOOL-SCOURING WASTEWATER TREATMENT AT LIU-TU INDUSTRIAL DISTRICT IN TAIWAN, R.O.C.

by

CHIANG-PI HSIAO
Diploma in Civil Engineering
Taipei Institute of Technology
Taiwan, China, 1961

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

ABSTRACT

The objective of this report was to determine the most practical means to improve the Liu-Tu Industrial District Wastewater Treatment Plant in Taiwan, the Republic of China. The wastewaters of high grease concentration which are discharged by the woolen mills in the District have destroyed the functions of the plant. Also, the flow of the raw wastewater has exceeded the design capacity of the plant. It is obvious that the present conditions need to be improved and the plant needs to be upgraded. The report was divided into two major parts. The first part covers wool-scouring wastewater pretreatment in the woolen mills. The second part covers the recommendations for the plant.

This report comprises the following four chapters: a brief introduction for the objective of the report; a description of the existing facilities including design functions, flow and quality of the wastewater; the pretreatment of wool-scouring wastewater; and the recommendations for the plant.

The recommendations were obtained from the analysis of the plant functions which is based on the data of 1971. They may provide a guide for the improvement of the plant.