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

by

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

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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%

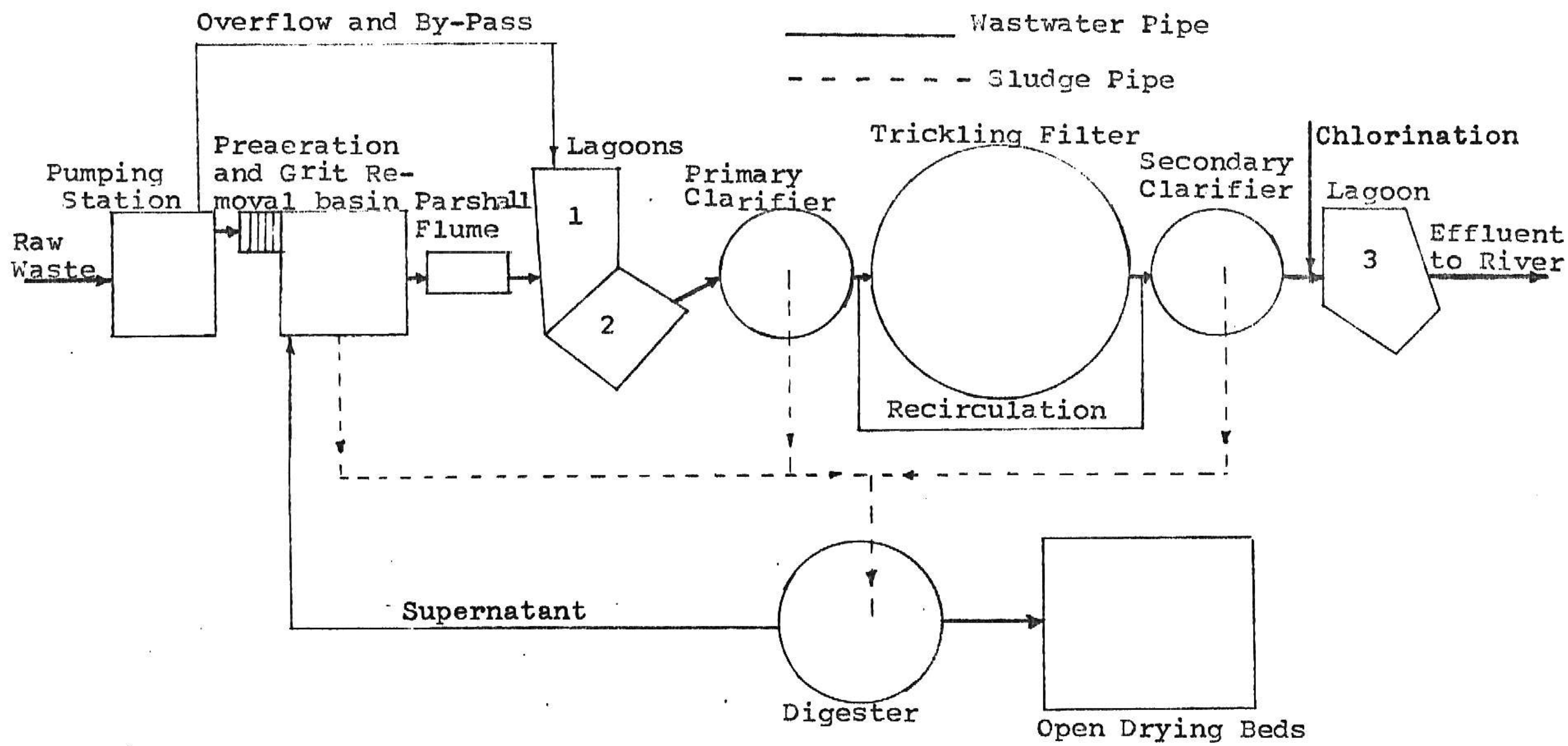

Fig. 1 EXISTING FLOW DIAGRAM OF LIU-TU WASTEWATER TREATMENT PLANT

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