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No. 38

FINAL REPORT
FOR
THE STUDY ON INDUSTRIAL WASTE WATER
TREATMENT
AND
RECYCLING PROJECT
IN
THE REPUBLIC OF KOREA

AUGUST 1993

JAPAN INTERNATIONAL COOPERATION AGENCY

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Preface

In response to a request from the Government of the Republic of Korea, the Government of Japan decided to coduct a study on The Industrial Waste Water Treatment and Recycling Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Korea a study team headed by Mr.Totaro Goto, Water Re-Use Promotion Center, four times between March 1990 and May 1993.

The team held discussions with the officials concerned of the Government of Korea, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Korea for their close cooperation extended to the team.

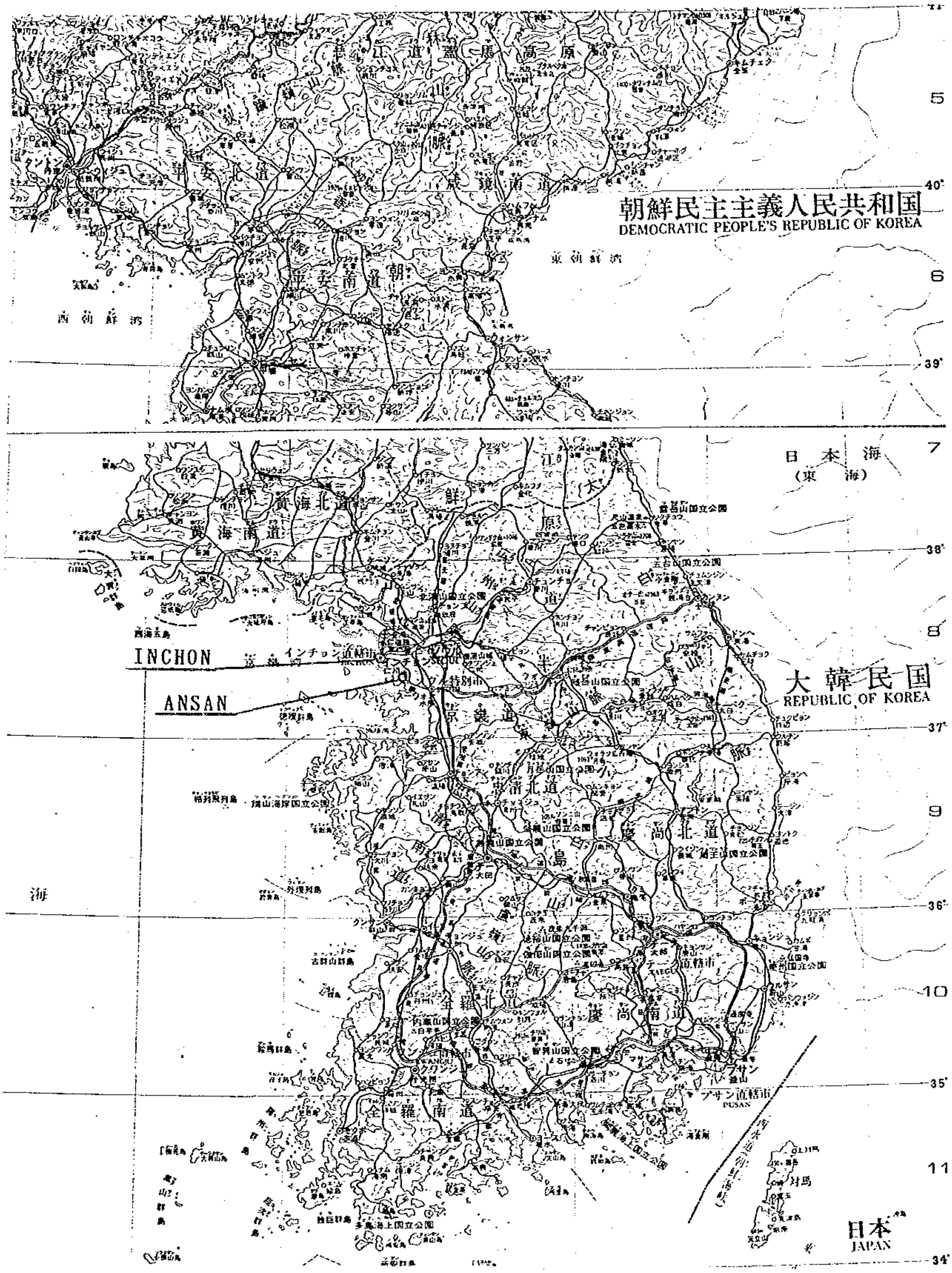
August, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

大韓民国地図

MAP OF KOREA



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I. Introduction

I. Introduction

1. Background

1.1 Background

At the outset of its first five-year plan in 1962, the Republic of Korea shifted its economic policy from import to export and has since registered remarkable economic growth.

However, this rapid economic development was accompanied by undesirable consequences such as environmental pollution and the destruction of nature, to the extent that environmental destruction due to industrial wastewater has now emerged as a serious social problem in some parts of the country.

In addition, it is predicted that shortages of water resources and land subsidence are likely to occur as a direct result of this rapid economic development.

Under these circumstances, the Korean Government made a request to Japan to carry out an investigation concerning industrial wastewater treatment and reclamation, and this forms the background to this Study.

In response, JICA dispatched its first study team to Korea in December 1990 to discuss the matter with the Korean counterparts. Consequently agreement was reached on the content of the Study, and the scope of the work was prepared.

On this basis, JICA formed another study team in March 1991 and conducted first step field stage, which identified some circumstantial difficulties for the investigation of the dyeing industrial estate in Taegu, previously agreed to be as a designated site.

In August 1991, the Korean counterparts communicated their desire to change the study site to Banwol Dyeing Industrial Estate so as to readjust to this new development. JICA agreed, after dispatching its second study team to Ansam City in December 1991 to gain first-hand information on the proposed industrial estate.

1.2 Study Site and Objectives

1.2.1 Study Site

The Study is conducted covering the following industrial estates and industries:

(1) Industrial Estates

1) A small-scale plating industrial estate in Inchon
2) A dyeing industrial estate within the Banwol industrial estate

(2) Industries

1) Electro-plating
2) Dyeing

1.2.2 Objectives of the Investigation

Based on the matters agreed on between the two countries, the objectives of the Study were set as follows:

1) To investigate the present state of the wastewater treatment facilities at the two industrial estates to be covered by the study, point out any identified problems, and put forward solution options to improve the situation.
2) To determine optimum wastewater treatment and reclamation systems for model electro-plating and dyeing industrial estates in Korea, by regarding the above industrial estates as such, so that the results of the Study, conducted as a mere case study, can be generalized to all industrial estates in these respective industries.
3) To prepare guidelines for wastewater treatment and reclamation in the two industries based on the study results.

In the course of the Study, relevant technologies were to be transferred to the counterparts.

1.3. Content of the Study

1.3.1 Principles of the Study

(1) Reduction of wastewater loading
(2) Investigation of the present state of water balance at factories
(3) Selection of wastewater treatment processes
(4) Introduction to Japanese wastewater treatment and reclamation system
(5) Survey of individual factories at each industrial estate
(6) Preparation of guidelines for wastewater treatment and reclamation
(7) Technology transfer

1.3.2. Preparation for the Study

To carry out the Study, a team of experts was formed as shown in Table 1.3.1. KIST members also taking part are shown in Table 1.3.2.

1.4 Implementation of the Study

The work was executed in accordance with the flowchart shown in Figure 1.4.1., while the schedule of work done is shown in Figure 1.4.2.

Table 1.3.1 Study Team Members and Their Assignments (1/2)

Name	Function	Assignment
Totaro GOTO	Team Leader Overall Management	Overall management and Coordination Home office Work: Items described above Field work: Negotiation with counterparts Control of study team
Shigeru HASEBA	Sub-Leader Water Treatment Technology	Water treatment technology Home office work: Summarization of field study results Field work: Collection of information and data,and summarization of field study items
Naoto HASHIMOTO	Plant Designing	Study on waste water treatment and recycling facilities Home office work: Items described above Field work: Items described above
Yoshihiro TANAKA	Water Analysis	Inorganic water Analysis Study on waste water treatment facilities of electro plating process plant designing Home office work: Items described above Field work: Inorganic water analysis Study and analysis of waste water treatment of electro plating process
Tetsuya HIRAMATU	Study on related Technologies	Summarization of Japanese waste water treatment technologies (Home office work only)
Yosihiko KUBO	Study on related Technologies	Summarization of Japanese waste water treatment technologies (Home office work only)

Table 1.3.1 Continued (2/2)

Name	Function	Assignment
Sueo NAGASAWA	Water Analysis	Organic water analysis Study on waste water treatment facilities of dyeing process Home office work: Items described above Field work: Organic water analysis Study and analysis of waste water treatment of dyeing process
Manabu FUJIKAWA	Socio-Economic and Financial Analysis	Compilation of socio-economic and financial analysis of waste water treatment systems Home office work: Socio-economic and financial analysis based of field study results Field work: Study on items required for socio-economic and financial analysis
Tetsuo FUJIOKA	Study on related Technologies	Summarization of Japanese waste water treatment technologies (Home office work only)
Tatsuji OKADA	Water treatment Technologies	Study and plant designing of waste water treatment and recycling facilities of dyeing process Home office work: Items described above Field work: Study and analysis of waste water treatment of dyeing process

Table 1.3.2 List of KIST Staff

Name	Title	Division
Won-Hoon Park, Ph.D.	Director	Division of Environment & Welfare Technology
Kil-Choo Moon, Ph.D.	Director	Environment Research Center
Kyu-Hong Ahn, Ph.D.	Professor	Environment Research Center
Daewon Pak, Ph.D.		Environment Research Center
Kyung-Guen Song		Environment Research Center

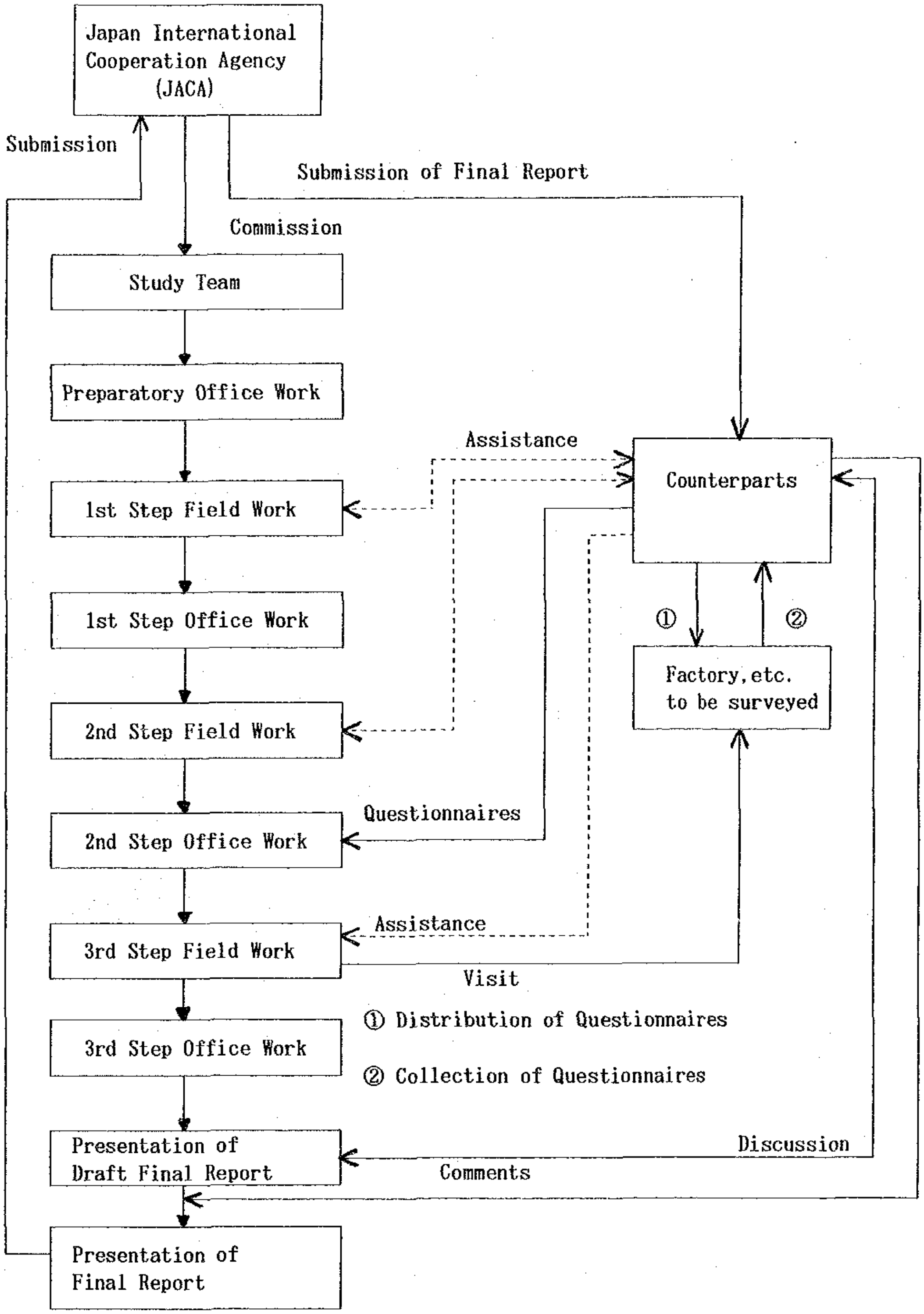


Fig. 1.4.1 Flowchart for the Study

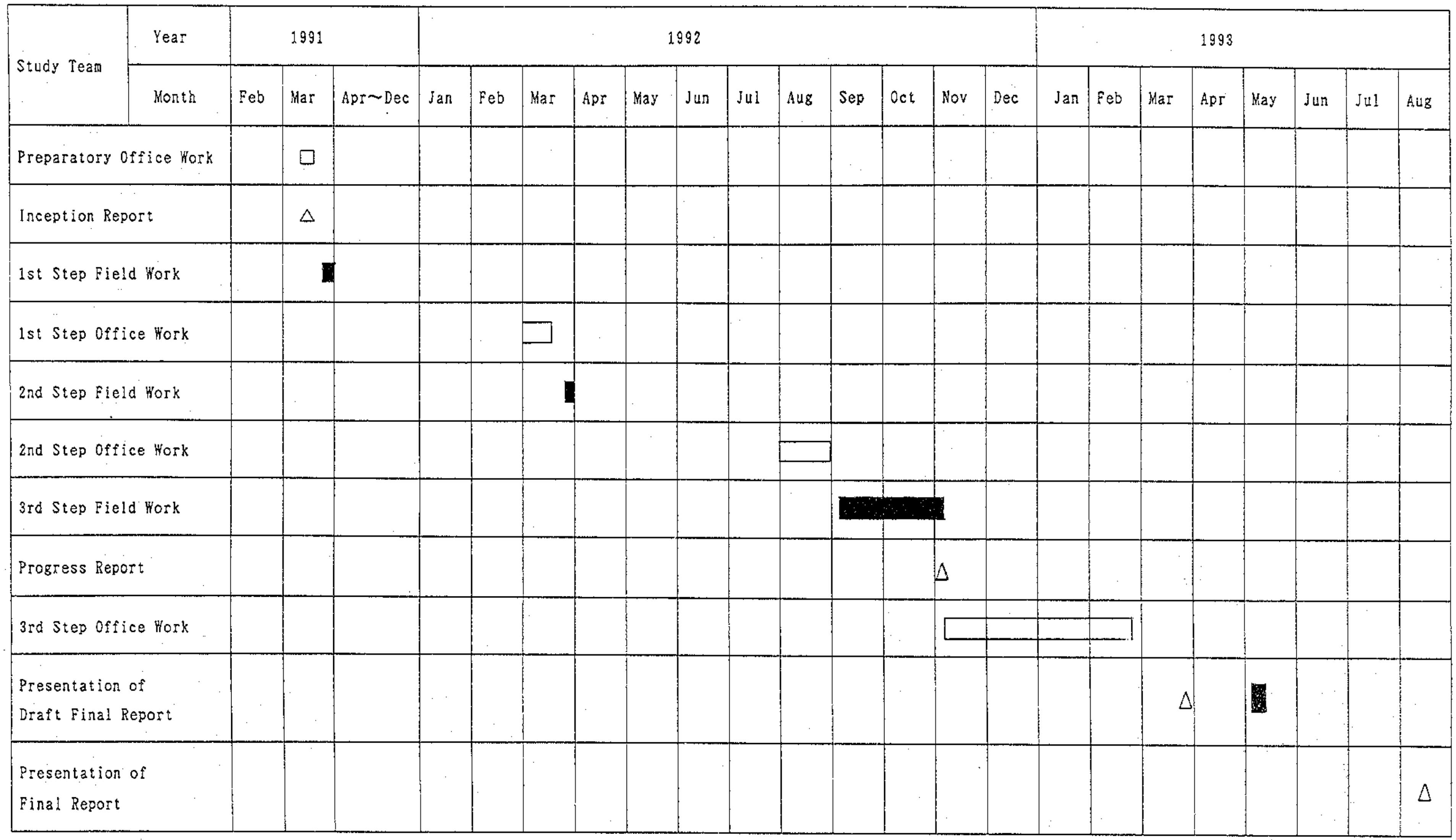


Fig. 1.4.2 Schedule of the study

2. Outline OF Study Areas

2.1. Overview of Korea

(1) General

Korea is a peninsula located in Northeast Asia. The land area of southern part of Korea is 9,927,400 ha. Only 21% of the land area is cultivable land and the remaining 66 % is mountainous. The population of Korea at the end of 1990 was 43.5 million. Therefore, its population density is one of the highest in the world with 438.4 person per km^2. For almost three decades, Korea has been experiencing rapid economic growth with an average annual GNP growth rate of more than 8 %. This was due to the government-led export driven economic development policy. In 1990, Korea's GNP per capita exceed US $5,000, making Korea's total GNP the 15th largest in the world. Because of Korea's dependency on foreign trade, it ranks as the 13th largest in terms of volume of exports and imports. Furthermore, Korea has been successful in developing heavy and chemical industries such as automobile, steel, shipbuilding and petrochemical as well as light industries such as textiles and clothing.

Besides this unprecedented rapid industrialization, Korea has also experienced rapid urbanization during the past quarter of century. As of 1990, more than 25% of Korea's whole population live within the city limit of Seoul. However, if the population living in the Seoul region is included, it is fair to say that more than 40% of the whole population of Korea live in the metropolitan area of Seoul. In addition to Seoul, Pusan, Taegu, and Taegeon have also shown significant increase in population during the past two decades.

Korea's environmental problems are largely due to rapid industrialization and urbanization during the past twenty-five years. In late 1977, the first major environmental statue, the Environmental Preservation Act was enacted, and in 1980, the Environmental Administration was established. As the nation's economy grew massively during the 1980's and as peoples awareness of environmental protection grew, it became obvious that Korea's environmental laws and institutions needed a major reform. The results was the enactment of series of environmental statutes in 1990 and 1991, and the establishment of Ministry of Environment replacing the Environmental Administration in 1990.

The Korean government has applied a number of principles and mechanisms to protect the environment and to realize sustainable development. Environmental impact assessment and various mechanism based on the principle of "Polluters Pay Principle" are the major policy tools of the government to bring about sustainable development. The future of Korea's environment will largely depend on people's awareness and participation and the government's response strategies.

(2) Natural Conditions

1) Climate

Korea has a typical temperate climate which is influenced by the Pacific Ocean in summer and by the Asian Continent in winter. Therefore, the climate is typified by monsoonal summers with a rainy season and by continental winters of freezing weather. Annual precipitation ranges from 500 to 1,500 millimeters and annual mean temperature from 5 C to 14 C. Due to its topographic complexities, Korea exhibits a diverse distribution of climatic conditions, resulting in a variety of forest communities (or ecosystem).

2) Soil

About 66% of strata in Korea was molded in the Cenozoic Era, and granite and gneiss occupy more than 70% of all mother-rock. Due to a changeable continental climate and summer time torrential rain showers, the soil is susceptible to the weathering process and erosion. The majority of the forest soil is acidic sandy loam.

3) Water

(a) Overview

Korea is one of the few countries in the world which is endowed with ample clean fresh water. However, along with rapid industrialization and urbanization in the 1960's and 1970's, many rivers and streams became polluted. Korea has four major river basins: the Han, Nagdong, Geum and Yeongsan. Each of these receives a significant wastewater input which, in turn, delivers substantial pollutant loads into the coastalwaters where they empty.

(b) Water Resources

The total volume of annual mean water resources due to precipitation is 114,000 million m^3. 58% of this total is the surface run off and 42 % is lost in the form of evaporation and infiltration. In 1989, out of 114,000 million m^3, stream water is 17,500 million m^3 or 15% of the total water resources. Dam water is 8,500million m^3 or 7 % of the total resources. This indicates that only 23% of the total water resources are presently utilized. Such a low rate of use can be explained by the fact that two-thirds of precipitation is concentrated in the period from June to September, the summer season, and hence most of it is lost as flood water.

On the other hand, underground water resources are estimated to be 1,324,000 million m^3, out of which 117,000 million m^3 are usable. Currently, only about 1,600 million m^3 of underground water are utilized. If underground water use (1,600 million m^3) is added to surface water use (26,000 million m^3), the total volume of water resources use becomes 27,000 million m^3. An investigation of the use of water resources shows that domestic water uses 5,100 million m^3 industrial and agricultural water use 2,600 million m^3 and 12,800 million m^3 respectively. Other amount to 7,100 million m^3.

2.2. Inchon Area

2.2.1. Natural Conditions

(1) Climate

The Inchon Area is located at the middle west of the Korea Peninsula and its climate is influenced by both the Pacific Ocean and the Asian Continent ; warm with high humidity in summer and cold with dry air in winter. The temperature difference between summer and winter are considerably large.

1) Temperatures

Annual average : 11.4 C
Monthly average in August : 24.8° C
Monthly average in January : -6.7° C
Highest in summer : 34.9° C on July 13, 1981
Lowest in winter : -18.4° C on January 5, 1986

2) Precipitation

Annual average : 1,088.1 mm

a little less than 1,362.0 mm of the Korean average

Precipitation between July and September : 640.3 mm (59%)

Precipitation in winter : only 57.9 mm (5.3%)

Highest precipitation in a day : 302.5 mm on July 27, 1987

3) Relative humidity

Annual average : 70%

Rainy season in July : 82%

Dry season in January and February : 63%

4) Wind direction

Predominant in spring : South

summer : SSE

autumn : WNW

winter : NW

5) Wind velocity

Annual average : 3.2 m/s

Maximum moment velocity : 32.0 m/s of SW on August 30, 1987

The outline of climate in the Inchon Area is shown in Table 2.1.

(2) Geological and geographical features

1) Geological features

The geological map shows that gneiss with some granite and schist is predominant at the west of Inchon where we concern. Alluvia of sedimentary rocks, acid and basic dike rocks, etc. constitute the reclamation area on the west coast. There are layers of silt, clay, sand or gravel bed on the sea bottom.

2) Geographic features

The city of Inchon is located on the west coast of the Korea Peninsula. She is not only the marine gate to Seoul, but also plays a central role of trade port for the west coast. On the south-west of Inchon, a hilly country of peninsula type exists with a small mountain range of Mt. Kaeyang (elevation of 396 m), Mt. Choulma (elevation of 202 m), MT. Naksa, Mt. Gouma, which divides Bupoung from Inchon. In table 2.2, the elevation and inclination analyses of the Inchon planning area are shown. As seen in the table, there are considerable lands to be developed

Table 2. 1 Meteorological Data

Month	Temperature(°C)			Precipiation	Evaporation	Relative	Atmospheric	Daylight	Wind	
	Mean	Highest	Lowest	(mm)	(mm)	humidity (%)	pressure (mb)	(hr)	Velocity (m/s)	Direction
1	-3.4	2.4	-6.7	22.8	41.6	63	1,025.2	176.9	3.2	NW
2	-1.3	2.6	-4.6	12.8	52.9	63	1,023.4	187.9	3.2	WNW
3	4.2	8.5	0.9	43.7	85.0	65	1,020.0	213.5	3.5	WNW
4	10.6	15.3	7.0	58.8	123.6	66	1,015.7	223.9	3.6	SSW
5	16.0	20.5	12.5	84.9	147.7	71	1,011.6	242.3	3.4	S
6	20.6	25.0	17.3	79.3	148.1	76	1,008.0	222.0	2.8	S
7	21.5	26.9	21.1	283.2	129.1	82	1,006.3	160.1	2.6	SSE
8	24.8	28.3	22.1	232.9	139.9	80	1,007.3	197.2	2.9	SSE
9	20.4	24.6	16.7	124.2	121.9	74	1,013.7	209.4	2.7	WNW
10	12.3	18.8	10.4	62.0	98.7	70	1,019.1	208.8	2.8	WNW
11	7.0	10.9	3.5	61.3	64.2	67	1,022.7	171.3	3.6	NW
12	-0.1	3.5	-3.4	22.3	47.4	64	1,024.4	179.1	3.5	NW
Annual	11.4	15.4	8.1	1,088.1	1,200.1	70	1,016.4	2,392.3	3.2	NW

Reference :Meteorological Yearbook (1980～1989)

Table 2. 2 Inclination and Elevation Analyses

Classification		Aarea	Percentage(%)	Remarks
Total		478.920	100.0	
Inclination	less than 5 %	424.040	88.5	sea area included
	5 ~ 10 %	17.310	3.6	
	10 ~ 15 %	11.750	2.5	
	15 ~ 20 %	6.130	1.3	
	20 ~ 25 %	8.660	1.8	
	25 %	11.060	2.3	
Elevation	less than 50 m	439.364	91.7	sea area included
	50 ~ 70 m	15.541	3.2	
	70 ~ 100 m	11.063	2.3	
	100 ~ 200 m	11.800	2.5	
	200 ~ 300 m	0.946	0.2	
	300 m	0.206	0.1	

Reference :Statistical Yearbook of Inchon city (1989)

with less than 15 % inclination and 70 m elevation. The coastal area is gently sloping and shallowed, which means that building of an artificial port is easy.

2.2.2. Social Conditions

(1) Population

The average annual increase rate of population during 1979 and 1988 is 5.7%, exceeding that of Seoul, 2.4% in the same period. The figure is 2.9 times of the national-wide increase rate, 2.0%. As of 1988, the ratio of men to women is 50.3:49.7, men being a little more than women. While the average number per family was 4.65 in 1979, it is 3.93 in 1988, which shows a clear current of core-family. The changes of population is given in Table 2.3.

The population, its composition, density and family for each region in 1988 are shown in Table 2.4.

The recent population movement of Inchon is demonstrated in Table 2.5. In the table, the moving-in is more than the moving -out in 1984-1988; this is due to the geographical conditions of a coastal industrial zone in the vicinity of the metropolitan area and due to buildings of residence and industrial estates in accordance with a rapid development of industries.

(2) Land usage

As of 1988, land usage of Inchon is as follows: 25.7% for forest and field, 17.1% for residence and 14.1% for rice pad, respectively (see Table 2.6). These percentages are rather high. While there are recent trends that the land uses for schools, road, industries and residence increased by 5.6%, 6.2%, 3.0% and 3.2% respectively, in the past 6 years, those for field, rice pad and forest are decreasing continuously. The planned land usage of Inchon is given in Table 2.7. The fact that 33.9% of all the land including sea areas and salt fields, were appointed to a non-assigned land, shows an intention to cope with the land shortage in further.

2.2.3. Economic Conditions

(1) Commerce

Table 2. 3 Change of Population

Year	Family number	Population			Number per family	Increase rate to previous year(%)
		Total	Men	Womwn		
1979	224,431	1,043,744	521,000	522,744	4.65	11.5
1980	243,625	1,083,906	542,215	541,691	4.44	3.8
1981	254,184	1,141,705	568,473	573,232	4.49	5.3
1982	265,880	1,179,558	588,126	591,432	4.44	3.3
1983	281,350	1,220,311	610,121	610,190	4.34	3.5
1984	304,791	1,259,107	648,957	646,150	4.24	3.2
1985	339,580	1,386,911	692,516	694,395	4.08	10.2
1986	355,149	1,441,131	721,211	719,920	4.06	3.9
1987	377,335	1,526,435	766,013	760,411	4.05	5.9
1988	410,929	1,616,017	813,485	802,532	3.93	5.9

Reference :Statistical Yearbook of Inchon City (1989)

Table 2. 4 Distribution of Population

Region	Family number	Population				Popurlation density (Person/km^2)	Persons per family
		Total	Men	Women	Percentage		
Total	410,919	1,616,017	813,485	802,532	100.0	7,757	3.93
Jung - gu	21,073	81,319	40,854	40,465	5.0	6,423	3.86
Dong - gu	35,505	139,370	70,804	68,566	8.6	24,280	3.92
Nam - gu	111,892	451,445	227,682	223.763	27.9	9,898	4.03
Nam dong-gu	63,378	251,388	125,921	125,467	15.6	4,964	3.97
Buk - gu	132,008	508,118	255,783	252,405	31.4	11,067	3.85
Se - gu	47,073	184,307	92,441	91,866	11.4	3,860	3.92

Reference :Statistical Yearbook of Inchon city (1989)

Table 2. 5 Population Movement

(unit: person)

Year	Social factor				Natural factor					
	Moving-in	Increase rate (%	Moving-out	Increase rate (%)	Birth	Death	Marrige	Divorce	Total	Increase rate (%)
1984	425,509	6.7	366,888	1.3	25,158	5,211	8,215	1,111	39,695	△ 2.9
1985	409,361	△ 3.8	359,242	△ 2.1	24,999	5,000	8,706	1,117	39,822	0.3
1986	382,620	△ 6.5	349,477	△ 2.7	25,616	5,489	9,305	1,241	41,651	4.6
1987	434,814	13.6	383,822	9.8	26,068	5,603	9,585	1,356	42,612	2.3
1988	476,438	9.6	423,090	10.2	27,983	5,861	10,717	1,332	45,893	7.7

Reference :Statistical Yearbook of Inchon City (1989)

Table 2. 6 Change of usage

(unit: km^2)

Year	1982	1983	1984	1985	1986	1987	1988	'88 Percentage(%)	Annual increase
Tctal	201.93	202.03	202.10	206.60	206.95	208.32	208.32	100.0	0.5
Field	23.55	22.31	22.21	22.23	21.84	20.76	20.21	9.7	△ 1.7
Rice pad	32.29	31.06	30.94	30.57	30.28	29.77	29.36	14.1	△ 1.4
Forest	56.16	55.24	55.15	54.92	54.83	54.06	53.63	25.7	△ 0.7
Residence	29.21	31.58	31.71	31.99	32.61	34.60	35.58	17.1	3.1
Industry	7.93	9.12	9.27	8.57	8.73	8.83	9.32	4.5	3.0
School	1.83	1.92	2.10	2.55	2.64	2.73	2.81	1.3	5.6
Road	9.94	10.90	11.05	12.68	13.79	14.34	14.80	7.1	6.2
Cthers	41.02	39.90	39.67	43.09	42.23	43.23	42.61	20.5	0.6

Reference :Statistical Yearbook of Inchon City (1989)

Table 2. 7 Land usage

		Area(m^2)	Percentage(%)
Residential area	Total	53,367,473	11.1
	Residential area	48,258,278	10.0
	Sub-residential area	5,109,200	1.1
Commercial area		9,681,235	2.0
Industrial area	Total	45,893,623	9.6
	Exclusive industrial area	3,283,200	0.7
	Industrial area	24,443,000	5.1
	Semi- industrial area	18,167,423	3.8
Green area	Total	207,609,834	43.4
	Productive green area	10,956,700	2.3
	Natural green area	196,653,134	41.1
Undecided area		162,367,830	33.9
Total		478,920,000	100.0

Reference :Statistical Yearbook of Inchon (1989)

In 1988, there are 96 market places in total at Inchon. However, since Inchon is involved in the Seoul life circumstances, the distribution economy is absorbed in the metropolitan area.

(2) Industrial structure

The industrial structure of Inchon is shown in Table 2.8. The economically active population is 550,757; employees are 530,836, and the unemployment rate is 3.1% in 1989. The primary, secondary and tertiary industries occupy 3.3%, 43.8% and 52.9%, respectively, on employment base; the weight of tertiary industry is high compared with other cities.

Inchon has a typical industrial structure, but not enough functions of finance, information, communication and export services that are required for central management performance of a big city. On the other hand, the structure is consumer-intensive with restaurants, hotels, bath business etc.

(3) Industries

The distributions of factory are given in Table 2.9. As seen in the table, most of the factories are of small size, and only 111 factories belong to large enterprises.

Table 2.10 shows the existing industrial estates at Inchon. In addition to these, Nandong Industrial Estate is under construction.

2.2.4. Water Supply and Usage

(1) Water supply

The water supply source of the Inchon area is Paltang Dam in connection with the metropolitan large water supply system. Water is transported from Paltang Dam and Kajerng Pumping Station with 1,200-1,800 mm diameter pipes.

The outline of the Inchon water supply system is shown in Table 2.11. Ass seen in the table, the water supply rate of Inchon is 95.8% which is higher than that of the national average rate, 85.1%. The water supply per day per capita is 370L which is also higher than that of the national average rate, 325PL.

(2) Industrial Water

Table 2. 8 Industrial Structure

Item	Economically active population (person)	Percentage (%)
Total	530,836	100.0
Primary industrial	17,541	3.3
Secondary industrial	232,452	43.8
Tertiary industral	280,843	52.9

Reference :Korean City Yearbook (1989)

Table 2. 9 Factory Distribution

	Total	Jung-gu	Dong-gu	Nam-gu	Nam dong-gu	Buk-gu	Se-gu
Enterpraise	2,672	110	107	524	310	1,064	557
Employee	202,872	9,287	14,301	28,111	65,492	73,853	10,932

Reference :Minucipal white paper (1989)

Table 2. 10 Factory Distribution

Item	Total		Texitile		Chemical		Mechanical		Food		Others	
	Enter-prise	Emplo-yee	Enter-prise	Emplo-yee	Enter-prise	Emplo-yee	Enter-prise	Emplo-yee	Enter-prise	Emplo-yee	Enter-prise	Emplo-yee
Large scale Enterprise	111	83,740	18	10,562	7	5,895	28	28,046	6	3,336	52	37,901
Small and Medium scale Enterprise	2,561	119,131	245	18,673	298	10,173	957	59,503	103	7,820	958	22,963
Total	2,672	202,872	263	29,325	305	16,086	985	85,549	109	11,156	1,010	60,864

Reference :Korean City Yearbook (1989)

Table 2. 11 Water Supply System

Item		Content
Population (person)	Total population	1,616,017
	Water supply population	1,548,144
Rate of water supply(%)		95.8
Capacity (m^2/day)		500,000
Supplied water (m^2/day)		583,256
Daily supplied water per person		370

Reference :Statistical Yearbook of Inchon (1989)

There is no industrial water supply system at present. However, there are many industries, and the consumption of industrial water is estimated at 84 million m^3/year.

(3) water Quality

1) River water

There are 7 sub-registered rivers that are regulated by a law. They all flow to the Inchon sea area. All of the waste water from the town and rain fall are discharged to the rivers which play a role of drain channels. This arises not only pollution of the rivers but also deterioration of the coastal sea area. Table 2.12 shows the chemical analysis data of the Hak-ik district, near the Dyeing Industrial Estate.

2)Underground water

Most of drinking water is provided by the water supply system, but underground water is still used for drinking to some extent. Water samples of the Hak-ik district were analyzed and the results are given in Table 2.13. It was found that the sample is potable chemically and physically, but not biologically.

2.2.5. Waste Water Treatment

The installation rate of sewage pipeline is 79.0% that is higher than that of the national average, 51.0%. The waste water system is divided into 7 districts dependent on geographical conditions. All the sewage from the districts flows to Han River and Inchon Bay. Therefore, constructions of sewage treatment plant are urgently needed in order to reduce the sewage pollution. The city has planned 6 plants. Among them, Kajwa sewerage is completed. Table 2.14 shows the plan of sewerage construction.

2.3 Ansan Area

2.3.1. Natural Conditions

(1) Climate

Table 2. 12 Analysis of River Water

	W - 1			W - 2			W - 3		
	First	Second	Mean	First	Second	Mean	First	Second	Mean
Weather	fine	cloudy	-	fine	cloudy	-	fine	cloudy	-
Ambient temperature	31.0	29.2	-	31.0	28.5	-	31.5	29.0	-
Water temperature	28.4	26.0	-	30.5	25.4	-	31.0	27.2	-
pH	7.4	7.2	7.3	7.3	7.1	7.2	7.3	7.2	7.3
DO (mg/ℓ)	1.5	1.8	1.65	0.6	0.9	0.75	1.6	1.4	1.50
BOD (mg/ℓ)	41.6	33.2	37.40	195.0	143.0	169.0	72.5	96.3	84.40
COD (mg/ℓ)	30.0	21.5	25.75	123.0	92.5	107.75	38.0	49.0	43.50
SS (mg/ℓ)	25.5	22.3	23.90	54.0	41.2	47.60	44.7	50.3	0.50
TKN (mg/ℓ)	6.93	6.11	6.52	7.21	7.48	7.35	9.87	9.01	9.44
TP (mg/ℓ)	0.57	0.50	0.54	0.38	0.50	0.44	0.91	0.80	0.86
CN (mg/ℓ)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr^{+6} (mg/ℓ)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd (mg/ℓ)	0.008	0.006	0.007	0.009	0.009	0.009	0.009	0.007	0.008
Pb (mg/ℓ)	0.021	0.018	0.020	0.021	0.025	0.023	0.025	0.022	0.024
As (mg/ℓ)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg (mg/ℓ)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Coliform (MPN/100mℓ)	5.2×10^6	3.1×10^6	4.2×10^6	4.2×10^6	1.6×10^6	1.7×10^6	9.6×10^6	9.8×10^6	9.7×10^6

ND : no detected

Table 2. 13 Analysis of Ground Water

Item	Standard	SW - 1		SW - 2	
		First	Second	First	Second
Date	-	1990. 8. 3	1990. 9. 2	1990. 8. 3	1990. 9. 2
Weather	-	fine	cloudy	fine	cloudy
Ambient temperature(° C)	-	32. 5	27	33. 0	27. 5
Water temperature (° C)	-	18. 4	18. 0	15. 0	14. 7
Color	not more than 5 degree	less than 5 degree	less than 5 degree	less than 5 degree	less than 5 degree
Turbidity	not more than 2 degree	less than 2 degree	less than 2 degree	less than 2 degree	less than 2 degree
Odor	no odor or	no odor	no odor	no odor	no odor
Taste	no taste, not caused sterilization	no taste	no taste	no taste	no taste
pH	5. 8～8. 5	7. 1	7. 0	6. 4	6. 3
Cl- (mg/ℓ)	less than 150	41. 3	43. 4	41. 7	40. 3
NH_3-N (mg/ℓ)	less than 0. 5	0. 15	0. 20	0. 05	0. 05
NO3-N (mg/ℓ)	less than 10	0. 2	0. 3	9. 5	9. 0
COD_{Mn} (mg/ℓ)	less than 10	3. 48	3. 53	1. 11	1. 03
Total hardness (mg/ℓ)	less than 300	155	164	169	160
Bacteria (No./mℓ)		$2.9x10^2$	$3.1x10^2$	$2.7x10^2$	$2.3x10^2$
Coliform	not detected/50mℓ	positive	positive	positive	Positive

Table 2. 14 Plan of Sewerage Construction

Name	Location	Capacity (m^3/D)	Remarks
Hak lee	Hak lee-dong near previous landfill	100,000	
Ga ja	Ga ja-dong near landfill	260,000	Under construction
Sung gi	Dong chun-dong 648 address area	270,000	
Gul po	Bu chun city Da jang-dong area	200,000	Bu chun sewerage
Gong chon	Chung do near landfill	55,000	Composite treatment
Hea an	Under planning	100,000	

The Ansan Area is located at the middle west coast of Korea Peninsula and the climate is similar with that of Inchon.

1) Temperatures

Annual average : 11.5°C
Monthly average in August : 28.3°C
Monthly average in January : -3.2°C
Highest in summer : 35.2°C
Lowest in winter : -18.4°C (January, 1986)

2) Precipitation

Annual average : 1,071.5 mm
less by 239.3 mm than the Korean average
Precipitation between June and September : 712.6 mm (67%)
Highest precipitation in a day : 302.5 mm on July 27, 1987
Highest precipitation in a year : 1,619.0 mm in 1987

3) Relative humidity

Annual average : 70%
Rainy season in July : 83%
Dry season in January and February : 63%

4) Wind direction

Predominant in spring : South
summer : SSE
autumn : WNW
winter : NW

5) Wind velocity

Annual average : 3.5 m/sec
Maximum moment velocity : 25.7 m/sec on October 25, 1980

The outline of climate in Ansan Area is shown in Table 2.15.

(2) Geological and geographical features

1) Geological features

In the mountainous region in the north, fine and medium grained ground mass is characterized by components and structures of biotite granite. Quartz and feldspar are predominant, but plagioclase, biotite, sericite, chlorite etc. are found sometimes. The hilly region in the south east is mainly composed of fine and medium grained granitic mass.

Table 2. 15 Meteorological Data

Month	Mean temperature	Relative humidity	Wind velocity	Wind direction	Precip-tation	Daylight rate	Daylight time	Cloud	Evaporation
1	- 3.2	64	3.9	WSW	19.5	57.2	171.7	3.8	42.4
2	- 1.3	64	4.2	WSW	14.5	60.4	184.2	3.8	51.9
3	4.3	65	4.1	WNW	44.7	58.0	211.3	4.4	83.9
4	10.6	67	4.0	SSW	71.0	56.6	222.1	4.7	121.9
5	15.9	71	3.4	SE	77.6	57.1	245.2	5.0	151.9
6	20.6	76	2.9	NNE	103.7	47.5	212.1	6.0	146.0
7	23.7	83	3.0	NE	279.6	35.8	160.2	7.2	132.8
8	24.8	80	3.0	E	222.3	47.0	196.0	6.1	140.9
9	20.4	75	2.7	SE	107.3	53.3	199.3	5.2	121.1
10	14.6	70	2.8	WNW	51.7	60.2	208.0	4.0	100.6
11	7.0	66	3.7	W	54.1	56.0	168.4	4.2	65.1
12	0.5	66	3.8	W	25.4	54.5	167.1	4.0	46.5
Annual	11.5	71	3.5	WNW	1,071.5	53.6	2,345.6	4.9	1,204.1

Reference :Yearbook of Central Meteorological Observatory (1977¯1989)

The Dyeing Industry Estate exist on a reclamation land, which is composed of upper and lower sedimentary layers. The upper layers is a clay stratum mixed with silt whose thickness is 3.9-9.5 m (mean:7.9 m). The lower is a gravel bed with some silt. The bed rock appears in 5.5-22.0 m (mean:14.0 m) depth. The N value of the weathered granitic gneiss is more than more than 50/15.

2) Geographical features

The area is a typical ria coast with hilly lands inside. The mean elevation is 3-4 m, but 20-30 m in some part. Most of the lands have inclinations less than 5% ; only 4% of the land is larger than 5% and inclination. Table 2.16 and 2.17 show the elevation and inclination analyses.

2.3.2. Social Conditions

(1) Population

As of 1989, the population of Ansan is 202,051 with 54,193 families (average family of 3.7 persons). The population increased by 22.9% in the past 9 years (1980-1989). This is due to a social factor.

The population structure is characterized by a large portion of twenties and thirties generations (49.4%) ; Ansan is a newly developing industrial city. The economically active population is given in Table 2.18.

As seen in the table, the ratio of economically active population to the total is 45% which is higher than that of the national average, 36.3%. The employees of secondary industry occupy 54.2% of the total, the highest among industries, which means that Ansan is an industrial city.

(2) Land usage

As of 1989, the total area of Ansan, 74.85 Km^2 is classified into cultivated fields of 26%, forests and fields of 29%, residence of 10% and others of 35%. On the other hand, use-registered lands consist of 55.2% for green area, 24.5% for residence, 17.5% for industries and 17.5% for commerce. (see Table 2.19 for further details).

2.3.3. Economic Conditions

Table 2. 16 Elevation Analysis

Classification	Area(m^2)	Percentage (%)
Total	7,125,900	100.0
Less than 5m More than 5m	6,698,773 341,976	94.0 4.8

Reference : Banwol Regional Development Plan (1991)

Table 2. 17 Inclination Analysis

Classification	Area(m^2)	Percentage(%)
Total	7,125,900	100.0
Less than 5 % More than 5 %	6,698,773 427,127	94.0 6.0

Reference : Banwol Reginal Development Plan (1991)

Table 2. 18 Economically Population

Population	Ppopulation older than 15					Labor force by industry		
	Total	Eeconomically active population			Economically inactive population	Primary (%)	Scondary (%)	Tertiory (%)
		Ssub-total	Employed	Unemployed				
202,051 (100)	142,802 (70.7)	90,940 (45.0)	87,850 (43.5)	3,090 (1.5)	51,862 (25.7)	6,277 (7.1)	47,548 (54.2)	34,025 (38.7)

Reference :Statistics of Ansan City

Table 2. 19 Land Usage

		Area(m^2)	Percentage(%)
	Total	57,800,000	100.0
Residential area	Sub-total	14,139,040	24.5
	Usual residential area	13,998,250	24.2
Commercial	Semi-residential area	140,790	0.3
Industrial area	Sub-total	10,136,3491	17.5
	Usual industrial area	99,078,991	17.1
	Semi-industrial area	228,450	0.4
Green area	Sub-total	31,911,500.9	55.2
	Productive green area	6,102,000	10.6
	Natural green area	15,638,472.9	27.1
	Preservative greea area	10,171,028	17.5

Reference :statistical Yearbook of Ansan city (1990)

(1) Agriculture and Forestry

The total area of cultivated land that forms the base of agriculture, is 1,214 ha in 1988, whose compositions are rice pad of 1,033 ha (85.1%) and cultivated field of 181 ha (14.9%). Most of forest area, 2,570 ha, consist of conifer (39.9%) and mixed (42.0%) forest with some broad leaf forest (10.1%).

(2) Industries

As of 1988, the distributions of factory are given in Table 2.20. As seen in the table, mechanical industry has the largest shares in both factory and employee numbers.

2.3.4. Water Supply and Usage

(1) Water supply system

About 98% of the total population was provided with water by the water supply system of Ansan in 1988, whose capacity was 150,000m^3/day. In 1990, the capacity was expanded to 250,000 m^3/day. Considerable amount of water processed in the plants, leaks through water transportation, and therefore, there is a big difference between water supply and real consumption. Table 2.21 shows the outline of water supply system in the recent years.

(2) Water quality

In order to comprehend the water quality of rivers at Ansan and its vicinity. 6 places were chosen to sample on January 14-16 and February 6-8, 1991. The analytical results are shown in Table 2.22.

1) According to the data, pH and DO range 7.3-7.9 and 4.3-7.7 mg/l, respectively. This means that the river water is Grade IV of life environment.
2) Data of BOD and COD correspond to Grade V of river water standard and organic pollution is serious.
3) CN, Cr^{6+}, Cd, Hg, Pb and As were not found, but trace amount of Zn and Cu were detectable in all the samples. SS was 24-41 mg/l, and colon bacilli were $2.4*10-1.1*10^3$ MPN/100 ml.

Underground water is used for domestic use. Samples from 3 selected points were analyzed according to the legal method. The

Table 2. 20 Factory Distribution

Item	Total	Textile	Chemical	Mechanical	Others
Factory number	875	87	136	245	407
Employee number	59,475	8,941	5,603	16,698	28,233

Rreference :Statistical Yearbook of Kyong-ki Do(1989)

Table 2. 21 Water Supply System

Year	Total population (person)	Water supply population (person)	Rate of spread (%)	Capacity (m^2/day)	Supplied water (m^2/day)	Daily supplied water per person (l/day.person)
1983	61,442	47,804	77.8	150,000	32,740	219
1984	80,595	64,700	80.3	150,000	51,133	227
1985	96,487	78,050	81.0	150,000	62,300	228
1986	127,231	120,804	95.0	150,000	81,000	230
1987	162,569	158,566	97.5	150,000	113,876	222
1988	172,420	167,652	98.0	150,000	116,721	275

Reference: Satistical Yearbook of Ansan City (1988)
Satistical Yearbook of Kyong-ki Do (1989)

Table 2. 22 Water Analysis

(unit: mg/ℓ)

Smpling point	pH	Temp °C	DO	BOD	COD (Mn)	SS	T-N	T-P	Cd	Cu	Pb	Zn	Hg	Cr^{+6}	As	CN	Escherichia.coli (MPN/100mℓ)
W - 1	7.4	3.0	4.3	9.2	10.9	41	0.84	0.065	ND	0.012	ND	0.073	ND	ND	ND	ND	$1.1x10^3$
W - 2	7.9	2.8	4.4	8.8	10.7	33.7	0.96	0.06	ND	0.020	ND	0.032	ND	ND	ND	ND	$3.3x10^2$
W - 3	7.3	2.7	7.7	1.2	1.4	3.0	0.17	0.03	ND	0.007	ND	0.019	ND	ND	ND	ND	2.4x10
W - 4	7.8	2.3	5.4	7.1	9.0	24.0	0.91	0.05	ND	0.016	ND	0.034	ND	ND	ND	ND	$2.8x10^2$
W - 5	7.8	3.3	5.3	6.8	8.5	26.0	0.89	0.04	ND	0.017	ND	0.031	ND	ND	ND	ND	$2.5x10^2$
W - 6	7.5	2.9	7.7	1.4	1.7	2.4	0.19	0.03	ND	0.001	ND	0.024	ND	ND	ND	ND	2.4x10

Table 2. 23 Capacities of Water Supply Plants

(unit:m^3/day)

	Banwol Water Supply Plant		Ansan Water Supply Plant		Remark
	Industrial (2nd treatment)	Domestic (2nd treatment)	Domestic (2nd treatment)	Industrial (1st treatment)	
Up to third stage	102,000	88,000	-	60,000	
4th stage	-	-	80,000	-	80,000m3/day from the expanded 83,000m3/day, is supplied to Banwol
Total	102,000	88,000	80,000	60,000	
		168,000			

Table 2. 24 Capacities of Ansan Sewerage Treatment Plant

		Eexisting	1996
Treatment population(person)		267,000	-
Plant area(m^2)		164,717	164,717
Capacity(m^3/day)		121,000	385,000
Waste Water	Domestic sewage	47,000	179,000
	Industrial waste water	74,000	206,000

results show that 6 chemical and physical items were less than the standard limits but colon bacilli test was positive and more than the standard limits. Therefore, boiling or disinfection is necessary for drinking of the underground water tested.

2.3.5. Forecast of Water Supply

According to the four-stage water supply plan for the metropolitan area which will finish in 1995, the ensured water amount for Ansan is 330,000 m^3/day. Among them, water of 270,000 m^3/day will be treated at the Banwol and Ansan water supply plants, and then be provided Ansan, using 6 water distribution ponds.

Industrial water of 60,000 m^3/day is undergone a first treatment at Ansan water supply plant, and transported to the Dyeing Industrial Estate through the other water pipe, using a water distribution pond. The plan of domestic and industrial water supply is shown in Table 2.23. But,on the recent plan, capacity of the industrial water supply will be increased to 100,000m3/day. It's quantity increased is 40,000m3/day.

2.3.6. Waste Water Treatment

At present, all the sewage in Ansan is transported to Ansan sewerage. The process is a primary treatment and its capacity is 121,000m^3/day. As of 1988, the installation rate of sewage pipeline is 99.1%.

In the two-stage plan up to 1996, the capacity will be expended to 385,000 m^3/day with secondary treatment. In addition, the domestic and industrial waste waters will be treated separately. The plan is outlined in Table 2.24.

3. Related Policies, Laws, Regulations, and Standards

3.1. Outline

In Korea, environmental pollution became visible as the country shifted its main industry from agriculture to manufacturing. It was in December of 1963 that the first anti-pollution law was promulgated.

Since then, the rapid growth of population and GNP has aggravated the environmental problems. To cope with this situation, the anti-pollution law was substantially revised, giving rise to the Environment Protection Law in 1978. An outline of this law is as follows:

Chapter 1. General

Standards for environmental quality are established in this chapter.

Chapter 2. Facilities related to effluent and effluent prevention

Effluent standards and pollution load levies are provided this chapter. Pollution load levies are imposed on any factory whose discharge of wastewater exceeds the effluent standards. The levy rate is determined in accordance with the amount of excess.

Chapter 3. Protection of air

Chapter 4. Regulations of noise and vibration

Chapter 5. Protection of water quality and soil

Effluent standards for sewage treatment plants are established in this Chapter.

(Subsequent chapters are omitted here.)

In January 1980, the Bureau of the Environment was set up to take charge of all sorts of environmental problems. Thus, as far as institutional aspects are concerned, preparations were made to combat environmental problems.

However, the chief of the Bureau of the Environment was not of the rank of minister, and the Environment Protection Law was all too vague to tackle particular problems such as air pollution, noise and water contamination.

Then, in order to make protection of the environment more effective, in 1989 the Bureau of the Environment became the Ministry of the Environment (of which the chief is a minister) , and fundamental revisions were made to the Environment Protection Law in August 1990. An outline of the new laws (based on 1992 edition) is given in the following.

3.2. New Laws for Environmental Protection

The following is the list of the new laws, among which the Basic Environmental Policy Law is the core.

(1) Basic Environmental Policy Law

This law provides the basis for all other environmental laws. Article 10 of this Law sets the environmental standards.

(2) Air Protection Law

(3) Water Quality Protection Law

Details of this law are described below.

(4) Noise/Vibration Control Law

(5) Wastes Disposal Law

(6) Law for the Disposal of Sewage, Excrement, Urine and Stock Farm Wastewater

This law has little to do with industrial wastewater discharged from factories.

(7) Marine Contamination Prevention Law

(8) Toxic Chemicals Control Law

(9) Natural Environment Protection Law

This law is intended to prevent contamination of rivers, forests, swamps, coasts and the like.

(10) Law concerning the Control of Specified Substances and the Protection of the Ozone Layer

This law controls the production of Freon and other specified substances.

Among the laws listed above, (1) and (3) are closely related to water contamination.

3.3. Laws Concerning Water Contamination

(1) Environmental quality standards

Environmental quality standards indicate a set of conditions for air, water, noise and other factors that should be maintained in order to protect healthy daily life of people.

The standards for water are provided in Article 2 of the enforcement regulations based on the Basic Environmental Policy Law. Table 3.1 shows the contents of the standards.

(2) Effluent standards

These standards provide allowable limits for the qualities of water which is discharged to public waters. The effluent standards are stipulated in Article 8 of the Water Quality Protection Law. Table 3.2 shows the contents of the standards.

(3) Effluent standards for sewage and central wastewater treatment plants

A "central wastewater treatment plant" means a facility that treats industrial wastewater from more than one factory to be discharged to public waters. In the case of a sewage treatment plant and a central wastewater treatment plant, special effluent standards are applied instead of the effluent standards described in (2) above. The special standards are provided in Article 24 of the enforcement regulations of the Water Quality Protection Law. Table 3.3 shows the contents of the special standards.

(4) Pollution load levy

Table 3.1 Environmental Quality Standard
(1) River

Classi-fication	Class	Applied Water Usage	Water Quality Indicators				
			pH	COD mg/l	SS mg/l	DO mg/l	Caliform Bacillus MPN/100ml
Living Environ-ment	I	Potable Water 1st Class Nature Conservation	6.5～8.5	Under 1	Under 25	Over 7.5	Under 50
	II	Potable Water 2nd Class Fishery 1st Class Swimming	6.5～8.5	Under 3	Under 25	Over 5	Under 1,000
	III	Potable Water 3rd Class Fishery 2nd Class Industrial Water 1st Class	6.5～8.5	Under 6	Under 25	Over 5	Under 5,000
	IV	Industrial Water 2nd Class Agriculture	6.0～8.5	Under 8	Under 100	Over 2	—
	V	Industrial Water 3rd Class Living Environment Conservation	6.0～8.5	Under 10	No Dust etc.	Over 2	—

Classification	Class	Water Quality Indicators
Human Health Items	All Area	Cd : Under 0.01 mg/l, As:Under 0.05mg/l CN, Hg & Org-P ; Not Detected, Pb ; Under 0.1mg/l Cr^{+6} ; Under 0.05mg/l, PCB ; Not Detected ABS ; Under 0.5mg/l

Table 3.1
(2) Lake & Pond

Classi-fication	Class	Applied Water Usage	Water Quality Indicators						
			pH	COD mg/l	SS mg/l	DO mg/l	Caliform Bacillus MPN/100ml	T-P mg/l	T-N mg/l
Living Environ-ment	I	Potable Water 1st Class Nature Conservation	6.5～8.5	Under 1	Under 1	Over 7.5	Under 50	Under 0.010	Under 0.200
	II	Potable Water 2nd Class Fishery 1st Class Swimming	6.5～8.5	Under 3	Under 5	Over 5	Under 1,000	Under 0.030	Under 0.400
	III	Potable Water 3rd Class Fishery 2nd Class Industrial Water 1st Class	6.5～8.5	Under 6	Under 15	Over 5	Under 5,000	Under 0.050	Under 0.600
	IV	Industrial Water 2nd Class Agriculture	6.0～8.5	Under 8	Under 15	Over 2	—	Under 0.100	Under 1.0
	V	Industrial Water 3rd Class Living Environment Conservation	6.0～8.5	Under 10	No Dust etc.	Over 2	—	Under 0.150	Under 1.5

For Human health items, same standard of (1) are applied.

Table 3.1
(3) Sea

Class	Water Quality Indicators							
	pH	COD mg/l	DO Saturation Rate %	SS mg/l	Caliform Bacillus MPN/100ml	n-Hexane Extractor mg/l	T-N mg/l	T-P mg/l
I	7.8～8.3	Under 1	Over 95	Under 10	Under 200	Not Detected	Under 0.05	Under 0.007
II	6.5～8.5	Under 2	Over 85	Under 25	Under 1,000	Not Detected	Under 0.1	Under 0.015
III	6.5～8.5	Under 4	Over 80	—	—	—	Under 0.2	Under 0.03
Other Quality Indicators mg/l	Cr^{+6} : Under 0.05, As : Under 0.05, Cd : Under 0.01 Pb : Under 0.1, Zn : Under 0.1, Cu : Under 0.02 CN, Org-P, Hg & PCB; Not Detected							

Table 3.2 Effluent Standard for Industrial Wastewater

(1) BOD, COD and SS

Period	Area \ Water Quality Indicators \ Discharged Wastewater	Over 3,000m^3/day			Under 3,000m^3/day		
		BOD mg/ℓ	COD mg/ℓ	SS mg/ℓ	BOD mg/ℓ	COD mg/ℓ	SS mg/ℓ
Applied until end of 1995	1st Class (Clean Area)	50	50	50	50	50	50
	2nd Class	80	80	80	100	100	100
	3rd Class	100	100	100	150	150	150
	Special Area	30	50	70	30	50	70
Applied from beginning of 1996	1st Class (Clean Area)	30	40	30	40	50	40
	2nd Class	60	70	60	80	90	80
	3rd Class	80	90	80	120	130	120
	Special Area	30	40	30	30	40	30

Note : All value shows allowable maximum value.

Table 3.2 - 2

(2) Other Items

Area / Water Quality Indicators		1st Class	2nd Class	3rd Class	Special Area
Hydrogen Exponent pH		5.8～8.6	5.8～8.6	5.8～8.6	5.8～8.6
n-Hexane Extractor mg/ℓ	Mineral Oil	1	5	5	5
	Oil & Fat	5	30	30	30
Phenol mg/ℓ		1	3	3	5
Cyanide CN 〃		0.2	1	1	1
Chrome Cr 〃		0.5	2	2	2
Iron Fe 〃		2	10	10	10
Zinc Zn 〃		1	5	5	5
Copper Cu 〃		0.5	3	3	3
Cadmium Cd 〃		0.02	0.1	0.1	0.1
Mercury Hg 〃		Not Detected	0.005	0.005	0.005
Organic Phosphorus 〃		0.2	1	1	1
Arsenic As 〃		0.1	0.5	0.5	0.5
Lead Pb 〃		0.2	1	1	1
6-Valency Chrome 〃		0.1	0.5	0.5	0.5
Manganese Mn 〃		2	10	10	10
Fluorin F 〃		3	15	15	15
P C B 〃		Not Detected	0.003	0.003	0.003
Caliform Bacillus No./mg		100	3,000	3,000	3,000
Color Degree		200	300	400	400
Temperature ℃		40	40	40	40
Total Nitrogen mg/ℓ		30	60	60	60
Total Phosphorus 〃		4	8	8	8
Trichloro-ethylene 〃		0.06	0.3	0.3	0.3
Tetrachloro-ethylene 〃		0.02	0.1	0.1	0.1
A B S		3	5	5	5

Note : All value shows allowable maximum value.

Table 3.3 Effluent Standard for Sewage and Central Wastewater Treatment Plant

Water Quality Indicators (Classification / Period)		Unit	Sewage Treatment Plant: Until end of 1995	Sewage Treatment Plant: From 1996	Central Wastewater Treatment Plant: Until end of 1995	Central Wastewater Treatment Plant: From 1996
B O D		mg/ℓ	30	20	30	30
C O D		〃			50	40
S S		〃	70	20	70	30
Hydrogen Exponent		pH			5～9	
n-Hexane Extractor	Mineral Oil	mg/ℓ			5	
n-Hexane Extractor	Oil & Fat	mg/ℓ			30	
Phenol		mg/ℓ			3	
Cyanide	CN	〃			1	
Chrome	Cr	〃			2	
Iron	Fe	〃			10	
Zinc	Zn	〃			5	
Copper	Cu	〃			3	
Cadmium	Cd	〃			0.1	
Mercury	Hg	〃			0.005	
Organic Phosphorus		〃			1	
Arsenic	As	〃			0.5	
Lead	Pb	〃			1	
6-Valency Chrome		〃			0.5	
Manganese	Mn	〃			10	
Fluorin	F	〃			15	
P C B		〃			0.003	
Trichloro-ethylene		〃			0.3	
Tetrachloro-ethylene		〃			0.1	
Temperature		℃			40	
Total Nitrogen		mg/ℓ		60		60
Total Phosphorus		〃		8		8

Note:All value shows allowable maximum value.

If a factory has discharged wastewater which contains pollutant above the allowable limits, improvement is ordered and, until the improvement is achieved, a levy is imposed according to the amount of pollutant. This is stipulated in Article 19 of the Water Quality Protection Law and Article 10 of its enforcement regulations. Details are shown in Table 3.4.

(5) Wastewater treatment subcontractor

A "wastewater treatment subcontractor" means a subcontractor that collects wastewater from factories (using a tank truck, for example) and treats it on a commercial basis (pursuant to Article 43 of the Water Quality Protection Law). The fees for subcontracting are set in Article 50 of the enforcement regulations of the Water Quality Protection Law. Table 3.5 shows the fees.

(6) Others

In addition to the above, water pollutant, specified toxic substances, specified wastewater discharging facilities and water contamination prevention facilities are defined in Article 2 of the Water Quality Protection Law.

3.4. Effluent Standards in Korea and Japan: Comparison

System of effluent standards in Korea and Japan are slightly different from each other.

In Korea, effluent standards which are applied to discharged wastewater are established for (1) factories, (2) central wastewater treatment plants and (39 sewage treatment plants. Effluent standards (1) also applies to wastewater discharged into a sewage treatment plant from a factory or from a central wastewater treatment plant.

In Japan, in addition to (4) an effluent standards for direct discharge from factories or from central wastewater treatment plants to public waters and (6) an effluent standards for sewage treatment plants, (5) an effluent standard (called the Hazard Elimination Standard) for wastes discharged from factories, etc. to sewage treatment plants is established separately.

Table 3.4 Basis for Estimation of Pollution Load Level

Classification / Pollutant		Load Levy Won/kg	Assessing Indices for Over Discharging Rate %								For Individual Area		
			Under 20	20～40	40～80	80～100	100～200	200～300	300～400	Over 400	1st & 2nd Class	3rd Class	Special Area
Organic Substances		250	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
Suspended Solid		250	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
Chrome	Cr	75,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
Toxic Sub-stances	Phenol	150,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	CN	150,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	Cu	50,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	Cd	500,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	Hg	1,250,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	Org-P	150,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	As	100,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	Pb	150,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	Cr^{+6}	300,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	PCB	1,250,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	C_2HCl_3	300,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1
	C_2Cl_4	300,000	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	2	1.5	1

Table 3.5 Charge for Wastewater Treatment

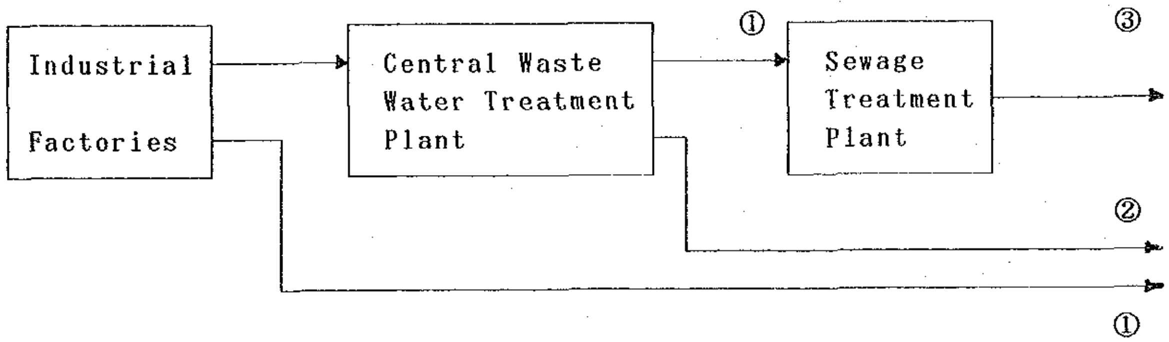
Classification	Charactor	Concentration	Charge Won/t	Transportation Basis Won/t	Transportation Distance Won/km	Total
Plating	Oxidation (CN etc.)	Under 100mg/ℓ	50,800	3,000	150	Charge+ Basis+ Distance
		101～1000mg/ℓ	66,900			
		Over 1001mg/ℓ	84,500			
	Reduction (Cr etc.)	Under 300mg/ℓ	53,700			
		301～3000mg/ℓ	106,300			
		Over 3001mg/ℓ	190,100			
	Mixed	Under 300mg/ℓ	66,200			
		301～3000mg/ℓ	121,900			
		Over 3001mg/ℓ (4,000)	211,100			
Loboratory	Heavy Metals	Under 300mg/ℓ	65,000	3,000	150	
		301～3000mg/ℓ	109,700			
		Over 3001mg/ℓ	163,200			
Other Heavy Metals	Pb, Cu, Hg, Ag etc.	Under 300mg/ℓ	53,600	3,000	150	
		301～3000mg/ℓ	98,000			
		Over 3001mg/ℓ	175,900			
Waste Acid	Sulfuric Acid	Under 10%	52,400	3,000	200	
		11～30%	100,500			
		Over 31%	151,700			
	Hydrochloric Acid	Under 10%	64,300			
		11～30%	134,500			
		Over 31%	217,000			
Waste Alkali	Caustic Soda	Under 10%	37,500	3,000	150	
		11～30%	64,300			
		Over 31%	78,000			
	Ammonia	Under 10%	40,600			
		Over 11%	68,700			
Other Metals	Fe, Zn, Al etc.	Under 500mg/ℓ	43,700	3,000	150	
		501～2000mg/ℓ	51,200			
		2001-5000mg/ℓ	58,700			
		Over 5001mg/ℓ	62,600			
Others	C O D	Under1000mg/ℓ	32,600	3,000	150	
		1001-5000mg/ℓ	36,900			
		Over 5001mg/ℓ	43,300			
Wastewater from Boiler	De-scaling		48,900	2,000	150	
	Neutratization		41,800			
Wastewater from Photographic Development	Acidic	High Concentration	144,800	3,000	150	

The relationship between these are illustrated in Fig. 3.1. and the Effluent Standards are shown in Table 3.6.

Furthermore, in many areas in Japan, standards tighter than (4) called added standards are established by local authorities.

Table 3.6 shows a comparison of Korean and Japanese effluent standards. In Japan, some local governments impose very rigorous standards.

(1) Korea



(2) Japan

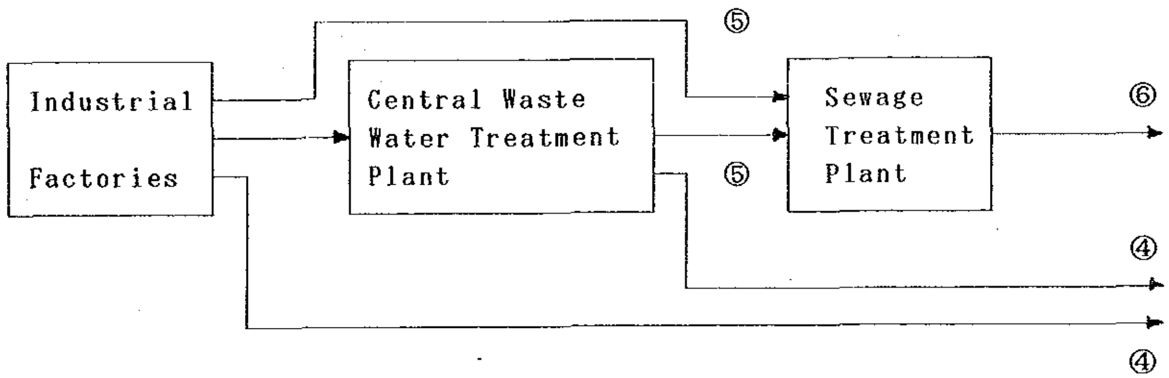


Fig. 3.1 Comarison of Effluent Standard

Table 3.6 Effluent Standard in Korea and Japan(No.1)

Korea in 1996, ( ) shows in 1993

Classification / Water Quality Indicators	Industrial 3rd Class 〉 3,000m^3/d	Central Treatment Plant	Seawage Treatment Plant
B O D mg/l	80 (100)	30	20(30)
C O D 〃	90 (100)	40	
S S 〃	80 (100)	30	20(70)
Hydrogen Exponent pH	5.8～8.6	5～9	
n-Hexane Extractor mg/l: Mineral Oil	5	5	
n-Hexane Extractor mg/l: Oil & Fat	30	30	
Phenol mg/l	3	3	
Cyanide CN 〃	1	1	
Chrome Cr 〃	2	2	
Iron Fe 〃	10	10	
Zinc Zn 〃	5	5	
Copper Cu 〃	3	3	
Cadmium Cd 〃	0.1	0.1	
Mercury Hg 〃	0.005	0.005	
Organic Phosphorus 〃	1	1	
Arsenic As 〃	0.5	0.5	
Lead Pb 〃	1	1	
6-Valency Chrome 〃	0.5	0.5	
Manganese Mn 〃	10	10	
Fluorin F 〃	15	15	
P C B 〃	0.003	0.003	
Caliform Bacillus No./mg	3,000	—	
Color Degree	400	—	
Total Nitrogen mg/l	60	60	60(-)
Total Phosphorus 〃	8	8	8(-)
Trichloro-ethylene 〃	0.3	0.3	
Tetrachloro-ethylene 〃	0.1	0.1	
A B S	5	—	
Alkylmercuric compound	—	—	

Note:All value shows allowable maximum value.

Table 3.6 Comparison of Effluent Standerd

(2)Standard of Japan, (Present value)

Water Quality Indicators / Classification		Industrial Wastewater, General ④	Flow into Seawage ⑤ Treat. Plant	Sewage Treatment Plant ⑥
B O D	mg/l	160	300	20
C O D	〃	160		
S S	〃	200	300	70
Hydrogen Exponent pH		5.8～8.6	5.7～8.7	5.8～8.6
n-Hexane Extractor mg/l	Mineral Oil	5	5	5
	Oil & Fat	30	30	30
Phenol	mg/l	5	5	5
Cyanide CN	〃	1	1	1
Chrome Cr	〃	2	2	2
Iron Fe	〃	10	10	10
Zinc Zn	〃	5	5	5
Copper Cu	〃	3	3	3
Cadmium Cd	〃	0.1	0.1	0.1
Mercury Hg	〃	0.005	0.005	0.005
Organic Phosphorus	〃	1	1	1
Arsenic As	〃	0.5	0.5	0.5
Lead Pb	〃	1	1	1
6-Valency Chrome	〃	0.5	0.5	0.5
Manganese Mn	〃	10	10	10
Fluorin F	〃	15	15	15
P C B	〃	0.003	0.003	0.003
Caliform Bacillus No./mg		3,000	—	3,000
Color	Degree	—	—	—
Total Nitrogen	mg/l	120	150	120
Total Phosphorus	〃	16	20	16
Trichloro-ethylene	〃	0.3	0.3	0.3
Tetrachloro-ethylene	〃	0.1	0.1	0.1
A B S		—	—	—
Alkylmercuric compound		Not Detected	Not Detected	Not Detect

Note:All value shows allowable maximum value.

II. Plating Industrial Estate

II Plating Industrial Estate

1. Condition of the Industrial Estate

1.1 Outline of the Industrial Estate

The plating industrial estate, being run by S Co., Ltd., is situated at the western verge of Inchon City. Business places which have joint wastewater treatment plants in this estate are Business Place No.1 and Business Place No.2.

(1) Location of the each of the business places mentioned above is shown in Fig.1.1.1. and is as follows:
Business Place No.1: 178-35 Ka Jaw Dong, Suh Ku Inchon
Tel: 032-575-7438,9
Business Place No.2: 223-42 Suk Nam Dong, Suh Ku Inchon
Tel: 032-573-7250, 7260

(2) Scale of the plating industrial estate

Business Place No.2 has a total site area of about 4600m^2 and in this site area, a 3-storied building occupying a site of about 1200m^2, a 1-storied plating factory occupying a site are of about 780m^2, and a joint wastewater treatment plant occupying a site area of about 460m^2. The 3-storied building is of apartment type. Plating factories of 23 companies in total are located in this building; 10 companies on the first floor and 13 companies on the second floor. The third floor is occupied by an office room and a testing and analysis room. The 1-storied building accommodates plating factories of 8 companies. The wastewater from each of these plating factories is discharged into the joint wastewater treatment plant and the effluent from the treatment plant is finally discharged into the public sewerage system.

Business Place No.1 has approximately the same scale as Business Place No.2, and in its site, there are a new 3-storied

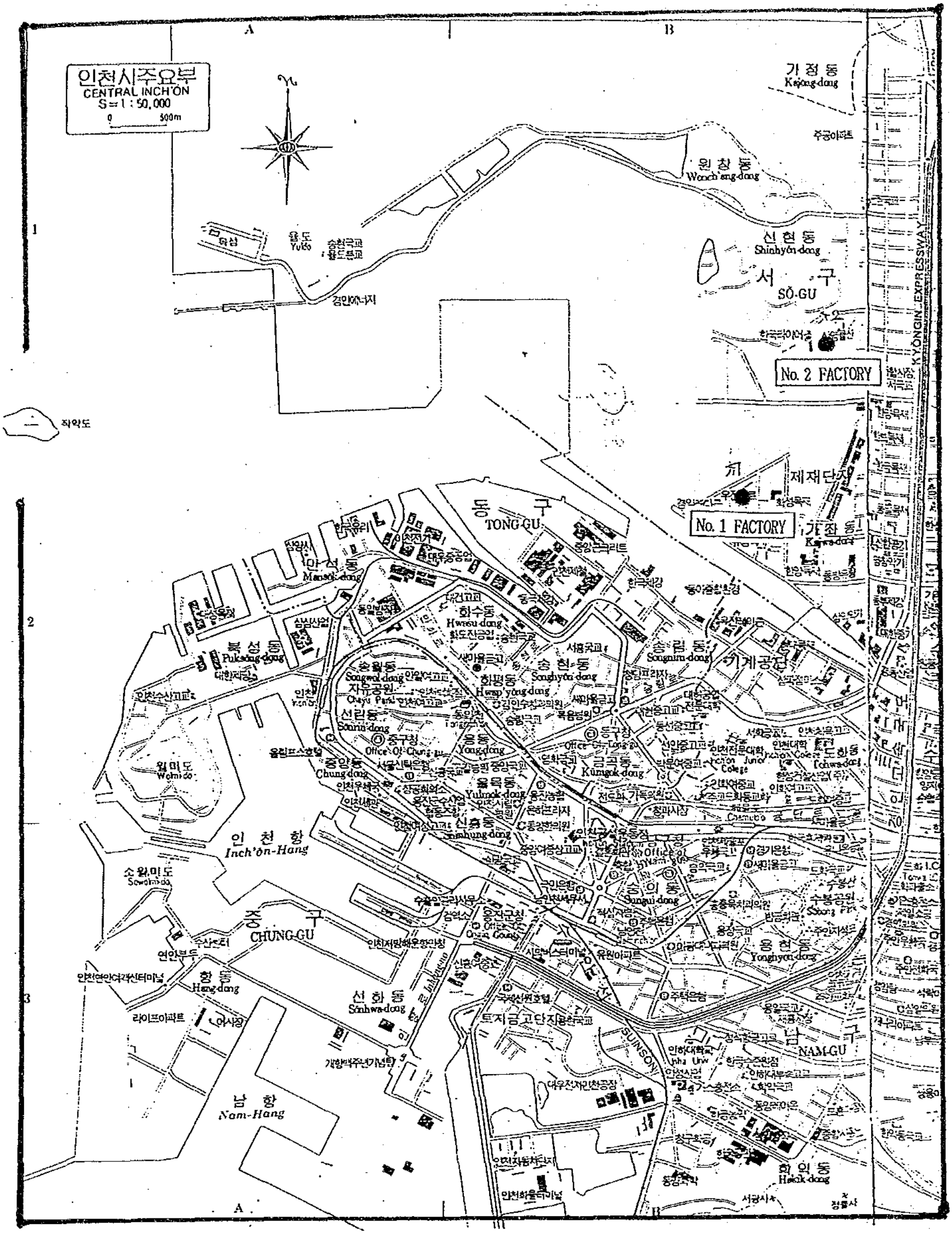


Fig. 1.1.1 Location of the plating industrial estate

building, an old 1-storied (partly 2-storied) building for plating factory, a power substation, and a joint wastewater treatment plant. The 3-stoied new building is of apartment type. Plating factories of 14 companies in total are located in this building; 5 companies on the first floor, 5 companies on the second floor, and 4 companies on the third floor. The third floor is also occupied by an office and a testing and analysis room. Underground, there is a dining room for employees. The old building is occupied by plating factories of 14 companies on the first floor and plating factories of 3 companies on the second floor. The wastewater from each of these plating factories is discharged into the joint wastewater treatment plant and the effluent from the treatment plant is finally discharged into the public sewerage system.

In addition to the above, there is Business Place No.3 which was constructed in 1991. It has no joint wastewater treatment plant. The surface treatment factory of one company in this business place was surveyed. The wastewater from the factories located in this business place is discharged into a reservoir tank in the site of the business place, from which it is then transported by tank lorry to Business Place No.1 where it is treated.

In any of Business Place No.1, Business Place No.2 and Business Place No.3, the plating factories are small-scale enterprises having 100-200 m^2 site area and 3-16 employees.

Fig.1.1.2. through Fig.1.1.6. show the location of the each of the factories occupying in these buildings.

(3) Organization

S Co., Ltd, has technology regarding wastewater treatment. It has been engaged in the manufacture of environmental equipment, while it is running a plating industrial estate as a part of its business.

In the plating industrial estate, small-scale plating companies can be located free of charge on the condition that they should observe the regulations. The wastewater and exhaust gas

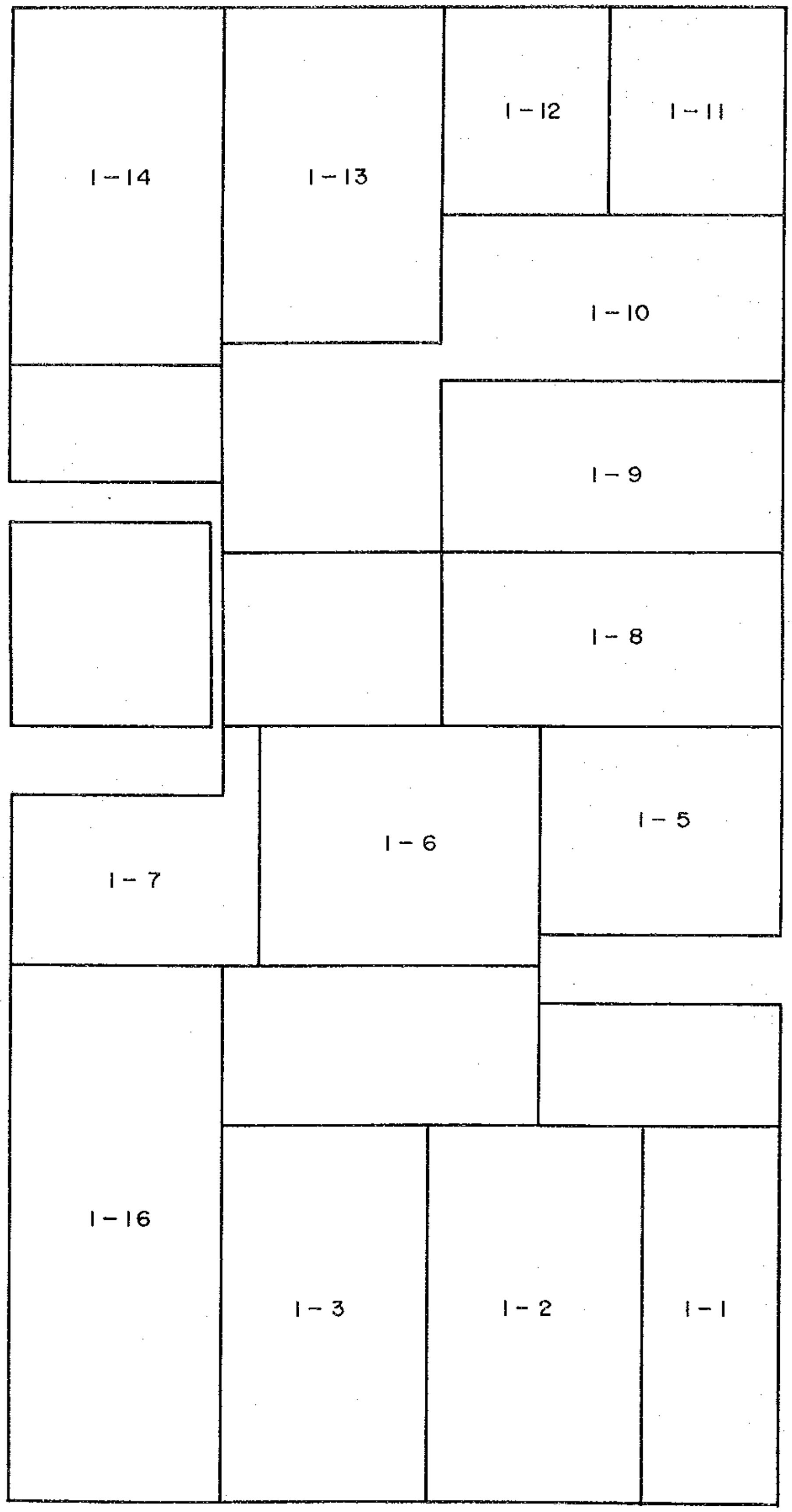


Fig. 1.1.2. The arrangement of factories in the 1st Estate Section
(old storied building)

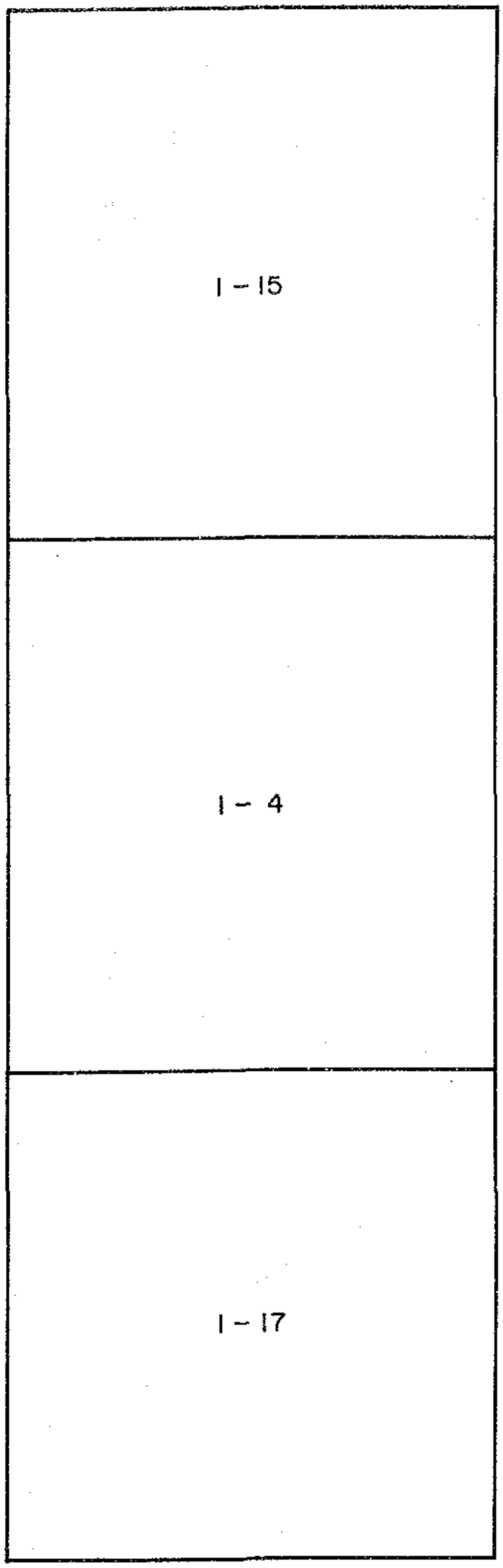


Fig. 1.1.3. The arrangement of factories in the 2nd Estate Section (old 2-storied building)

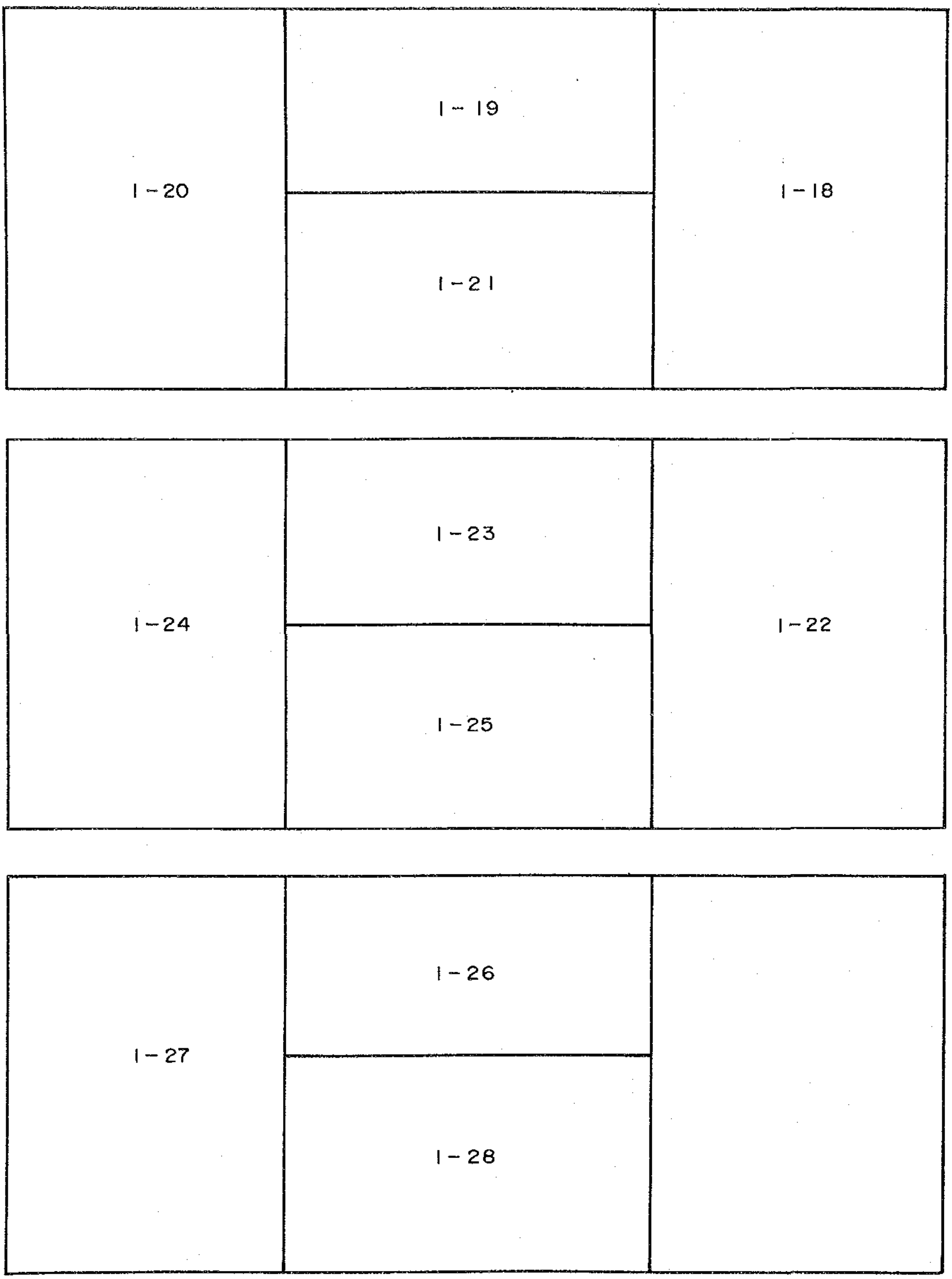


Fig. 1.1.4. The arrangement of factories in the 2nd Estate Section
(new storied building)

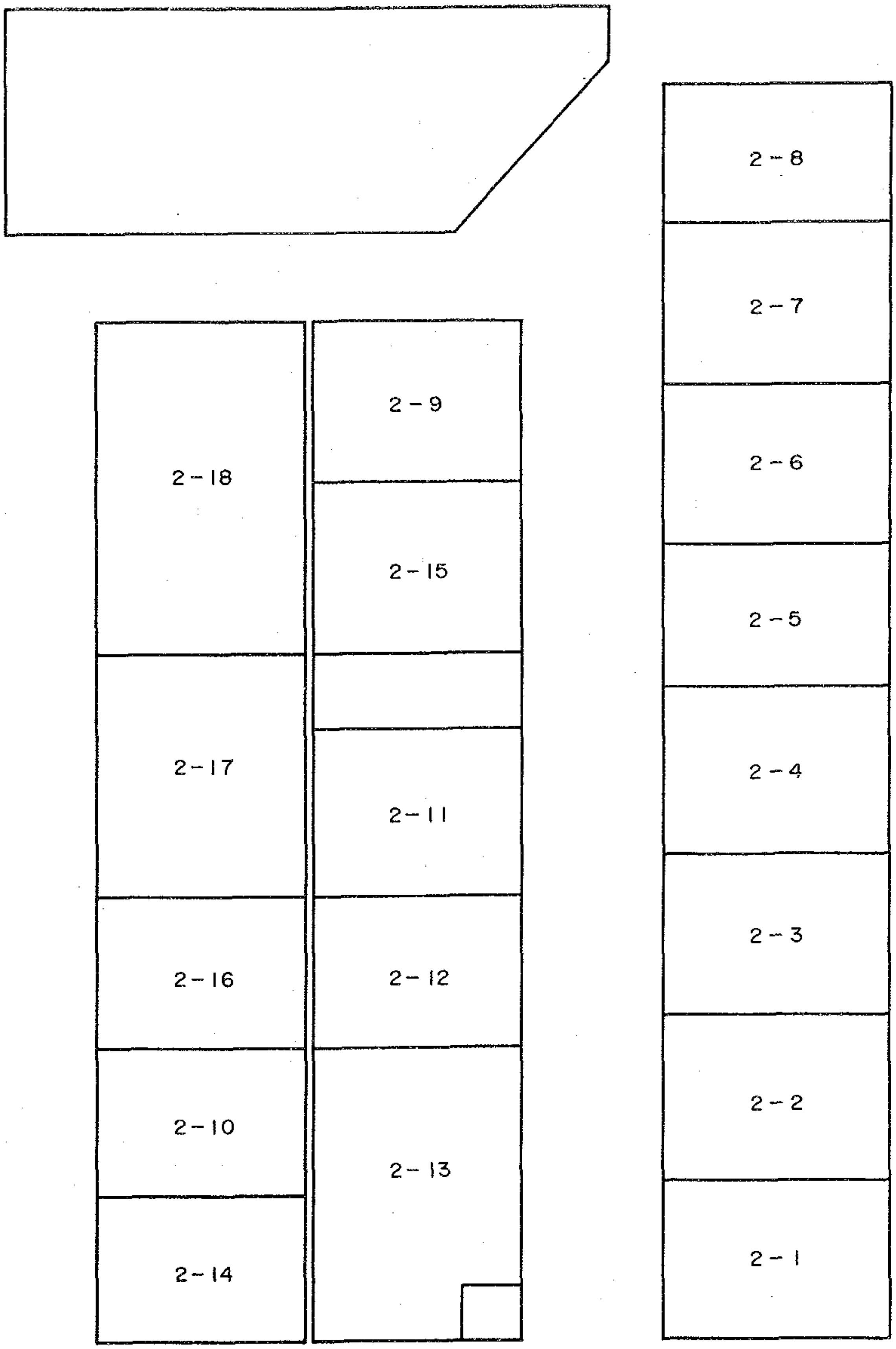


Fig. 1.1.5. The arrangement of factories in the 2nd Estate Section
(1-storied building)

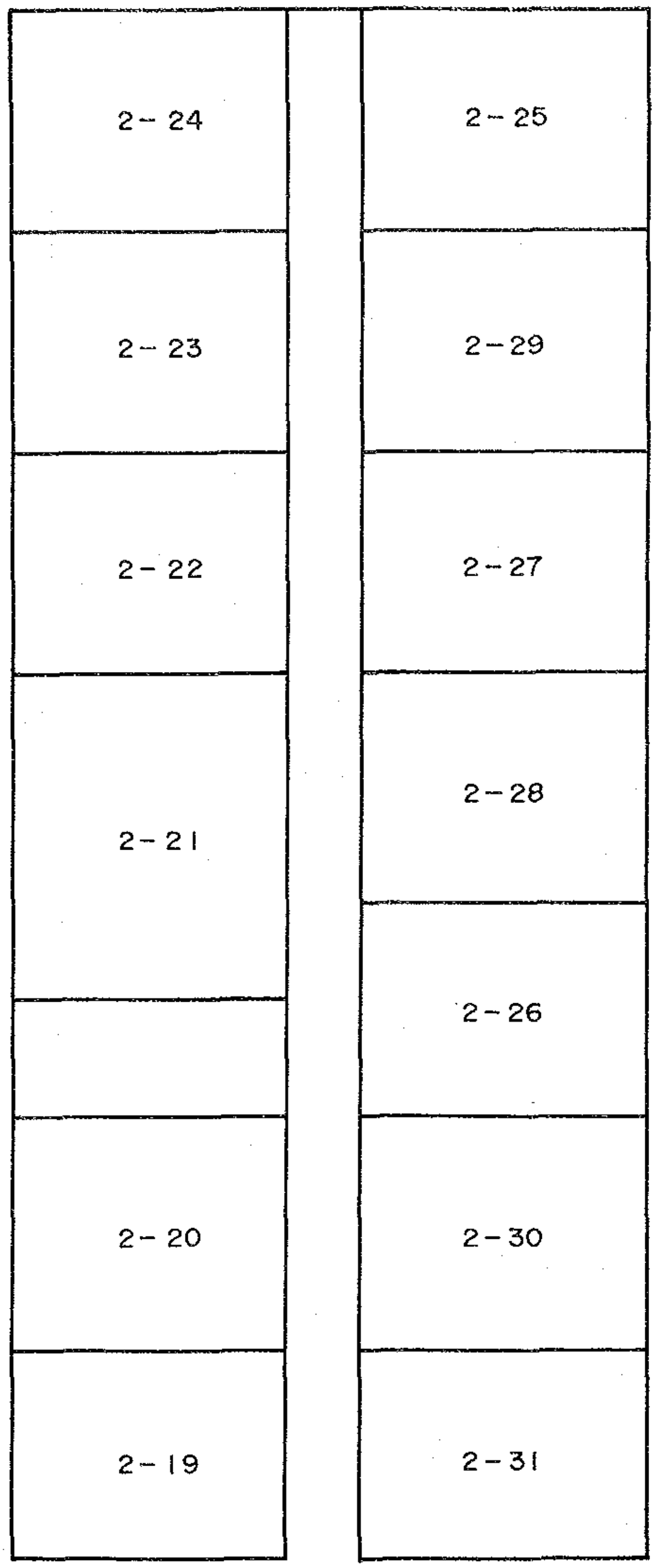


Fig. 1.1.6. The arrangement of factories in the 2nd Estate Section
(2-storied fuilding)

from the factories should be treated in the joint treatment plants installed in the plating industrial estate, and this is the basis for the running of plating industrial estate.

(4) Enterprises located in the estate

Table 1.1.1. through Table 1.1.3. show the kinds of plating and manufactured items the plating factories located in the plating industrial estate.

In most plating factories, anti-rusting and decorative plating of cion and plastic raw materials is done for home goods, etc. and in some plating factories, pattern etching and pattern plating of printed wiring boards, and decorative plating with precious metals such as gold and silver are done.

1.2 The State of Wastewater, Wastewater Treatment and Reclamation

(1) Wastewater quantity and quality

Table 1.2.1. and Table 1.2.2. show the wastewater quantity discharged from the plating factories located in Business Place No.1 and Business Place No.2.

Table 1.2.3. through Table 1.2.9. show the results of analysis of wastewater contained in each tank of each plating factory which was surveyed by visiting.

(2) Scale of wastewater treatment plants

Joint wastewater treatment plants were designed and constructed by S Co., Ltd. They are if approximately the same scale and are installed in /business Place No.1 and Business Place No.2.

The wastewater to be treated flows from each plating factory directly into the joint wastewater treatment plant, or is transported from the other business place and plating factories located outside the plating industrial estate by tank lorry (5t).

Table 1.1.1. The kinds of Plating and manufacturing Items of the 1st Estate Section

Factory (No)	Kinds of Plating・Products	Note
1－ 1	General Plating／Hanger	
1－ 2	Plastic Plating	
1－ 3	Printed Circuit	studied
1－ 4	Lighting Fixture	
1－ 5	Plastic Button Plating	
1－ 6	Aluminium Coloring	
1－ 7	General Plating／Musical Instrument	
1－ 8	Zinc Plating・Ion Wire	
1－ 9	Gold Plating／Spoon	
1－10	Aluminium Stick Coloring	
1－11	Chromium Plating／Valve	
1－12	Zinc Plating／Parts of Automobile	Studied
1－13	General Plating／Bath・Accessories	
1－14	Parts of Electronic Machine	
1－15	Reflex Mirror made by Aluminium	
1－16	General Plating／Hanger	studied
1－17	General Plating／Construction Material	
1－18	Sink	
1－19	Nickel・Chromium Plating／Hanger	
1－20	Copper・Chromium／Chair	studied

Table 1.1.1. The kinds of Plating and manufacturing Items of the 1st Estate Section(continued)

Factory (No)	Kinds of Plating・Products	Note
1－21	Sash・Mold	
1－22	Plastic Plating／Accessories	studied
1－23	Precious Plating／Watch・Accessories	studied
1－24	Frame made by Aluminium	
1－25	Bag・Accessories	
1－26	Gold Plating／Button	studied
1－27	Plastic Plating／Electronic Machine	
1－28	Plastic Plating／Accessories	

Table 1.1.2. The kinds of Plating and manufacturing Items of the 2nd Estate Section

Factory (No)	Kinds of Plating・Products	Note
2－ 1	Parts of Tableware	
2－ 2	Bolt for Electronic Computer	
2－ 3	Condenser	
2－ 4	Bolt for Electronic Computer	
2－ 5	Parts of Furniture	
2－ 6	Accessories	
2－ 7	Screw Nail	
2－ 8	Hot Air Machinery	
2－ 9	Screw Nail	
2－10	Hot Air Machinery	
2－11	Parts of Camera	
2－12	Parts of Gas Mask	
2－13	Parts of Fishing	stidied
2－14	Parts of Automobile	studied
2－15	Chain・Volt	
2－16	Construction Materials	
2－17	Electronic Machine／Switch	
2－18	Lighting Fixture	
2－19	Parts of Automobile & Sanitation	
2－20	Screw Nail	

Table 1.1.2. The kinds of plating and manufactured items of the 2nd Estate Section (continued)

Factory (No)	Kinds of Plating · Product	Note
2 − 21	Spoon	
2 − 22	Parts of Iron	
2 − 23	Parts of Electric Device	
2 − 24	Spoon	
2 − 25	Metholine	
2 − 26	Electronic Machine	
2 − 27	Frame	
2 − 28	Parts of Semiconductor	
2 − 29	Dressing Case	
2 − 30	Accessorires	
2 − 31	Accessorires	

Table 1.1.3. The kinds of plating and manufactured items of the 3rd Estate Section

Factory (No)	Kinds of Plating · Product	Note
3 − 1	Parkerizing	studied

Table 1.2.1. The Quantity in Wastewater discharged from the Plating factories (1st Estate Section)

(m^3/month)

No. of factory	CN Wastewater	Cr Wastewater	H・OH Wastewater
1 － 1	48	64	27
1 － 2	－	69	28
1 － 3	79	－	67
1 － 4	50	90	59
1 － 5	78	74	26
1 － 6	－	－	109
1 － 7	62	58	27
1 － 8	32	22	16
1 － 9	63	41	38
1 － 10	－	－	205
1 － 11	－	69	11
1 － 12	30	23	28
1 － 13	75	90	37
1 － 14	74	90	62
1 － 15	－	－	117
1 － 16	42	70	40
1 － 17	39	30	36
1 － 18	－	30	164
1 － 19	66	76	39

Table 1.2.1. The Quantity in Wastewater discharged from the Plating factories (1st Estate Section) (continued)

(m^3/month)

No. of factory	CN Wastewater	Cr Wastewater	H·OH Wastewater
1 − 20	80	50	75
1 − 21	20	27	19
1 − 22	52	55	31
1 − 23	32	20	26
1 − 24	−	69	141
1 − 25	150	114	106
1 − 26	67	72	37
1 − 27	50	50	37
1 − 28	49	58	54

Table 1.2.2. The Quantity in Wastewater discharged from the Plating factories (2nd Estate Section)

(m^3/month)

No. of factory	CN Wastewater	Cr Wastewater	H·OH Wastewater
2 − 1	18	−	29
2 − 2	59	−	99
2 − 3	13	15	3
2 − 4	31	−	52
2 − 5	50	−	84
2 − 6	54	68	21
2 − 7	54	69	22
2 − 8	44	56	17
2 − 9	38	−	64
2 − 10	45	57	17
2 − 11	47	59	18
2 − 12	−	−	159
2 − 13	69	87	27
2 − 14	48	61	19
2 − 15	43	54	17
2 − 16	51	65	21
2 − 17	78	98	31
2 − 18	65	−	108
2 − 19	45	57	17

Table 1.2.2. The Quantity in Wastewater discharged from the Plating factories (2nd Estate Section) (continued)

(m^3/month)

No. of factory	CN Wastewater	Cr Wastewater	H·OH Wastewater
2 − 20	45	58	16
2 − 21	35	44	13
2 − 22	38	49	15
2 − 23	39	49	16
2 − 24	13	−	23
2 − 25	33	−	55
2 − 26	51	65	21
2 − 27	37	47	15
2 − 28	−	30	35
2 − 29	24	−	41
2 − 30	−	−	92
2 − 31	−	−	84

Table 1.2.3. The Quality of Waste Water in Each Factory

(FACTORY) No. 1-13

ITEM \ SAMPLE	BRASS PLATING BATH (1)	BRASS WATER WASHING TANK (1)	BRASS WATER WASHING TANK (2)	BRASS PLATING BATH (2)
pH	11.6	11.3	9.98	9.40
Alkalinity (epm)	971	61.9	3.84	2,940
Conductivity (μs/cm)	—	6,970	506	—
COD_{cr} (mg/l)	3.7	232	24	15,100
Cu (mg/l)	12,300	868	41.7	53,800
Ni (mg/l)	—	—	—	14.0
Cr^{6+} (mg/l)	—	—	—	< 0.5
Zn (mg/l)	—	—	—	31,400

(FACTORY) No. 1-16

ITEM \ SAMPLE	H_2SO_4 WATER WASHING TANK (1)	ELEC-CLEAN WATER WASHING TANK (1)	ELEC-CLEAN WATER WASHING TANK (2)	COPPER WATER WASHING TANK (1)
pH	1.78	2.78	2.77	8.90
Acidity (epm)	51.4	3.02	3.96	—
Alkalinity (epm)	—	—	—	1.67
Conductivity (μs/cm)	16,400	1,700	2,270	354
COD_{cr} (mg/l)	< 5	< 5	< 5	< 5
Cu (mg/l)	—	—	—	19.0
Fe (mg/l)	0.24	0.14	0.25	0.32
CN (mg/l)	—	—	—	198

ITEM \ SAMPLE	COPPER WATER WASHING TANK (2)	COPPER WATER WASHING TANK (3)	CHROME WATER WASHING TANK (1)	CHROME WATER WASHING TANK (2)
pH	10.6	11.6	1.86	3.18
Acidity (epm)	—	—	28.6	—
Alkalinity (epm)	7.76	47.9	—	—

Table 1.2.4. The Quality of Waste Water in Each Factory

(FACTORY) No. 1-16

ITEM \ SAMPLE	COPPER WATER WASHING TANK (2)	COPPER WATER WASHING TANK (3)	CHROME WATER WASHING TANK (1)	CHROME WATER WASHING TANK (2)
Conductivity (μs/cm)	1,180	5,900	11,900	707
COD_{cr} (mg/l)	20	82	–	–
Cu (mg/l)	62.0	148	–	–
Cr^{6+} (mg/l)	–	–	–	115
CN (mg/l)	228	1,330	–	–

ITEM \ SAMPLE	ELECTROLYTIC CLEANING BATH
pH	12.7
COD_{cr} (mg/l)	4,470
CN (mg/l)	16,500

(FACTORY) No. 1-23

ITEM \ SAMPLE	GOLD RECOVERY TOWER	H_2SO_4 WATER WASHING TANK (1)	ELEC-CLEAN WATER WASHING TANK (1)
pH	4.18	2.70	8.74
Acidity (epm)	–	4.90	–
Alkalinity (epm)	–	–	1.02
Conductivity (μs/cm)	284	2,540	214
COD_{cr} (mg/l)	120	67	40
CN (mg/l)	6.91	–	0.53

(FACTORY) No. 1-26

ITEM \ SAMPLE	Cr-ETCHING WATER WASHING TANK (1)	ALKALI WATER WASHING TANK (1)	CHEMICAL NICKEL PLATING BATH	CHEMI(Ni) WATER WASHING TANK (1)
pH	7.97	0.76	8.86	12.6
Acidity (epm)	–	450	–	–

Table 1.2.5. The Quality of Waste Water in Each Factory

(FACTORY) No. 1-26

ITEM \ SAMPLE		Cr-ETCHING WATER WASHING TANK (1)	ALKALI WATER WASHING TANK (1)	CHEMICAL NICKEL PLATING BATH	CHEMI(Ni) WATER WASHING TANK (1)
Alkalinity	(epm)	25.7	—	—	32.3
Conductivity	(μs/cm)	6,410	—	—	7,720
COD_{cr}	(mg/l)	434	67	30,800	134
Ni	(mg/l)	—	—	7,730	8.68
Cr^{6+}	(mg/l)	< 0.5	< 0.5	—	—
T-P	(mg/l)	—	—	30,300	67.8
$NH_4 + NH_3 - N$	(mg/l)	—	—	27,000	54

ITEM \ SAMPLE		Ni(N)-PLAT WATER WASHING TANK (1)	Ni(B)-PLAT WATER WASHING TANK (1)	Ni(B)-PLAT WATER WASHING TANK (2)	Au-PLAT WATER WASHING TANK (1)
pH		7.82	7.33	1.36	4.76
Acidity	(epm)	—	—	192	—
Conductivity	(μs/cm)	1,110	195	—	725
COD_{cr}	(mg/l)	73	72	227	450
Ni	(mg/l)	321	0.21	182	—
Au	(mg/l)	—	—	—	0.59
CN	(mg/l)	—	—	—	2.29

Table 1.2.6. The Quality of Waste Water in Each Factory

(FACTORY) No. 2-12

ITEM \ SAMPLE	ALKALI WATER WASHING TANK	ANODIC OXIDATION BATH	OXIDATION WATER WASHING TANK (1)	OXIDATION WATER WASHING TANK (2)
pH	12.7	0.32	0.97	2.20
Acidity (epm)	–	2,750	129	3.47
Alkalinity (epm)	78.9	–	–	–
Conductivity (μs/cm)	14,050	–	–	1,330
COD_{cr} (mg/l)	164	29	70	53
Al (mg/l)	433	1,681	202	20.3

ITEM \ SAMPLE	SEALING BATH	COLORING BATH	COLOLING WATER WASHING TANK
pH	6.17	5.95	6.28
Conductivity (μs/cm)	198	–	319
COD_{cr} (mg/l)	45	1,090	70
Al (mg/l)	0.44	–	2.25

(FACTORY) No. 2-13

ITEM \ SAMPLE	CHROME PLATING BATH	CHROME WATER WASHING TANK	ELECTROLYTIC CLEANING BATH	CYANIDE Cu PLATING BATH
pH	10.3	9.01	–	13.3
Alkalinity (epm)	–	11.5	4,290	924
COD_{cr} (mg/l)	2,120	70	132	2,010
Cu (mg/l)	–	–	–	11,900
Cr^{6+} (mg/l)	<0.5	<0.5	–	–
Fe (mg/l)	–	–	407	–
CN (mg/l)	–	–	–	13,900
T-P (mg/l)	–	–	407	–

Table 1.2.7. The Quality of Waste Water in Each Factory

(FACTORY) №. 2-13

ITEM \ SAMPLE		COPPER SULFATE PLATING BATH	COPPER WATER WASHING TANK (1)	COPPER WATER WASHING TANK (2)	NICKEL PLATING BATH
pH		0.20	3.42	0.89	4.51
Acidity	(epm)	2,640	0.25	404	—
Conductivity	(μs/cm)	—	414	—	—
COD_{cr}	(mg/l)	972	10	6	4,130
Cu	(mg/l)	54,600	27.7	28.5	—
Ni	(mg/l)	—	—	—	46,500
Fe	(mg/l)	—	0.26	6.17	—
CN	(mg/l)	—	4.46	1.23	13.7

ITEM \ SAMPLE		BLACK CHROME PLATING BATH	ELEC-CLEAN WATER WASHING TANK	ALKALI CLEANING BATH
pH		0.04	0.85	12.8
Acidity	(epm)	3,200	147	—
Alkalinity	(epm)	—	—	236
Conductivity	(μs/cm)	—	—	—
COD_{cr}	(mg/l)	—	34	830
Cu	(mg/l)	—	—	2,900
Fe	(mg/l)	—	15.7	—
CN	(mg/l)	—	—	3,480
T-P	(mg/l)	20.8	14.1	—
F	(mg/l)	—	—	—

Table 1.2.8. The Quality of Waste Water in Each Factory

(FACTORY) No. 2-14

ITEM \ SAMPLE		H_2SO_4 WATER WASHING TANK (1)	H_2SO_4 WATER WASHING TANK (2)	NaOH WATER WASHING TANK (1)	COPPER CYANIDE PLATING BATH
pH		1.93	1.10	12.59	13.6
Acidity	(epm)	16.8	226	—	—
Alkalinity	(epm)	—	—	326	3,540
Conductivity	(μs/cm)	9,410	—	—	—
COD_{cr}	(mg/l)	102	544	102	8,350
Zn	(mg/l)	—	—	—	41,500
Fe	(mg/l)	85.8	795	—	—
CN	(mg/l)	—	—	5,530	55,600

ITEM \ SAMPLE		BLACK CHROMATE TREATMENT BATH	CHROMATE WATER WASHING TANK (1)	WHITE CHROMATE TREATMENT BATH	CHROMATE(B)WATER WASHING TANK (1)
pH		0.63	5.94	2.11	2.08
Acidity	(epm)	722	—	165	55
Conductivity	(μs/cm)	—	254	—	—
Cr^{6+}	(mg/l)	31,100	13,500	152	3,370
Zn	(mg/l)	—	—	—	41,600
Ag	(mg/l)	—	—	—	15.7

Table 1.2.9. The Quality of Waste Water in Each Factory

(FACTORY) No. 3-1

ITEM \ SAMPLE		ALKALI CLEANING BATH	CLEANING WATER WASHING TANK (1)	PICKLING TANK	PICKLING WATER WASHING TANK (1)
pH		13.1	8.33	–	1.21
Acidity	(epm)	–	–	–	155
Alkalinity	(epm)	1,310	–	6,910	–
Conductivity	(μs/cm)	–	1,330	–	–
COD_{cr}	(mg/l)	5,520	54	544	12
Fe	(mg/l)	–	–	2,490	1,020

ITEM \ SAMPLE		PICKLING WATER WASHING TANK (2)	DIPPING TANK	COATING TANK	RUST WATER WASHING TANK (1)
pH		2.58	9.32	2.29	4.08
Acidity	(epm)	4.0	–	134	–
Conductivity	(μs/cm)	2,010	–	–	757
COD_{cr}	(mg/l)	122	8	143	8
Zn	(mg/l)	–	2.55	5,240	64.8
Fe	(mg/l)	56.5	37.3	893	20.5

ITEM \ SAMPLE		COATING OF RUST PREVENTIVES TANK
pH		5.25
COD_{cr}	(mg/l)	2,670
Zn	(mg/l)	23.0
Fe	(mg/l)	23.5
n-Hex	(mg/l)	2,900

City Water

ITEM \ SAMPLE		City Water
pH		6.94
Conductivity	(μs/cm)	191

The wastewater treatment is done for a consideration, and therefore, these plants are recognized as the industrial waste treatment plants.

The joint wastewater treatment plant in Business Place No.2 is described below.

At present, the following quantity of wastewater is treated, and this is about 60 % the plant's treatment capacity:

Cyanide wastewater:	1,240m^3/M	(217m^3/M from outside)
Chrome wastewater :	1,288m^3/M	(362.4m^2/M from outside)
Acid and alkali wastewater:	1,842m^3/M	(657.2m^3/M from outside)
(Total)	4,370m^3/M	(1,236.6m^3/M from outside)

In design, on 12 hour/day operation basis. the quantity of wastewater treated is cyanide wastewater 100m^3, chrome wastewater 100m^3, and acid and alkali wastewater 120m^3, 320m^3/day in total, but at present, in 8 hour/day (9:00-17:00) and 25m^3/day operation, average 180m^3/day is treated.

(3) Treatment system

The wastewater from each factory is classified into cyanide, chrome, and acid-alkali wastewater tanks.

The cyanide wastewater is conveyed from the cyanide wastewater tank through a water pump into a pH adjustment tank, where pH adjustment with sodium hydroxide is done, thence conveyed into the first reaction tank where the primary oxidation reaction with sodium hypochlorite takes place. Then, the wastewater is conveyed into the second reaction tank where pH adjustment with sulfuric acid is done, then secondary oxidation reaction with sodium hypochlorite takes place. In this process, cyanide is decomposed completely.

The chrome wastewater is conveyed from the chrome wastewater tank through a water pump into a pH adjustment tank, where pH adjustment with sulfuric acid is done, thence conveyed into the reduction tank where 6-valent chromium is reduced with sodium hydrogen sulfite to 3-valent.

The acid-alkali wastewater is conveyed, together with the treated cyanide wastewater and treated chrome wastewater, into the neutralizing tank, where pH adjustment with calcium hydroxide is done to precipitate heavy metals in the wastewater as hydroxides. Then, the wastewater is conveyed into the reaction tank where it is added with aluminum sulfate and calcium hydroxide to improve the coagulability, and flocs are formed with high molecular coagulants in the subsequent coagulation tank.

The mixed treatment water from the three systems mentioned above is conveyed into the sedimentation tank, where solid-liquid separation takes place. The supernatant liquor is conveyed into the pH adjustment tank, where pH adjustment is done, thence discharged through the water monitoring tank finally into the public sewerage system. Automatic control in this process is done with the use of pH meters and ORP meters.

If the treatment through the treatment processes mentioned above is insufficient and the treated water quality cannot meet the control standards, the treated water is returned to the wastewater tank for retreatment. If any complexed metal is detected, the treated water is additionally treated trough a filter tower packed with Anthracite, an activated carbon adsorption tank, a cation exchange resin tower, and a chalet resin tower before it is finally discharged.

On the other hand the sludge from solid-liquid separation is stored in the sludge storage tank, then dehydrated through a filter press, and the resulting dry cake is transported to an industrial waste treatment plant and finally disposed of.

(4) Conditions of reclamation

There is no plating factory where wastewater reclamation is done. Moreover, wastewater reclamation is not done in the joint wastewater treatment plants of Business Place No.1 and Business Place No.2.

On the other hand, most plating factories have no problems with the quality of water relating to the finished quality of plating, and seem to be contended with the present state of tap water supply. However, in the factories performing precious metal plating with gold or silver, ion exchange resin towers are installed in the factories to obtain deionized water by treating tap water.

1.3 Wastewater Sources

The production processes of the plating factories surveyed by visiting are shown below.

A. Factory No.1-3

a. Business content

Through-hole copper plating, electro copper plating, solder plating, etching of printed wiring boards used for Karaoke music devices

b. Factory area

$99m^2$ (refer to Fig.1.3.1.)

c. Working processes

Cleaning -- water washing -- surface etching treatment -- water washing -- pre-treatment -- water washing -- activa tion -- water washing -- chemical copper through-hole plat ing -- water washing -- drying -- (outside preparation of patterns) -- cleaning -- water washing -- pickling - elec tro copper plating -- water washing -- activation -- solder plating -- water washing -- etching -- resist stripping -- ink removing -- water washing -- drying

d. Conditions of water and wastewater

1) Water quantity and application
   Tap water: $6m^3$/day
   To feed washing water.
2) Conditions of wastewater generation
   Bath: Not discharged.
   Washing water: Effluent from multi-stage counter-current water washing is discharged during the work.
3) Contamination items: pH, COD, BOD, Cu, Zn, Cr6+, CN, F, P

e. Method of wastewater discharge

Washing water, including washing water for chemical plating, is discharged to the acid-alkali cleaning system.

B. Factory No.1-12

a. Business content

Coloring of gas mask parts and desk-top boards made of aluminum material

b. Factory area

$96m^2$ (refer to Fig.1.3.2.)

c. Working processes

Raking -- alkali cleaning -- water washing -- anodic oxidation -- water washing -- chemical polishing -- water washing -- neutralization -- water washing -- coloring -- sealing -- water washing -- drying

d. Conditions of water and wastewater

1) Water quantity and application

Tap water: $4m^3$/day

To make-up for washing water and bath

2) Conditions of wastewater generation

Bath: Effluents from alkali cleaning (200 1/week), anodic oxidation ($6m^3$/year, normally made-up for), coloring 200 1/week-10 days) and sealing (every day)

Washing water: Water spilled on the floor (tap water is supplied when it is bound necessary by visual inspection or by testing pH with a pH meter)

3) Contamination items: pH, COD, BOD, N, P

e. Method of wastewater discharge

Separate discharge: The bath is discharged after filtration, and the washing water is discharged directly.

C. Factory No.1-16

a. Business content

Copper plating, nickel plating, chrome plating of locks and bolts for aluminum sashes made of iron material.

b. Factory area

$182m^2$ (refer to Fig.1.3.3.)

c. Working processes

Alkali cleaning -- water washing -- sulfuric acid neutralization -- water washing -- copper cyanide plating -- water washing -- copper sulfate plating -- water washing -- non-bright nickel plating -- water washing --pickling -- water washing -- bright nickel plating -- water washing -- chrome plating or black chrome plating or black chromate -- water washing -- sodium hydroxide stripping

d. Conditions of water and wastewater

1) Water quantity and application
Tap water: $5m^3$/day
To make up for bath and washing water.

2) Conditions of wastewater generation
Bath: Not discharged.
Washing water: Discharged partly from renewal of water for batchwise water washing, and partly from counter-current water washing.

3) Contamination items: pH, COD, BOD, Cu, Ni, Cr^{6+}, CN, P

e. Method of wastewater discharge

Similarly to the method in Factory No.2-14, effluents from some washing tanks are used by other tanks by turns and if the effluent from any washing tank is judged to be renewed, it is discharged.

D. Factory No.1-20

a. Business content

Copper plating, nickel plating, brass plating of chandelier parts (for export) and support parts of microphones (for export to Japan) made of iron material.

b. Factory area

$231m^2$ (refer to Fig.1.3.4.)

c. Working processes

Electrocleaning -- water washing -- copper sulfate plating -- water washing -- copper stripping -- nickel sulfate plating -- water washing -- brass plating -- water washing -- chromate -- water washing -- lacquering/printing

d. Conditions of water and wastewater

1) Water quantity and application

Tap water: 4.5-5m^3/day

To make up for washing water and bath at the start of work.

2) Conditions of wastewater generation

Bath: Not discharged.

Washing water: Effluent from multi-stage counter-current water washing, and effluent from floor washing.

3) Contamination items: pH, COD, BOD, Cu, Ni, Zu, Cr6+, CN, F

e. Method of wastewater discharge

The effluent from the first washing tank is used for prepar ing bath similarly to Factory No.2-14, and effluents from other washing tanks are classified during the work to be discharged. Sediments (mainly zinc) of the bath are brought into S Co. Ltd. once or twice a year.

E. Factory No.1-22

a. Business content

Chemical copper plating of accessory parts made of plastic material.

b. Factory area

170m^2 (refer to Fig.1.3.5.)

c. Working processes

Chrome etching -- water washing -- nitric acid cleaning -- water washing -- alkali neutralization -- water washing -- chemical copper plating -- water washing -- elector copper plating -- water washing -- discoloration preventive treat ment -- dehydration

d. Conditions of water and wastewater

1) Water quantity and application

Tap: 7m^3/day

To make up washing water

2) Conditions of wastewater generation

Bath: Renewed as necessary, with the exception of chemical copper plating bath.

Washing water: Renewed once per day.

3) Contamination items: pH, COD, BOD, Cu, Cr6+, CN, N

e. Method of wastewater discharge

Separate discharge.

F. Factory No.1-23

a. Business content

Nickel plating -- gold or silver plating of frames and bands of clocks made of iron material.

b. Factory area

155m^2 (refer to Fig.1.3.6.)

c. Working processes

Dipping and electrocleaning -- water washing -- activation by hydrofluoric acid -- water washing -- nickel plating -- water washing -- gold or silver plating -- acid neutralization -- ultrasonic cleaning -- demineralized water washing -- oil washing drying-stripping liquid

d. Conditions of water and wastewater

1) Water quantity and application

Tap water: 4m^3/day

Tap water is purified by means of a demineralizer (cartridge filter + cation exchange resin + anion exchange resin) using ion exchange resins. To allow constant supply of washing water and to produce demineralized water.

2) Conditions of wastewater generation

Concentrated liquid: Wastewater from demineralizer regeneration is discharged once per month.

Washing water: Effluents from ion exchange resin treatment of washing water (counter-current 3-stage) for precious metals, and other washing water (counter-current 3-stage) are discharged during the work.

3) Contamination items: pH, COD, BOD, Ni, Cu, CN

e. Method of wastewater discharge

Washing water of acid-alkali cleaning and washing water of cyanide cleaning are discharged separately through pipings in the workshop.

G. Factory No.1-26

a. Business content

Copper plating, nickel or black nickel plating, brass plating, gold or silver plating of buttons made of ABS and polyester material.

b. Factory area

$132m^2$ (refer to Fig.1.3.7.)

c. Working processes

Chrome etching -- water washing -- pickling -- water washing -- alkali neutralization -- water washing -- chemical nickel plating -- water washing -- non-bright or bright nickel or black nickel plating -- water washing -- gold or silver plating -- water washing -- gold stripping

d. Conditions of water and wastewater

1) *Water quantity and application*

Tap water: $7m^3$/day

To make up for washing water twice or thrice per day.

2) Conditions of wastewater generation

Bath: Discharged when the chemical nickel plating bath is renewed.

Washing water: Batchwise discharge of drainage from multi-stage counter-current water washing in the morning or afternoon (the recovery tank is used for preparing the bath), and effluent from ion exchange resin treatment of gold plating 2-stage counter-current washing water.

3) Contamination items: pH, COD, BOD, Ni, Cu, Zn, Cr^{6+}, CN, N, P

e. Method of wastewater discharge

Gold plating bath is treated outside (100 1/M; gold is recovered). Chemical nickel plating bath and nickel plating bath are discharged to the acid-cleaning system, and washing water is discharged separately.

H. Factory No.2-13

a. Copper plating, nickel plating , chrome or black chrome plating of fishing tools (rods, reels) made of iron material

b. Factory area

$220m^3$ (refer to Fig.1.3.8.)

c. Working processes

Barrel polishing -- water washing -- electrocleaning -- water washing -- copper cyanide plating -- water washing -- copper sulfate plating -- water washing -- nickel plating -- water washing -- chrome plating or black chrome plating -- water washing -- drying

d. Conditions of water and wastewater

1) Water quantity and application

Tap water: 6-$7m^3$/day

To make up for bath once in 4M and for washing water every day.

2) Conditions of wastewater generation

Bath: Not discharged

Washing water: Discharged when the washing water is renewed for the batchwise water washing using plastic buckets in several steps.

3) Contamination items: pH, COD, BOD, Cu, Ni, Cr6+, CN, P

e. Method of wastewater discharge

Washing water is discharged at the end of day's work.

I. Factory No.2-14

a. Business content

Zinc plating, chrome plating, black chrome plating or black chromate of tent parts, fixed parts of automobile engines and electric parts made of iron material.

b. Factory area

$116m^2$ (refer to Fig.1.3.9.)

c. Working processes

Cleaning -- water washing -- pickling -- water washing -- copper cyanide barrel plating -- water washing -- copper sulfate plating -- water washing -- nickel plating -- water washing -- chrome plating or black chrome plating or black chromate -- water washing

d. Conditions of water and wastewater

1) Water quantity and application

Tap water: $5m^3$/day

To make-up for washing water

To make-up for washing water.

2) Conditions of wastewater generation

Bath: Not discharged because bath is used repeatedly after sodium sulfide is added once in 1M and resulting metal deposit is filtered out. However, the sludge flows on the floor surface of the workshop into the joint wastewater treatment plant.

Washing water: Discharged when the washing water is renewed for the batch wise water washing using plastic buckets in several steps.

3) Contamination items: pH, COD, BOD, Cu, Ni, Cr6+

e. Method of wastewater discharge

The effluent from the first washing tank in the multistage washing system is used for preparing the bath, and the effluent from the second washing tank is discharged into the joint wastewater treatment plant. The effluent from the third washing tank is conveyed to the second washing tank where it is reused. For the third tank, new water is used as make-up water, or relatively dilute wastewater from other tank is reused.

J. Factory No.3-1

a. Business content

Parkarizing (zinc) of fiber bobbins

b. Factory area

198m^2 (refer to Fig.1.3.10.)

c. Working processes (semi-automatic)

Alkali cleaning -- water washing -- pickling -- water washing -- dipping -- water washing -- rust preventives/cutting oil -- vegetable oil dipping -- drying

d. Conditions of water and wastewater

1) Water quantity and application

Tap water: 100m^3/day

To make up for washing water and bath at the start of work.

2) Conditions of wastewater generation

Bath: Not discharged.

Washing water: Discharged from 1-stage or 2-stage counter-current washing.

3) Contamination items: pH, COD, BOD, Zn, Mn, n-hexane

e. Method of wastewater discharge

Washing water is discharged into the acid-alkali system during the work.

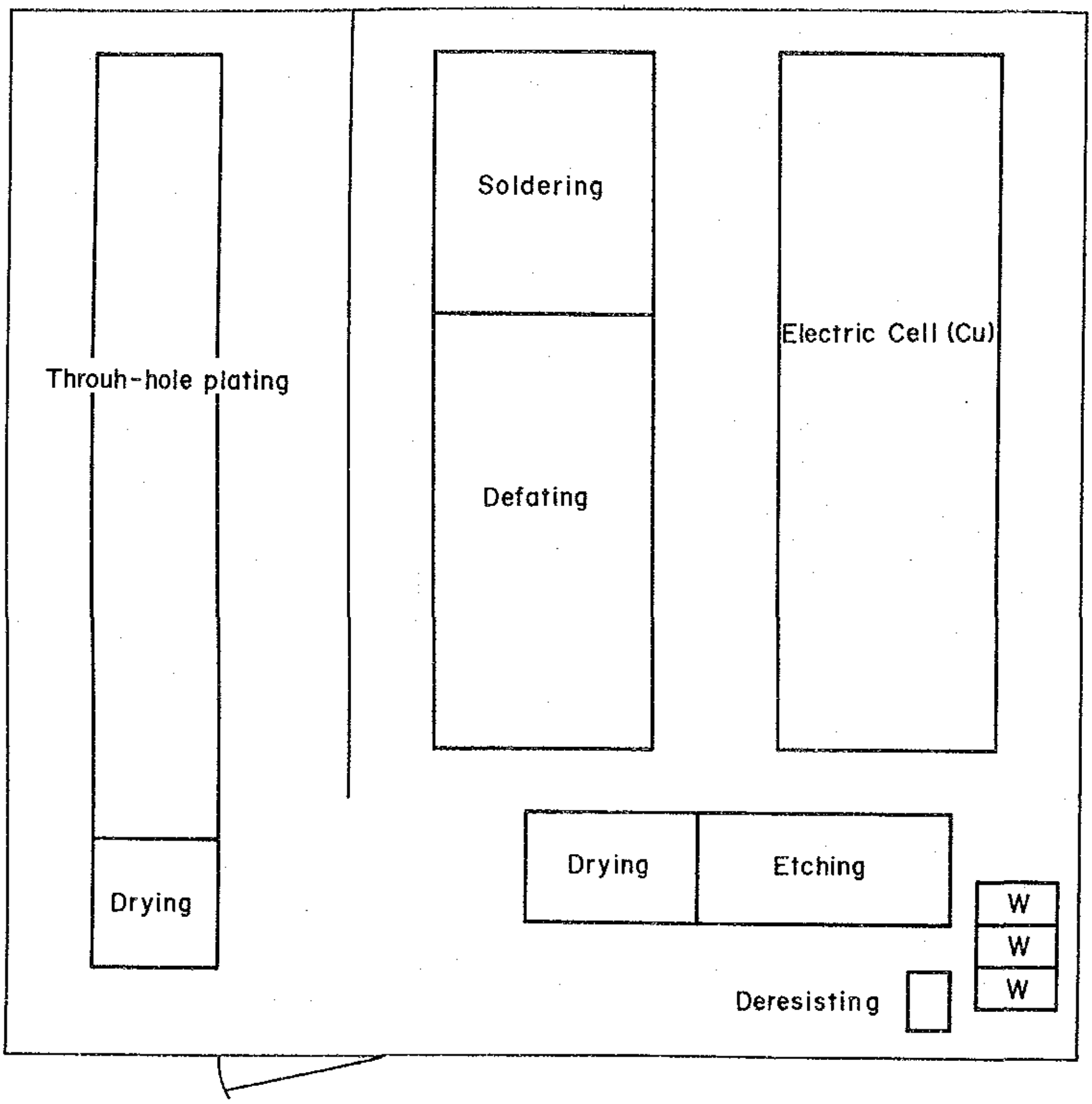


Fig. 1.3.1. The Arrangement of Factory No. 1-3

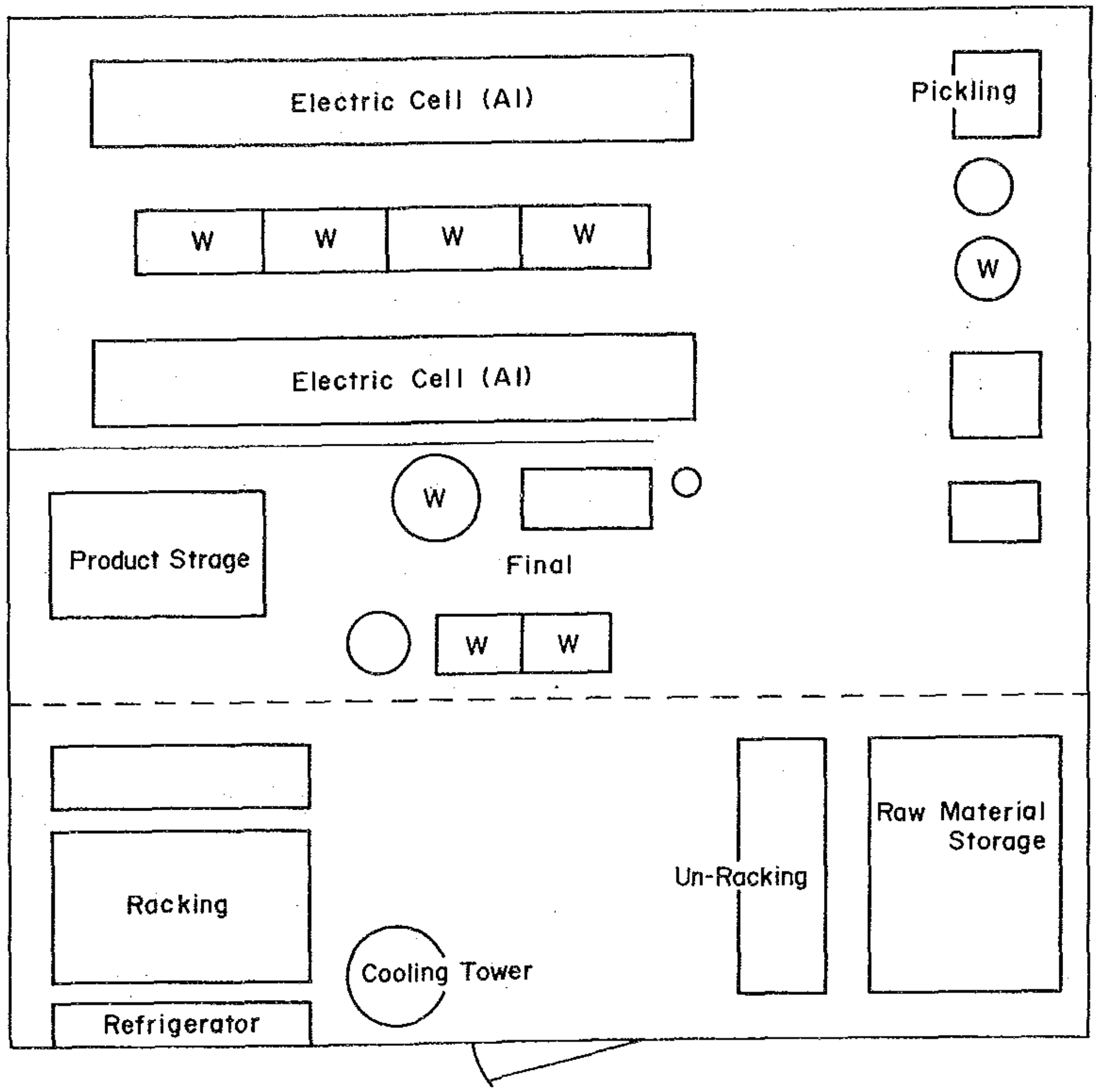


Fig. 1.3.2. The Arrangement of Factory No.1-12

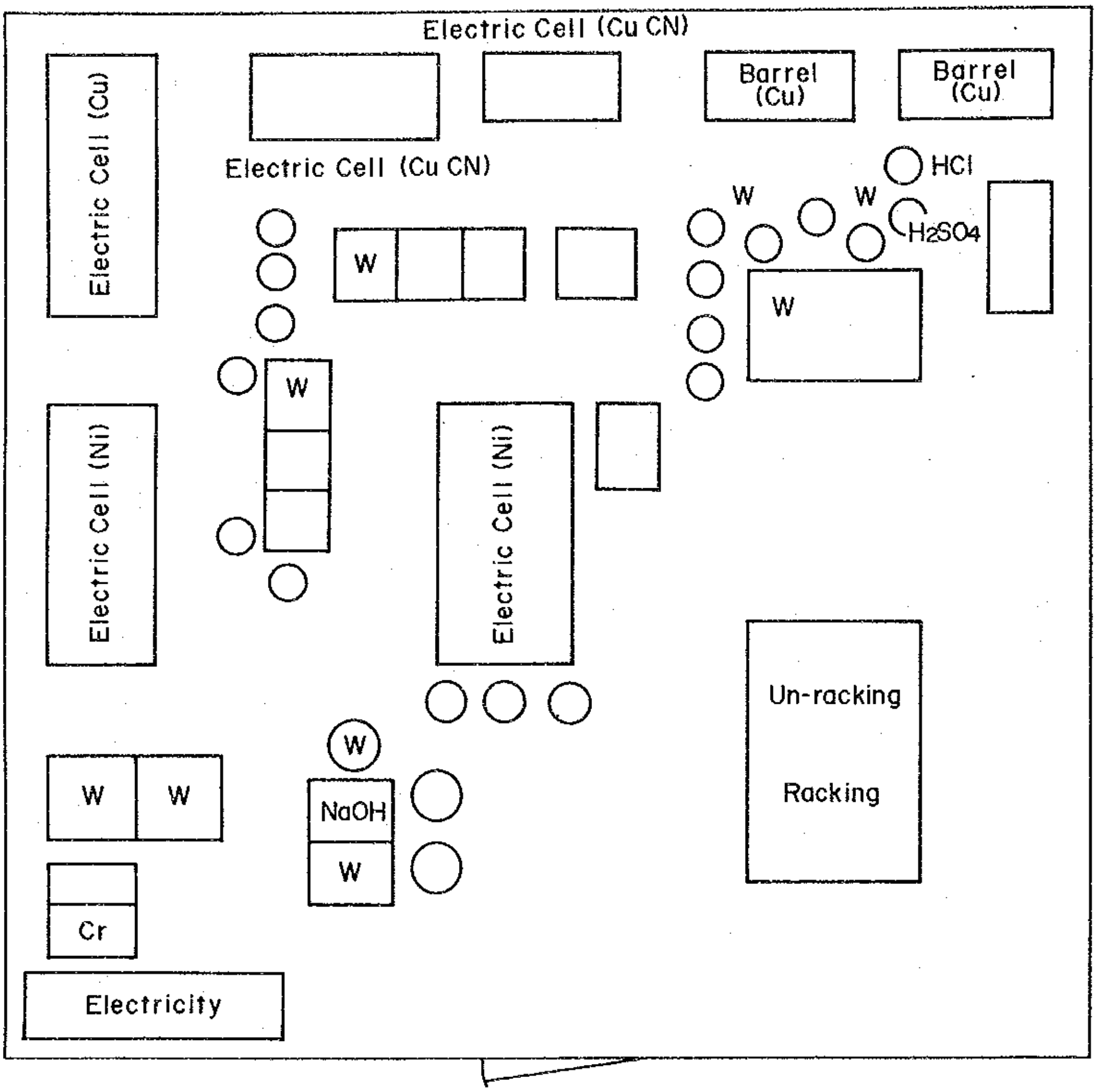


Fig. 1.3.3. The Arrangement of Factory No.1-16

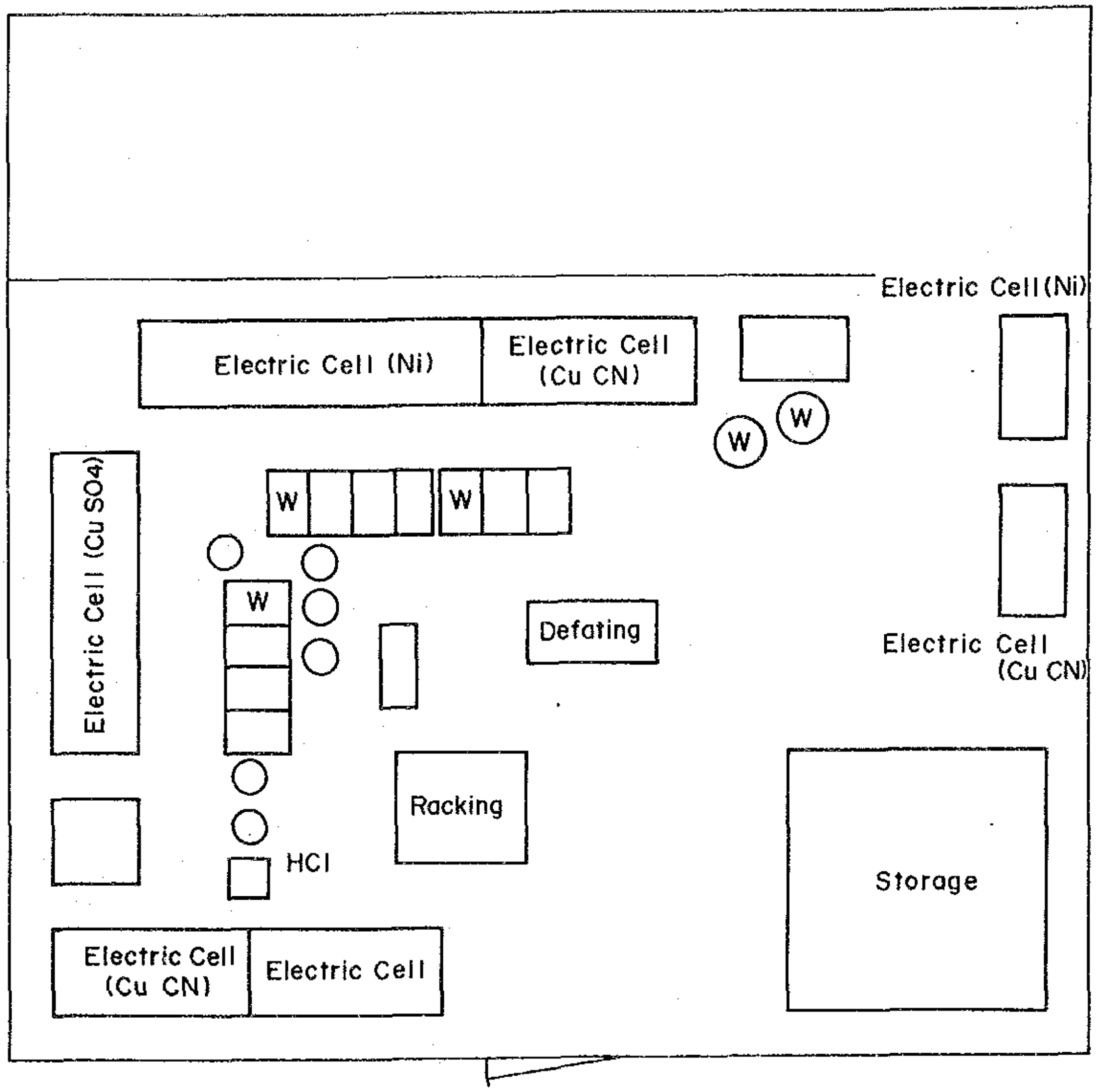


Fig. 1.3.4. The Arrangement of Factory No.1-20

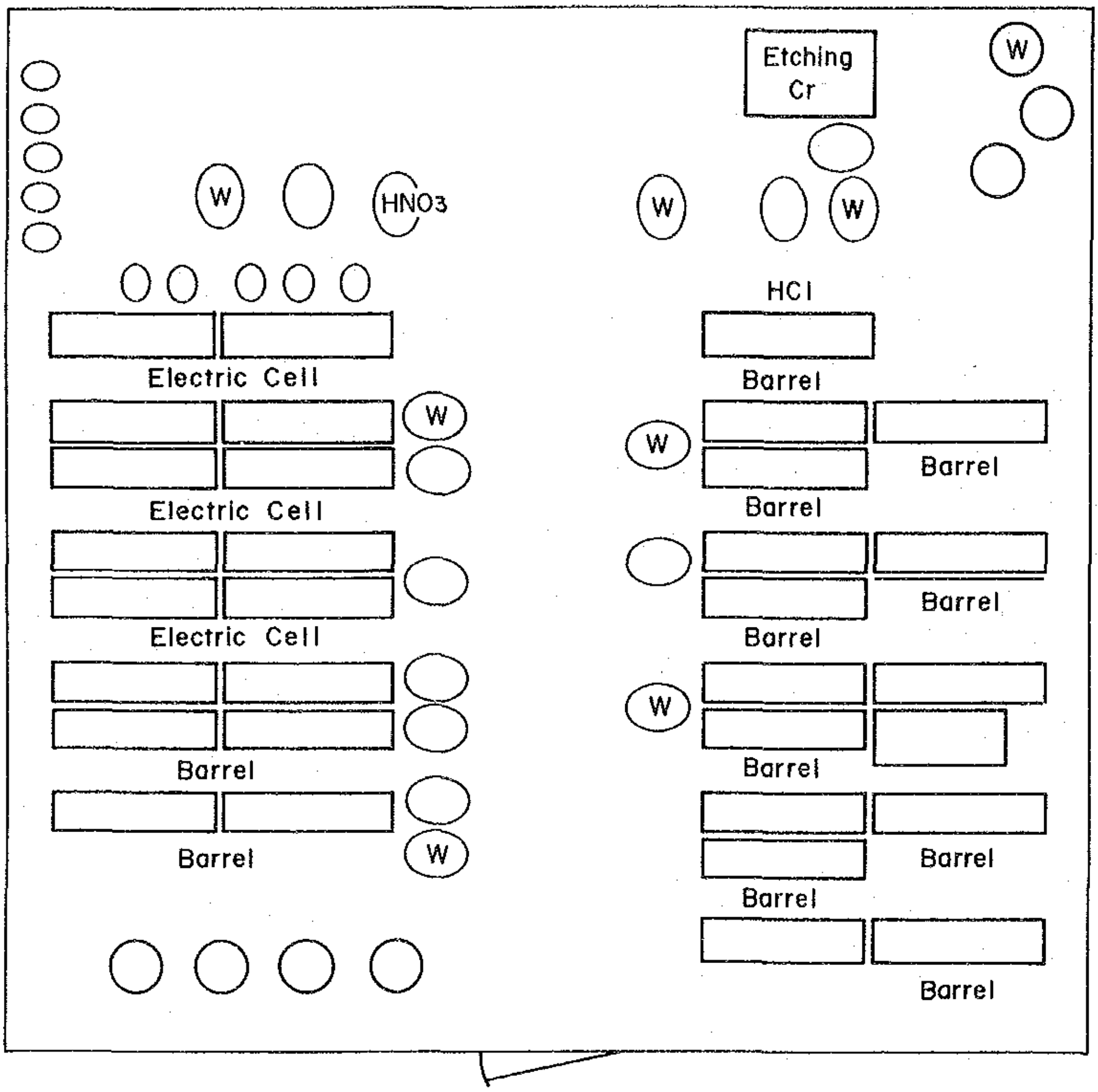


Fig. 1.3.5. The Arrangement of Factory No.1-22

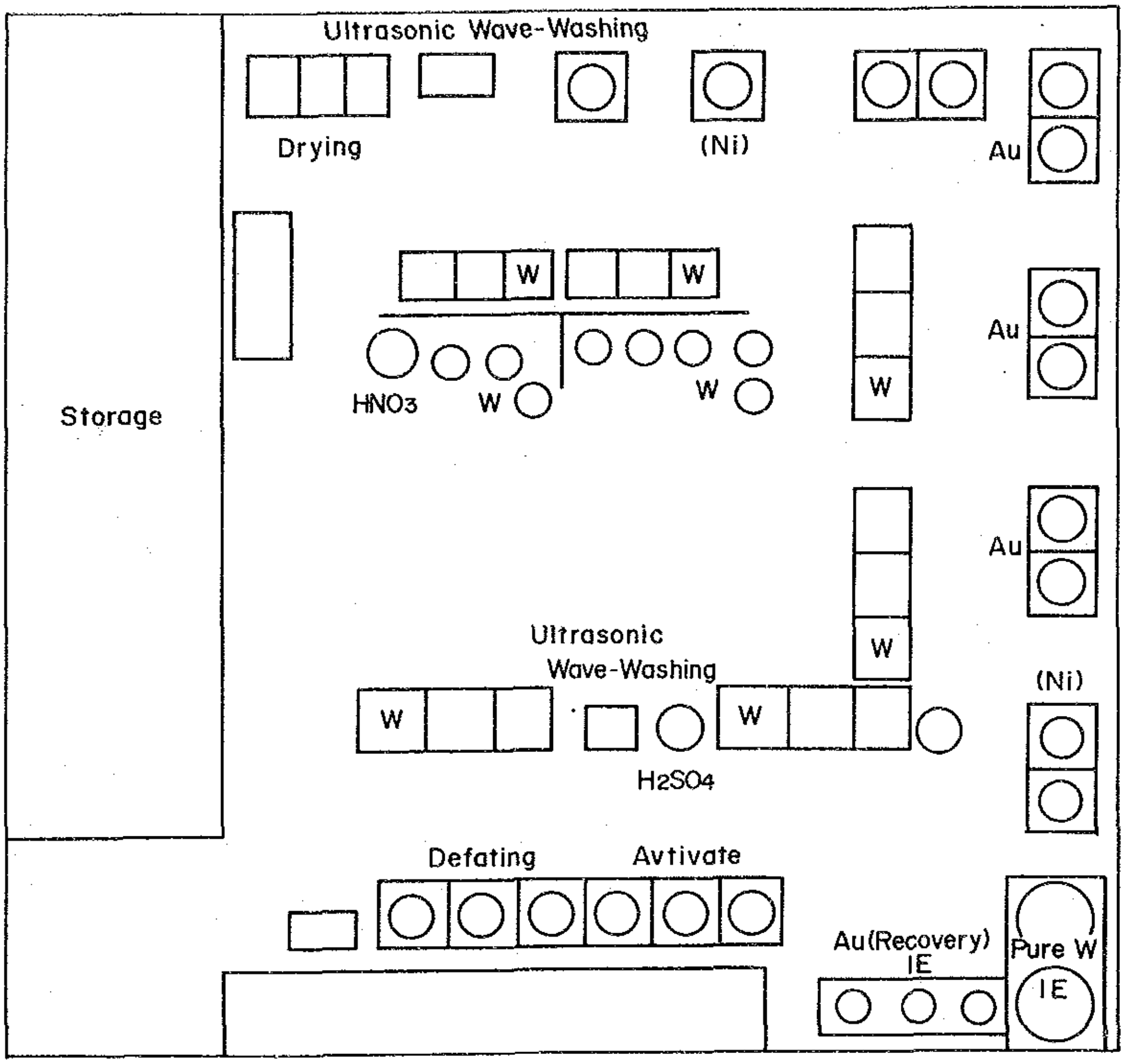


Fig. 1.3.6. The Arrangement of Factory No.1-23

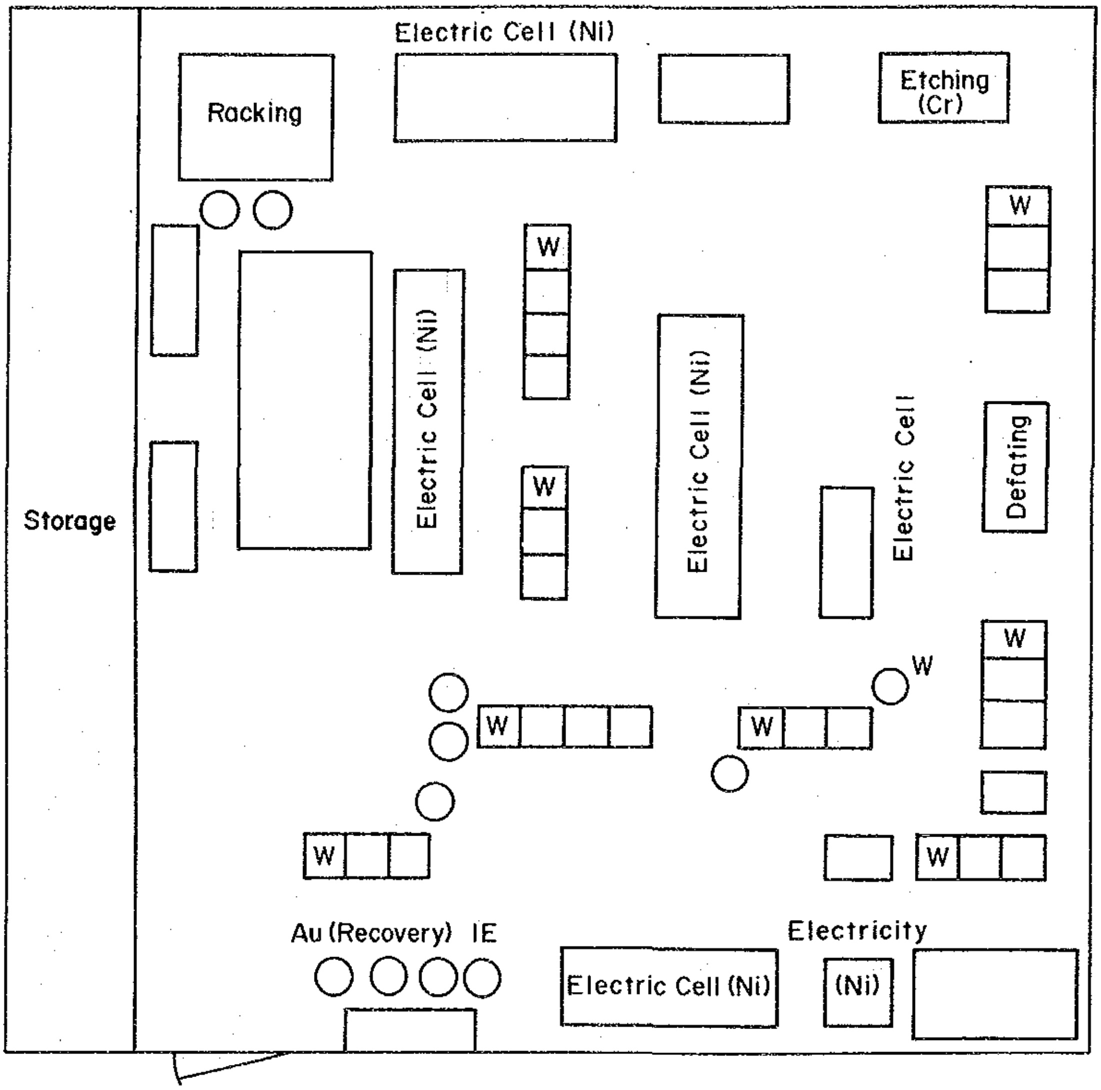


Fig. 1.3.7. The Arrangement of Factory No.1-26

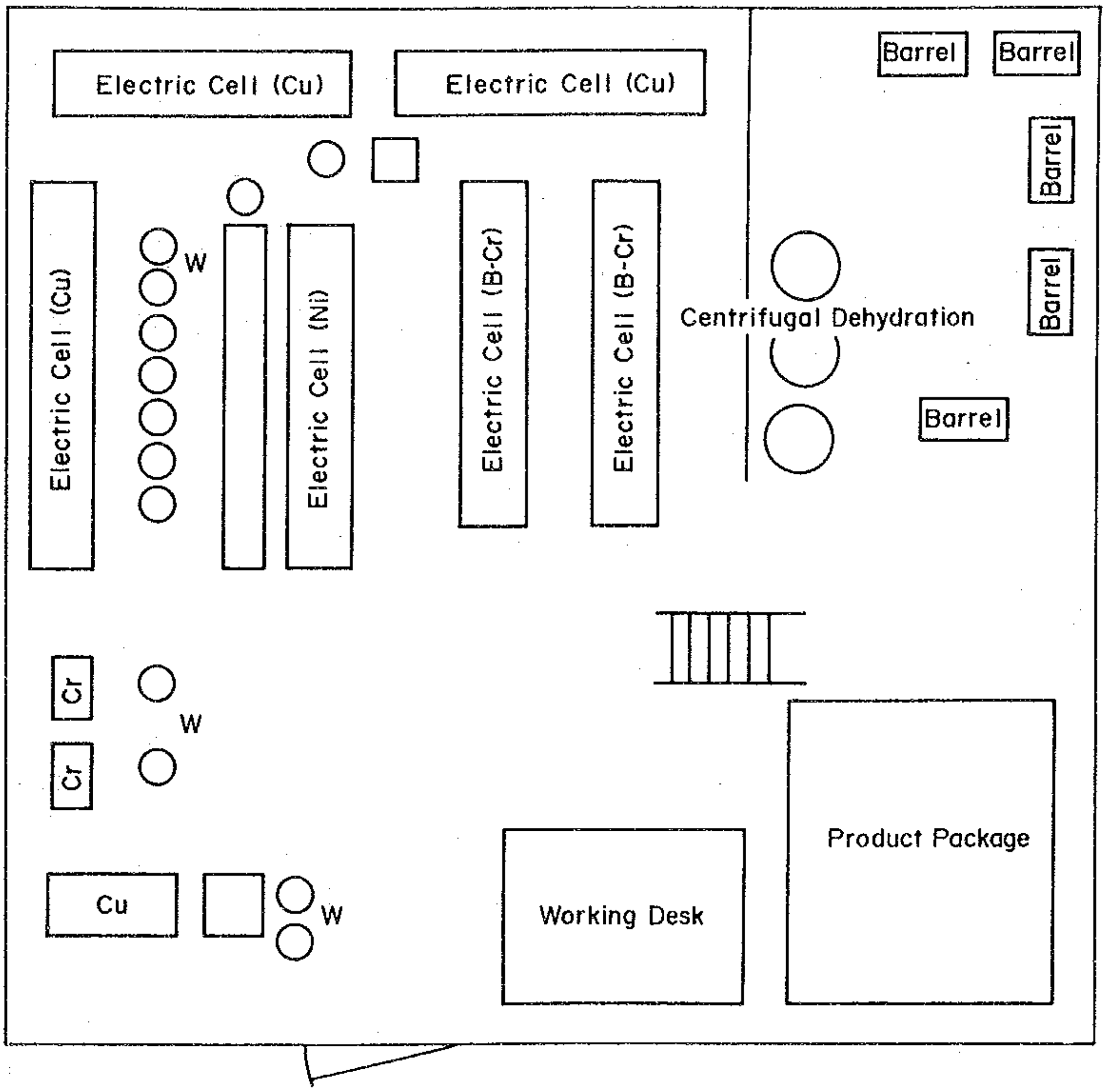


Fig. 1.3.8. The Arrangement of Factory No.2-13

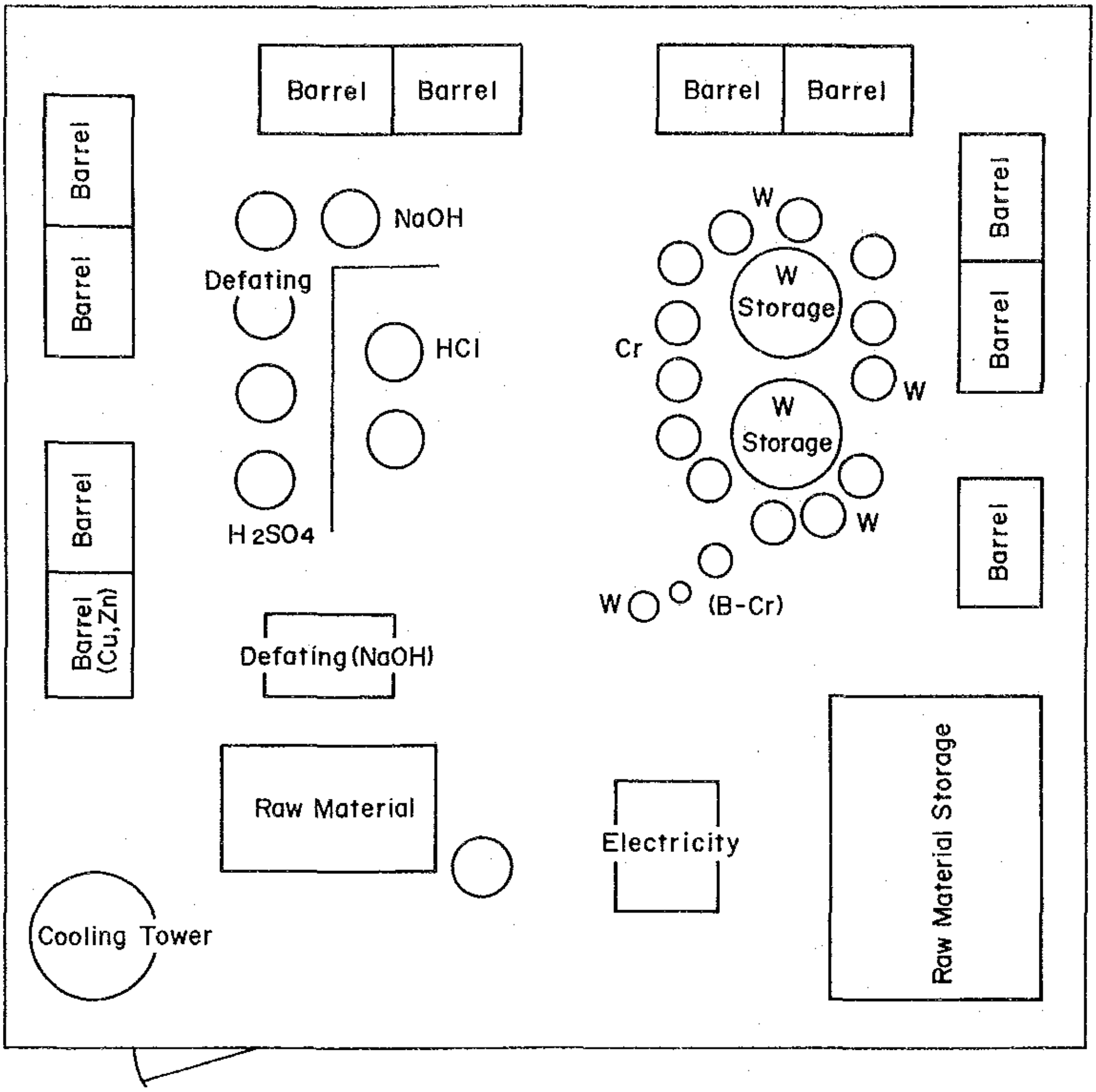


Fig. 1.3.9. The Arrangement of Factory No. 2-14

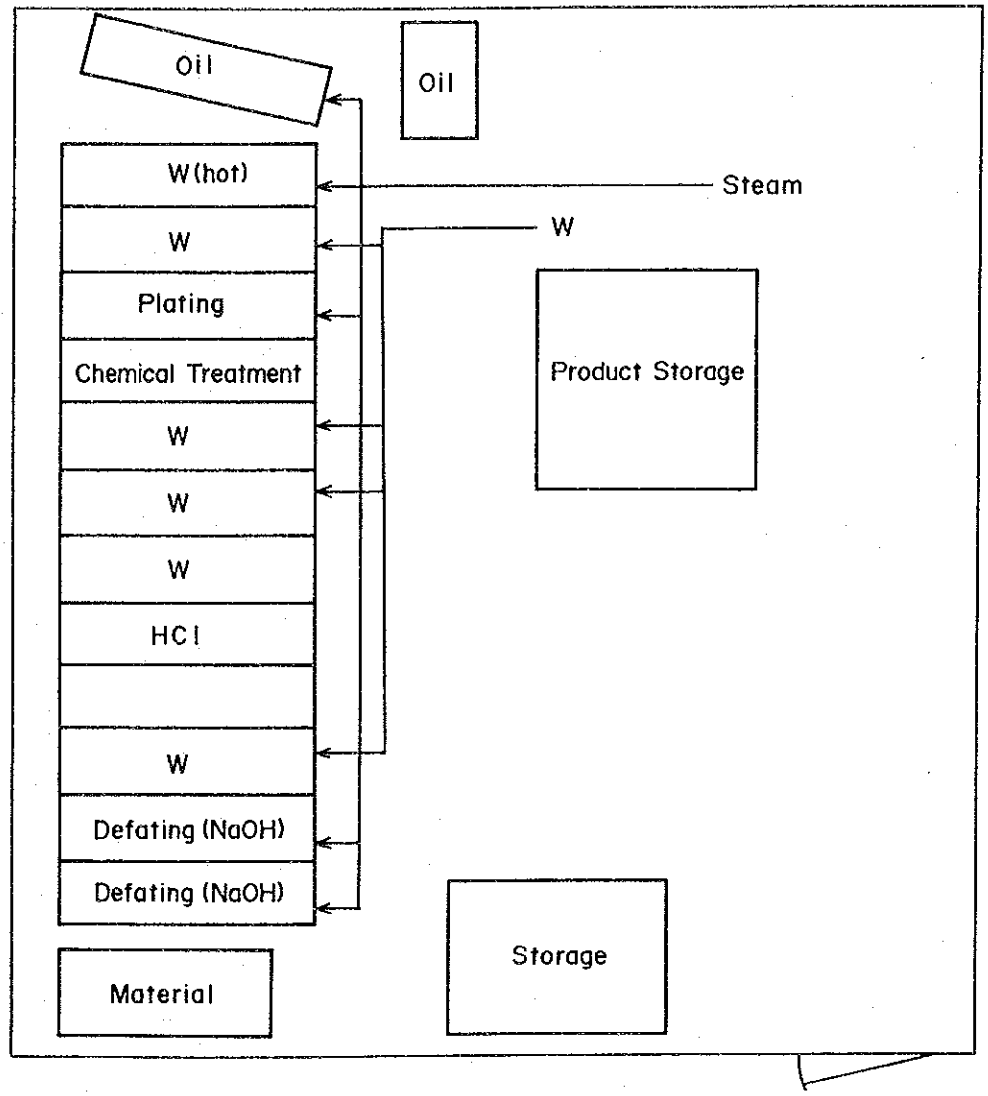


Fig. 1.3.10. The Arrangement of Factory No. 3-1

1.4 Service Water and Wastewater Systems

(1) Water systems

Water which is used in the plating industry estate is supplied by the tap water supply system in any of the 1st Estate Section, the 2nd Estate Section and the 3rd Estate Section.

Roughly speaking, tap water is used as (1) water for production use and (2) water for domestic use.

Water for production use is classified as (1) production water in each plating factory and (2) water in the central wastewater treatment plant. Water for domestic use is classified as (1) water for cooking, (2) water for flush toilet and (3) water for laundry.

Water used in each plating factory is used for (1) preparation of bath, (2) washing, (3) washing of floors, (4) cooling, etc. In addition, it is used also as recycled water in the central gas scrubber tower, which purifies the flue gas discharged from the hood inside the room. This tower is installed as a measure for improving the working environment in the factory.

Water used in the central wastewater treatment plant is used for (1) dissolving of chemicals, (2) washing of the dehydrator, (3) backwashing of the filter tower, (4) regeneration of ion exchange resins, (5) washing of other equipment, (6) washing of floors, etc.

Water for cooking is used in the 1st Estate Section. Water for flush toilet and water for laundry are used in both the 1st Estate Section, the 2nd Estate Section and the 3rd Estate Section.

(2) Wastewater systems

Wastewaters from production processes are classified and discharged from each factory and are received in the cyanide wastewater tank, the chrome wastewater tank, and the acid-alkali wastewater tank of the central wastewater treatment plant installed in the estate section. The conditions of discharge are as follows. Floor spilled water is discharged at all times. Washing water is discharged at all times or once a day. Bath liquor is discharged at a frequency of once or more in a year. Further, recycled water in the central gas scrubber tower is discharged. The wastewater quantity is equal to the quantity of water used for production use less a high concentration wastewater to be treated by entrusting outside, an evaporated quantity of hot bath liquor and cooling water, and an evaporation in the gas scrubber. On the other hand, in the central wastewater treatment plant, wastewaters transported from plating factories located outside the plating industrial estate are also received and treated. For this reason, the quantity of effluent from the wastewater treatment plant surpasses that from production processes. The treated wastewater is finally discharged into the public sewerage system.

The domestic wastewater is classified as nightsoil and miscellaneous wastewater. The former is treated in the sceptic tank usually by anaerobic treatment and the wastewater is combined with the latter to be discharged into the public sewage system.

1.5 Condition of Wastewater Treatment and Reclamation Plants

Among the three estate sections of the plating industrial estate being run by S Co., Ltd., the 1st Estate Section and the 2nd Estate Section have the wastewater treatment plant.

Reclamation plants are not installed in any of the estate section.

The wastewater treatment plant installed in the 1st Estate Section and the 2nd Estate Section are approximately equal to each other in (1) wastewater treatment system, (2) plant construction and scale, (3) unit apparatus installed in the treatment plant, (4) method of operation, (5) number of personnel involved in the operation, etc., and therefore, the wastewater treatment plant of the 2nd Estate Section only will be selected and its conditions be described.

(1) Flow sheet and layout of the wastewater treatment plant

Fig.1.5.1. and Fig.1.5.2. show the flow sheet and the layout of the wastewater treatment plant, respectively.

In the wastewater treatment plant are installed (1) cyanide wastewater tank, (2) chrome wastewater tank and (3) acid-alkali wastewater tank. Wastewaters discharged as classified as (1) cyanide wastewater, (2) chrome wastewater and (3) acid-alkali wastewater from each factory are received in these tanks on a gravity flow-down basis.

On the other hand, wastewaters transported by tank lorry from plating factories located outside the plating industrial estate, also as classified as (1) cyanide wastewater, (2) chrome wastewater and (3) acid-alkali wastewater, are received in (1) cyanide wastewater tank, (2) chrome wastewater and (3) acid-alkali wastewater tank.

The wastewater received in the cyanide wastewater tank is conveyed through a water pump to the cyanide-pH adjustment tank. In this tank, a pH meter is provided, and in order to adjust wastewater pH nearly to 10.5, a chemical feed pump is operated jointly with the pH meter for feeding a sodium hydroxide solution. As pH is adjusted, the wastewater flows by gravity into the primary oxidation tank. In this tank, a pH meter and an ORP meter are provided, and chemical feed pumps are operated jointly with them for feeding a sodium hypochlorite solution and a sodium hydroxide solution, respectively to control pH to 10.5 and ORP to 300 mV. Here, the primary oxidation reaction of cyanide is completed.

$$NaCN + NaOCl \text{ -- } NaCNO + NaCl \qquad \text{----- (1)}$$

Then, the wastewater flows by gravity into the secondary oxidation tank. In this tank, a pH meter and an ORP meter are provided, and chemical feed pumps are operated jointly with them for adding sulfuric acid and sodium hypochlorite, respectively to control pH to 7 and ORP to 600 mV. Here, the secondary oxidation reaction is completed.

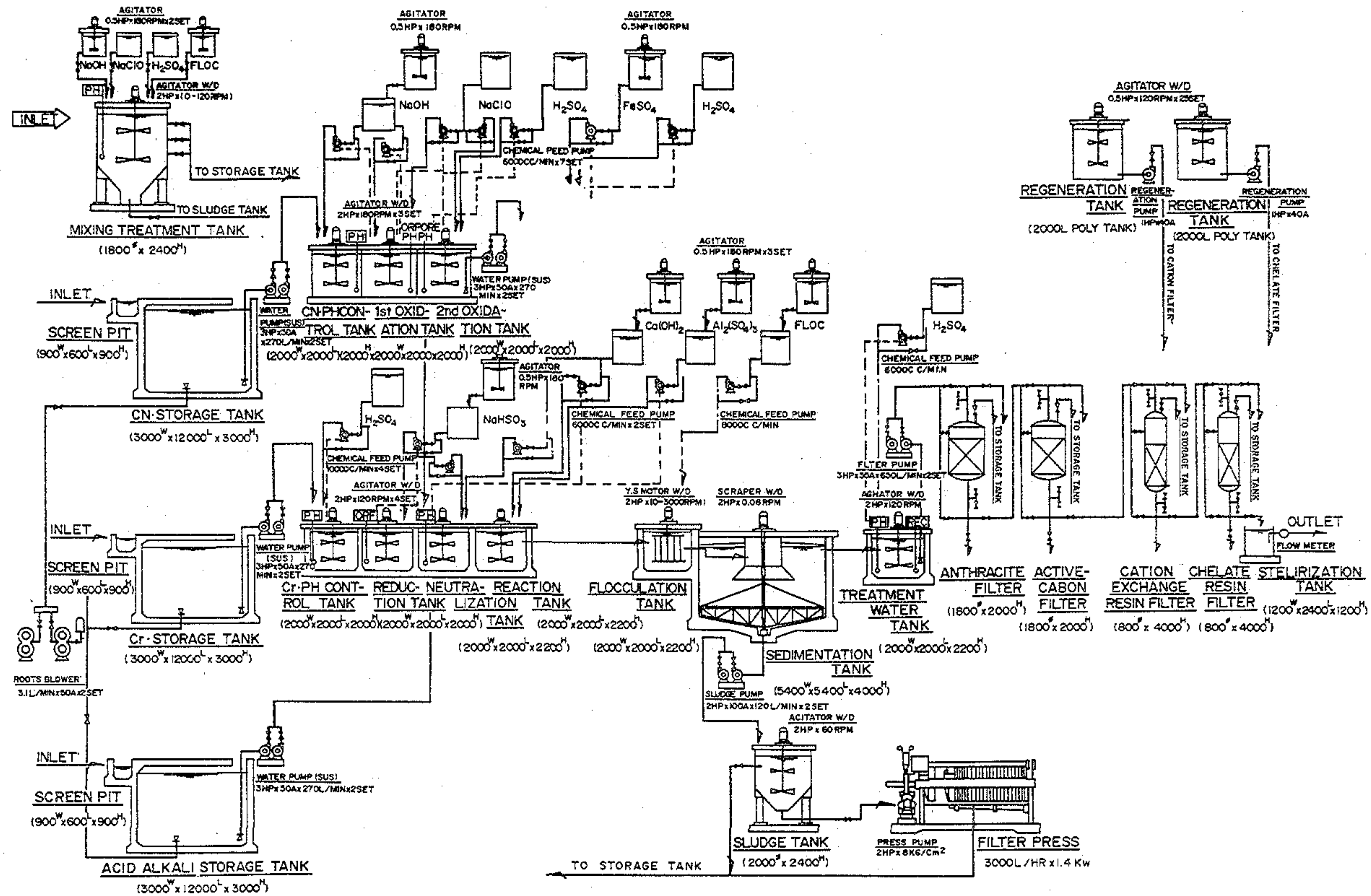


Fig. 1.5.1. Flow Sheet of Central Waste Water Treatment Plant (Metal Plating, 2nd Estate)

NO.	NEME	SIZE	NO	NEME	SIZE
1	CN SCREEN PIT	600 x 800 x 1800	13	SEDMENTATION TANK	5600 x 5600 x 4000
2	Cr SCREEN PIT	600 x 800 x 1800	14	TREATMENT WATER TANK	2800 x 2800 x 2800
3	ACID ALKALI SCREEN PIT	600 x 800 x 1800	15	ANTHRACITE FILTER	2000 x 2400
4	SCREEN PIT(STANDBY)	600 x 800 x 1800	16	ACTIVE CARBON FILTER	2000 x 2400
5	CN PH CONTROL TANK	2000 x 2000 x 2000	17	CHELATE RESIN FILTER	800 x 4600 x 2SET
6	1st OXIDATION TANK	2000 x 2000 x 2000	18	EFFLUENT TANK	900 x 900 x 900
7	2nd OXIDATION TANK	2000 x 2000 x 2000	19	MACHINE ROOM	5600 x 1600 x 1600
8	Cr PH CONTROL TANK	2800 x 2800 x 2800	20	SLUDGE TANK	2000 x 2400
9	REDUCTION TANK	2800 x 2800 x 2800	21	FILTER PRESS	3000L/HR x 2SET
10	NEUTRAUZATION TANK	2800 x 2800 x 2800	22	MIXING TREATMENT TANK	1600 x 3200
11	REACTION TANK	2800 x 2800 x 2800	23	REGENERATION TANK	2000L x 2SET
12	FLOCCULATION TANK	2800 x 2800 x 2800			

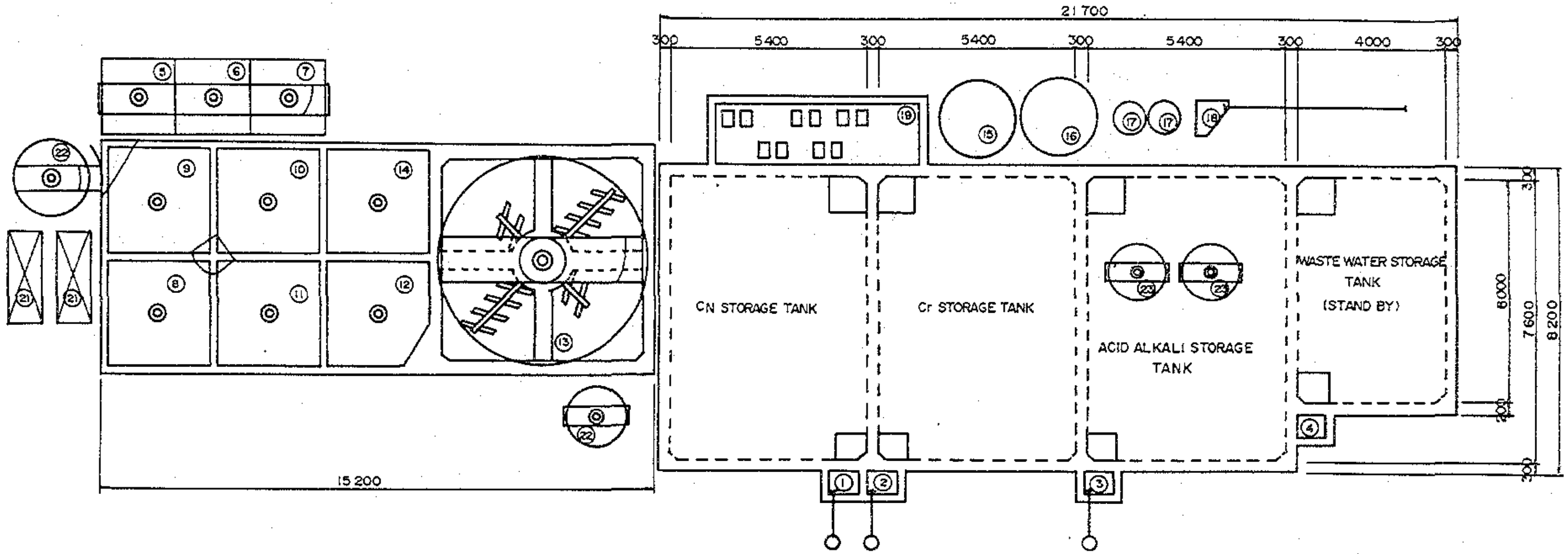


Fig. 1.5.2. Lay Out of Central Waste Water Treatment Plant (Metal Plating, 2nd Estate)

$2NaCNO + 3NaOCl + H_2O \rightarrow N_2 + 3NaCl + 2NaHCO_3$ ----- (2)

On the other hand, the wastewater received in the chrome wastewater tank is conveyed through a water pump into the chrome-pH adjustment tank. In this tank, a pH meter is installed, and in order to adjust wastewater pH to 3.5, a chemical feed pump is operated jointly with the pH meter for feeding sulfuric acid. As pH is adjusted, the wastewater flows by gravity into the reducing tank. In this tank, an ORP meter is provided, and a chemical feed pump is operated jointly with the ORP meter for feeding a sodium hydrogen sulfite to control ORP to 650 mV. The reducing reaction to convert 6-valent chromium to 3- valent is completed.

$4H_2CrO_4 + 6NaHSO_3 + 3H_2SO_4 \rightarrow 2Cr_2(SO_4)_3 + 3Na_2SO_4 + 10H_2O$ -- (3)

The chrome wastewater after completion of the reducing reaction flows by gravity into the neutralization tank. In this tank, it is mixed with the cyanide wastewater conveyed through a pump and the acid-alkali wastewater conveyed through a water pump from the acid-alkali wastewater tank. In the neutralization tank, a pH meter is provided, and in order to adjust mixed waste-water pH to 9.5, a chemical feed pump is operated jointly with the pH meter for feeding a sulfuric acid solution or calcium hydroxide solution. Here, heavy metals in the wastewater are precipitated as hydroxides, some of phosphate ions as calcium phosphate, and fluorine ions as calcium fluoride. Further, a part of organic substances in the wastewater, such as oil, are simultaneously coagulated and separated.

$Me^{n+} + nOH^- \rightarrow Me(OH)_n$ ----- (4)

$PO_4^{2-} + Ca^{2+} \rightarrow CaPO_4$ ----- (5)

$2F^- + Ca^{2+} \rightarrow CaF_2$ ----- (6)

The effluent from neutralization flows by gravity into the following reaction tank. In this tank, an aluminum sulfate solution and a calcium hydroxide solution are fed at metered rates to improve the coagulability, as well as to precipitate remaining phosphate ions as aluminum phosphate.

$3PO_4 + 2Al^{3+} \rightarrow Al_2(PO_4)_3$ ----- (7)

The wastewater treated by coagulation in the reaction tank flows by gravity into the following flocculation tank where a high polymer coagulant is fed to grow flocs.

The wastewater with grown flocs is conveyed into the following sedimentation tank where flocs are settled on the bottom, while the separated supernatant flows over tank into the following treated water tank.

In the treated water tank, a pH meter is provided, and in order to adjust treated water pH to within the range of standard discharge limits, a chemical feed pump is operated jointly with the pH meter for feeding sulfuric acid.

If the treated water quality satisfies the standard discharge limits, normally that the treated water is finally discharged through the water monitoring tank directly. On the other hand, if the treated water quality does not satisfy but can be treated by proceeding with unit operations so far described, the treated water is returned through a filter pump into each receiving tank where it is treated again before being finally discharged.

The wastewater after pH adjustment is conveyed under pressure through a filter pump into a rapid filter tower. The rapid filter tower is packed with Anthracite to remove remaining suspended solids. This is installed as a pre-treatment for the following process.

The filtered water is conveyed under pressure directly to the following activated carbon adsorption tower, Here, organic substances such as COD, BOD, etc, remaining in the treated water are removed through adsorption.

The treated water from activated carbon adsorption tower is conveyed under pressure directly to the following cation exchange resin tower. Here, traces of heavy metals remaining in the treated water are removed.

The treated water from the cation exchange resin tower is conveyed under pressure directly to the following chelate resin tower. Here, traces of chelated heavy metals remaining in the treated water are removed.

The treated water having passed the treatment processes mentioned above is finally discharged through the following water monitoring tank.

On the other hand, the sludge settled in the sedimentation tank is collected toward the center by means of the rake provided on the bottom of the tank and is then discharged through a sludge discharge pump into the sludge storage tank.

The thickened sludge stored in the sludge storage tank is dehydrated by means of a filter press. The dehydrated cake is stored in the bunker, thence transported by car to the waste disposition plant. The supernatant and the laundry wastewater are returned to the receiving tank where they are treated together with the received wastewater.

The backwashing wastewater from the rapid filter tower, the backwashing wastewater from the activated carbon adsorption tower, the wastewater from ion exchange resin regeneration, and the wastewater from chelate resin regeneration are returned to the respective receiving tanks where they are treated together with the received wastewater.

(2) Specifications of major apparatus

Table 1.5.1. shows the major apparatus in the central wastewater treatment plant installed in the 2nd Estate Section.

The wastewater treatment plant was constructed in 1987 by S Co., Ltd. itself with a construction cost of 469,315,000 wons (financed amount 439,000,000 wons, depreciation period 7 years, with no subsidy and no levy). In 1990, a chelate resin tower was added by a Japanese enterprise.

(3) Conditions of operation and maintenance

Six employees of S Co., Ltd. are engaged in the operation of the central wastewater treatment plant. One of them is an engineer and others are technicians (workers). The operating time is 8 hours per day corresponding to the operating time of each factory.

A. Receiving of wastewaters

According to the hearing at the central wastewater treatment

Table 1.5.1. Specification of Equipment in Central Wastewater Treatment Plant (The 2nd Estate Section)

No.	NAME	Q'TY	SPECIFICATION
1	CN STORAGE TANK	1	$3,000^{W} \times 12,000^{L} \times 3,000^{H}$
	SCREEN PIT	1	$900^{W} \times 600^{L} \times 900^{H}$
	PUMP	2	3HP × 50A × 270l/m
2	Cr STORAGE TANK	1	$3,000^{W} \times 12,000^{L} \times 3,000^{H}$
	SCREEN PIT	1	$900^{W} \times 600^{L} \times 900^{H}$
	PUMP	2	3HP × 50A × 270l/m
3	ACID ALKALI STORAGE TANK	1	$3,000^{W} \times 12,000^{L} \times 3,000^{H}$
	SCREEN PIT	1	$900^{W} \times 600^{L} \times 900^{H}$
	PUMP	2	3HP × 50A × 270l/m
4	CN·pH CONTROL TANK	1	$2,000^{W} \times 2,000^{L} \times 2,000^{H}$
	AGITATER	1	2HP × 120RPM
	pH CONTROLLER	1	
5	1st OXIDATION TANK	1	$2,000^{W} \times 2,000^{L} \times 2,000^{H}$
	AGITATER	1	2HP × 120RPM
	pH CONTROLLER	1	
	ORP CONTROLLER	1	
6	2nd OXIDATION TANK	1	$2,000^{W} \times 2,000^{L} \times 2,000^{H}$
	AGITATER	1	2HP × 120RPM
	pH CONTROLLER	1	
	ORP CONTROLLER	1	
7	Cr·pH CONTROL TANK	1	$2,000^{W} \times 2,000^{L} \times 2,000^{H}$
	AGITATER	1	2HP × 120RPM
	pH CONTROLLER	1	
8	REDUCTION TANK	1	$2,000^{W} \times 2,000^{L} \times 2,000^{H}$
	AGITATER	1	2HP × 120RPM
	ORP CONTROLLER	1	
9	NEUTRALIZATION TANK	1	$2,000^{W} \times 2,000^{L} \times 2,200^{H}$

Table 1.5.1. Specification of Equipment in Central Wastewater Treatment Plant (The 2nd Estate Section) (continued)

No.	NAME	Q'TY	SPECIFICATION
	AGITATER	1	2HP × 120RPM
	pH CONTROLLER	1	
10	REACTION TANK	1	$2,000^W \times 2,000^L \times 2,200^H$
	AGITATER	1	2HP × 120RPM
11	FLOCCULATION TANK	1	$2,000^W \times 2,000^L \times 2,200^H$
	AGITATER	1	2HP × 0-300RPM
12	SEDIMENTATION TANK	1	$5,400^W \times 5,400^L \times 4,000^H$
	PUMP	2	2HP × 100A × 120l/m
13	TREATMENT WATER TANK	1	$2,000^W \times 2,000^L \times 2,200^H$
	AGITATER	1	2HP × 120RPM
	pH CONTROLLER	1	
	PUMP	2	5HP × 65A × 650l/m
14	ANTHRACITE FILTER	1	$1,800\phi \times 2,000^H$
15	ACTIVE CARBON FILTER	1	$1,800\phi \times 2,000^H$
16	CATION EXCHAGE RESIN FILTER	1	$1,800\phi \times 2,000^H$
17	CHELATE RESIN FILTER	1	$1,800\phi \times 2,000^H$
18	STERILIZATION TANK	1	$1,200^W \times 2,400^L \times 1,200^H$
19	REGENERATION TANK	2	2,000l
	AGITATER	2	1HP × 120RPM
	PUMP	2	1HP × 40A
20	MIXING TREATMENT TANK	1	$1,800\phi \times 2,400^H$
	AGITATER	1	2HP × 120RPM
21	SLUDGE TANK	1	$2,000\phi \times 2,400^H$
	AGITATER	1	2HP × 60RPM
22	CHEMICAL TANK	13	
	CHEMICAL FEED PUMP	7	6,000 ml/m, 8,000 ml/m

plant, some of the high concentration wastewaters are not treated in this wastewater treatment plant, but is disposed ofby entrusting outside. Based on the visiting survey, some of the decorative plating factories of gold plating perform recovery of gold by adsorption on ion exchange resins in stalled in their own factories, but others dispose of the concentrate wastewater of gold plating by selling it to the outside.

On the other hand, wastewaters transported from plating factories located outside the plating industrial estate are treated with fixed entrusted treatment fees. At the fee determined initially, the wastewater is received automatically. The wastewater quality is not checked each time the wastewater is transported, and therefore, quantity and quality variations of wastewater to be treated are so severe that the plant operation is very difficult.

B. Conditions of operation

For the operation of the facilities in the central wastewater treatment plant, wastewater treatment (entrusted and for reuse) plant operation diaries have been kept.

The diary has columns for guidance and checking organization'sinspection seals and discharge facility manager's decision seal. The items to be entered are as follows:

a. Wastewater quantity generated and entrusted

There are entry spaces for quantity in stock from the previous day, quantity generated in the plant, quantity discharged from tenant factories, and quantity transported by truck from outside.

b. Wastewater quantity treated

For each kind of wastewater (oxidation or reduction), there are entry spaces for quantity finally discharged, quantity exhausted (evaporated), quantity converted to resource (for reuse), quantity entrusted, and others.

c. Treatment plant operating time, final discharge time and worker's kind of work and name. For each kind of wastewater, there are entry spaces for the operating time in a form of table sectioned into 24 hours per day.

d. Meter readings

There are entry spaces for meter readings of integrating power meter, integrating flowmeter for finally discharged water, and tap water flow meter, and for controlled condition.

e. Chemical consumption

There are entry spaces for chemical properties, application, quantity purchased, exhausted quantity breakdowns and remaining quantity of NaHSO3, NaOCl, Al2(SO4)3, H2SO4, high polymer coagulant, K.D, NaOH, NaOH (33 %) and K.D.K.

f. Industrial waste disposal

For each kind of waste, there are entry spaces for quantity transported, quantity generated for the day, quantity treated for the day, method of treatment (in the plant or by entrusting), quantity remaining on the day, and the condition of storage.

g. Failure of the treatment plant

For each equipment, there are entry spaces for failure time, failure condition, actions taken, interruption of wastewater treatment, and others.

h. Results of water analysis in the plant

For each item such as pH, BOD, SS, hexane extract (n-hexzne), CN, Cu, etc., there are entry spaces for maximum concentration and minimum concentration, sampling time and analysis time. In the case of entrusted sample analysis, the enterprise name can be entered. It is told that the water analysis is done twice per week or so.

C. Utilities

(Electric power consumption)

2.5 kW/place x 20 places x 8 h/day = 400 kW/day

(Chemical consumptions)

NaHSO	430 Won/kg	6,000 kg/month	2,580,000 Won/month
NaOCl	112 Won/kg	2,000 kg/month	244,000 Won/month
Al2(SO)4	170 Won/kg	1,000 kg/month	170,000 Won/month
H2SO4	125 Won/kg	1,500 kg/month	187,500 Won/month

Polymer coagulant	3,100 Won/kg	70 kg/month	217,000 Won/month
K.D	240 Won/kg	20,000 kg/month	4,800,000 Won/month
NaOH (70%)	380 Won/kg	8,000 kg/month	3,040,000 Won/month
NaOH (33%)	120 Won/kg	70,000 kg/month	8,400,000 Won/month
K. D. K	2,000 Won/kg	2,000 kg/month	4,000,000 Won/month

D. Received water quality and treated water quality

Table 1.5.2. and Table 1.5.3. show the water quality of waste water stored in each of the cyanide tank, chrome tank and acid-alkali tank, as well as of the treated water from 6-valent chrome reducing, sedimentation tank supernatant, activated carbon treated water and chelate resin treated water, in the central treatment plant installed in the 2nd Estate Section and the 1st Estate Section, respectively.

The wastewater stored in each tank is a mixture of wastewaters from plating factories located in the plating industrial estate and wastewaters transported from plating factories located outside the plating industrial estate. That is, samples for water analysis were taken from this mixed wastewater. Each unit apparatus after the rapid filter tank had not yet been transported to the 1st Estate Section and the 2nd Estate Section at the time of sampling. Therefore, the samples were taken from the treated water staying in each tower.

1.6 Other Related Conditions

(1) Conditions of the surroundings of the plating industrial estate

The plating industrial estate is located in the Inchon industrial zone which is crowded with small-scale workshops being positioned near the coast.

The Inchon industrial zone has Inchon Port for sea traffic, and also has highways and railways from Soul. Inchon Port and highways are utilized for the transportation of raw materials and products. Roads are used as industrial roads. The workers can go to work by rail or car.

Table 1.5.2.
The Quality of Raw Water and Treated Water in Central Treatment Plant
(Metal plating 2nd Estate)

ITEM \ SAMPLE		CN STORAGE TANK	Cr STORAGE TANK	ACID-ALKALI STORAGE TANK	Cr^{6+} REDUCTION REACTOR
pH		1.84	3.20	2.22	9.70
Acidity	(epm)	49.6	9.36	39.8	−
Alkalinity	(epm)	−	−	−	11.2
Conductivity	(μs/cm)	−	−	−	5,640
COD_{cr}	(mg/l)	548	269	429	429
Cu	(mg/l)	403	138	269	−
Ni	(mg/l)	204	133	50.3	−
Cr^{6+}	(mg/l)	< 0.05	353	< 0.05	< 0.05
Zn	(mg/l)	230	244	278	−
Fe	(mg/l)	278	−	116	−
CN	(mg/l)	239	113	212	53.2
T-P	(mg/l)	153	143	5,530	−

ITEM \ SAMPLE		SEDIMENTATION TANK	ACTIVATED CARBON TOWER	CHELATE RESIN TOWER
pH		9.45	7.74	7.44
Conductivity	(μs/cm)	5,030	467	433
COD_{cr}	(mg/l)	124	70	26
Cu	(mg/l)	55.4	2.70	2.58
Ni	(mg/l)	0.31	−	0.18
Cr^{6+}	(mg/l)	< 0.05	−	< 0.05
Zn	(mg/l)	1.00	−	0.36
Fe	(mg/l)	0.58	0.66	1.01
CN	(mg/l)	31.2	0.67	1.39
T-P	(mg/l)	2.01	−	0.53

Table 1.5.3.
The Quality of Raw Water and Treated Water in Central Treatment Plant
(Metal plating 1st Estate)

ITEM \ SAMPLE		CN STORAGE TANK	Cr STORAGE TANK	ACID-ALKALI STORAGE TANK	Cr^{6+} REDUCTION REACTOR
pH		2.07	2.27	1.72	11.5
Acidity	(epm)	47.9	28.1	78.3	–
Alkalinity	(epm)	–	–	–	7.93
Conductivity	(μs/cm)	–	–	–	2,940
COD_{cr}	(mg/l)	5,180	748	459	120
Cu	(mg/l)	3,270	463	675	–
Ni	(mg/l)	936	16.8	202	–
Cr^{6+}	(mg/l)	< 0.05	108	< 0.05	< 0.05
Zn	(mg/l)	170	451	250	–
Fe	(mg/l)	798	–	–	–
CN	(mg/l)	2,740	170	127	28.7
T-P	(mg/l)	942	467	257	–

ITEM \ SAMPLE		SEDIMENTATION TANK	CHELATE RESIN TOWER
pH		9.17	8.31
Conductivity	(μs/cm)	1,400	184
COD_{cr}	(mg/l)	273	164
Cu	(mg/l)	11.7	0.14
Ni	(mg/l)	2.22	0.08
Cr^{6+}	(mg/l)	< 0.05	< 0.05
Zn	(mg/l)	0.08	0.11
Fe	(mg/l)	0.34	0.42
CN	(mg/l)	11.2	< 0.005
T-P	(mg/l)	0.50	< 0.2

In the surroundings of the plating industrial estate, related companies of fundamental industries such as automobile, electric, electronic, machinery, etc. are located. Plating of the parts manufactured in these factories is undertaken on a processing fee basis by the plating factories located in the plating industrial estate. Processing of parts for home products is also done in the factories in the surroundings.

Therefore, the plating industrial estate has the locality unique to the Inchon industrial zone regarding acquirement of raw materials, selling routes for products, places of consumption, convenience of transportation, relationship to parent enterprises or related enterprises, geographical factors, etc.

(2) Operating condition of the plating industrial estate

S Co., Ltd. constructed the plating industrial estate and has allowed plating factories to be located in it free of charge. To each factory, utility supplies such as electric power, tap water, etc. are furnished for a consideration, and wastewaters and wastes are treated and disposed of also for a consideration.

On the other hand, the company undertakes an industrial waste treatment business to treat and dispose of for a consideration wastewaters from plating factories located outside the plating industrial estate. By means of the income, the plating industrial estate is being run.

It seems that the president, etc. will furnish their information about plating wastewater treatment technologies, etc. to the plating factories. On the other hand, each plating factory strongly wishes to collect information about plating technologies and is making investigation for itself, but in reality, it is difficult.

In case a problem with wastewater treatment occurs, engineers of plating factories are called to have a meeting to solve it. If it is found that the cause exists in a plating factory, S Co., Ltd. orders the plating factory to take an improvement measure. If the plating factory does not follow it, the plating factory may be dismissed.

It is said that the wastewater treatment cost in the central wastewater treatment plant is 12000-13000 wons/t.

On the other hand, the sludge quantity generated in the wastewater treatment plant is 1-2 t/day (water content 70-75 %), and the disposition cost is 87000 wons/t + 15000 wons/m^3 (transportation cost). Effective utilization of sludges, etc. is not done.

(3) Consciousness of tenant enterprises of pollution control

According to the visiting survey, the tenant enterprises' consciousness of pollution control is as follows:

a. Managers or engineers of surveyed factories are highly conscious of pollution control. From the facts that the recovery tank is installed in the case of water washing system, wastewaters are discharged as classified, the exhaust hood is installed, etc., it is suggested that the education by S Co., Ltd. in pollution control and working environment should be complete.
b. Personnel in the field are conscious of classified discharge of wastewaters, but in some plating factories, the same washing tanks were used in common to both cyanide and chrome. This means that the objective of classified discharge of wastewaters is not understood from the viewpoint of wastewater treatment.
c. In some plating factories, complete control of water and wastewater is done.