RESEARCH SURVEY OF
JOINT TREATMENT SYSTEM FOR
WASTE WATER TREATMENT SLUDGE

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JEC

n Environment Corporation (JEC)

CONTENTS

NOTE

- Method of Measuring COD
  The COD values given in the text, unless specified otherwise, are obtained by the manganese measuring method.
- Currency used in this report is all Japanese Yen (JPY or yen).

Chapter 1 Survey Process and Substance

1.1 Survey Summary

1.1.1 Survey Purpose

Sludge treatment and disposal has become present serious problems due to its huge amount of quantity and diversified quality. Harmful metals abound in this type of waste, accenting the need for environmental conservation measures. A host of technical, economic and social barriers has unfortunately prevented the establishment of definitive countermeasures, a failure that has clearly contributed to the deterioration of the environment.

The survey examined feasible approaches to the treatment and disposal of harmful sludge premised on the fundamental ideas of environmental conservation and sound industrial development. Economic and reliable treatment measures must be established in order to erect a model of a joint treatment project for sludge disposal.

1.1.2 Survey Method

The survey covered the surface treatment processing industry (the plating industry) and was sent to local governments in the form of a questionnaire. Responses were then collected and companies were verbally polled based on results of the questionnaires.

1.1.3 Survey Targets

The questionnaire was sent to 52 local governments (prefectural, municipal and ward) and chambers of commerce, and 14 plating plants, three joint treatment companies, three local governments and two group factories were verbally polled.

1.1.4 Summary of Survey Results

1) Summary of Questionnaire
The responses from the above mentioned targets were collected in an attempt to understand the status of the plating industry.

Item 1: Please state the relevant items regarding the actual status of the plating industry in the Enter column.

Item 2: Do you implement suitable waste water treatment guidance, (regular and thorough inspections, for example)?

Item 3: Do you think whether the rate of diffusion of waste water treatment facilities will increase or level off in the future, and what factors will determine your decision?

Item 4: What sort(s) of incentive measures do you provide for stimulating the operation and investment of waste water treatment facilities?

Item 5: What is the approximate quantity of sludge disposed by the private firms within your control area?

Item 6: What steps or measures are you currently taking to treat or dispose of emitted sludge?

Item 7: What do you think is the best way to treat or dispose of emitted sludge in the future?

Item 8: In order to treat emitted sludge, do you want to establish and use a joint treatment facility following the model of the Environmental Pollution Control Service Corporation*?

* The Environmental Pollution Control Service Corporation: The former name of Japan Environment Corporation.

Item 9: Please state any other thoughts or ideas relevant to the treatment or disposal of emitted sludge.

<Survey Result>

Twenty-two of the 52 questionnaires sent out were returned, 18 from local governments and four from chambers of commerce, for a return rate of 42.8%. However, since local chambers of commerce are essentially included within local governments, only the 18 returns received from local governments were examined.

Item 1: Actual states of the plating industry

Twelve of these 18 returns were valid, eight from regional cities and four from metropolitan cities. Of the total 1,384 companies examined, 358 (25.9%) still lacked waste water treatment facilities. Of the 639 companies located in the eight regional cities, 111 (17.4%) lacked facilities. Of the 745 companies in four metropolitan cities, 247 (33.2%) still lacked facilities. Therefore, roughly 15% more companies in larger cities than in regional cities lacked waste water treatment facilities. Most of these metro-area companies employed approximately five people.

A breakdown of the number of people employed at the 1,384 companies in the 12 cities reveals that 358 companies (25.9%) employed approximately five people, 512 companies (37%) employed between five and ten, 347 (25.1%) employed between ten and 30, 85 (6.1%) employed between 30 and 50, and 82 (5.9%) companies employed 100 or more people.

Companies with ten or fewer employees comprised over half of all companies (62.9%), whereas companies with 30 or fewer employees comprised 88% of all companies. Companies employing 100 or more employees included some which, though not specifically plating enterprises, used plating facilities on a portion of their products.

Responses from companies in regional cities and metropolitan areas show that 111 of the 639 companies in regional cities (17.4%) employed approximately five people, 154 (24.1%) employed five to 10, 248 (38.8%) employed 10 to 30, 48 (7.5%) employed 30 to 50 and 78 (12.2%) employed 100 or more. There were 513 companies with 30 or fewer employees, 80.3% of all companies.
Responses from companies in metropolitan areas show that 247 of the total 745 companies (33.2%) employed approximately five people, 358 (48.1%) employed five to 10, 99 (13.3%) employed 10 to 3, 37 (5%) employed 30 to 50 and four (0.5%) employed 100 or more. There were 704 companies with 30 or fewer employees, 94.5% of all companies. The survey clearly showed that more small companies (30 or fewer employees) were located in metropolitan areas than in regional cities and, conversely, that more large companies were located in regional cities than in metro areas.

Item 2: Implementation of suitable waste water treatment guidance and inspection

Local governments answered that they implemented waste water treatment inspections anywhere from once to four times each year, with one prefectural health center office answering "monthly." They inspect waste water treatment facilities and conduct surveys of water quality analysis. If such treatment facilities exceeded the local pollution control standards, local government would generally guide those companies to improve the defective parts of facilities. Also, local governments would warn companies and force them to submit the improvement (tentative and lasting) plans in case the abilities of their waste water treatment facilities failed to meet the local pollution control standards. Such failed treatment facilities would be under patrol guidances implemented by the responsible sections in local governments. Local governments also responded that technical instruction and training are given by water quality specialists at industry laboratories. The basic waste water technical instruction encourages discreet treatment by type of waste water at firms outside on a commission basis, which is effective for reuse of industrial water and recovery of resources.

Item 3: The rate of diffusion of waste water treatment facilities

The rate of diffusion of waste water is indicated by the following two current situations.

① Companies currently without waste water treatment facilities are small companies and cannot be expected to establish new facilities.

② Companies that emit waste water in the sewers are under-equipped to handle waste water treatment.

There is little hope that companies will increase their use of existing waste water treatment facilities, even if required by law. However, one local government reported that seven out of 10 companies had established a cooperative association for joint treatment of concentrated liquid waste, which is suggesting a trend in this direction.

Item 4: Incentive measures for waste water treatment investment and facility operations

We received responses on the number of companies that financed investment and the amount of financing for 1973 and 1974 from the Pollution Control Fund and the Industrial Waste Investment Fund. The number of companies in regional cities that financed investment for waste water treatment facilities dropped from 79 in 1973 to 29 in 1974. The total investment also plummeted drastically from JPY 5.24 billion in 1973 to JPY 1.74 billion in 1974. This was because a financing system was already implemented before 1973, and establishment of pollution control facilities had already reached its peak accompanying stronger pollution control regulations.

Loans for pollution control facility investment were made at 7.6 - 8% interest, approximately 3% of which were subsidized. One response indicated three financed investments in 1973 and 1974 and that additional funds of JPY 2 million were supplied for each.

Responses indicate that in the future subsidized interest financing from the Pollution Control Fund would expand not only to plating industry companies but also to unrelated small and medium-sized companies. One local government responded that it would finance JPY 5 billion from the Pollution Control Fund and JPY 900 million from the Industrial Waste Investment Fund in 1975 to fund small and medium-sized companies in their waste water treatment investment efforts.

Item 5: Quantity of sludge disposed

It was extremely difficult for local governments to determine monthly sludge emission accurately. The survey revealed a considerable disparity in responses, detracting from the reliability of the figures obtained. Nevertheless, responses concerning sludge emission by 106 companies with dehydrators indicate that 60 companies of them generated 200 tons per month, or approximately 3.3 tons per month for each company. While no figures are available on the total sludge emission by all 106 companies, the per-company emission figure is believed to be quite reliable. Of course, sludge emission figures will largely differ depending on the various types of plating and the waste treatment technology employed.

Item 6: Current steps or measures to sludge treatment and/or disposal

One local government reported that companies in 1975 continue to move forward on joint treatment plans using concrete solidification as the preferred method of waste treatment. Prefectural metal industry guilds lie at the core of this plan. Prefectural government are planning to pay for up to one-third of the costs of building concrete solidification facilities to treat waste water (excluding land costs).

Responses revealed, however, that high treatment costs could make it difficult for private industry to bear the remaining financial burden.

Many local governments reported that they would go forward with concrete solidification of waste.

Local governments handle waste water treatment according to the Waste Disposal and Public Cleaning Law. Where a landfill would be less than half full, local governments may proceed with reclamation; where over half full, then they use concrete solidification as the treatment method.

The local government above, however, was the only one with an actual treatment plan, with no specific treatment plans found among other survey responses.

Item 7: The best way of sludge treatment and/or disposal in the future

One response from local government best expressed the current state of affairs. A closed treatment system that does not generate sludge is preferred. That particular prefectural government had already made plans for investing in a waste treatment facility to cope with pollution. Therefore, obtaining the funds necessary to shift gears towards upgrading to a closed facility is difficult, meaning that, for the moment, anti-sludge action cannot be expected. Some responses stressed the growing importance of resources and "closed" treatment in the future. Plans for concrete solidification (joint treatment) are under way in this prefecture. Many other local governments responded that the promotion of joint sludge treatment methods and the development of treatment technologies in recycling resources should be continued in the future.

Item 8: Establishment and use of a joint treatment facility following the model of the Environmental Pollution Control Service Corporation

Of the 18 local governments that responded, eight answered "Yes" and two answered "No", while seven left the answer blank and one's response was unclear. The "Yes" response rate was 64%.

Some local governments that answered "Yes" want a joint treatment facility built as soon as possible. Due to lack of clarity in the question, the others left the answer blank, commenting that nothing concrete could be gleaned from it.

Two responses also noted that pursuing discussions with companies were necessary.

Item 9: Other concernings

While most local governments did not respond to this part of the questionnaire directly, their thoughts on the matter can be gleaned for the most part from their responses to the Item 7.

Instruction regarding maintaining waste water treatment facilities to prevent water pollution has move forward without sufficient attention to sludge treatment and disposal, and this applies not only to the plating industry but to all other related industries. Even where government is involved, sludge treatment and disposal have not been sufficiently addressed and appropriate action remains a topic in need of much greater focus.

Since most of the plating industry in this report employed a comprehensive waste water treatment method, most of the sources of sludge resource have been eliminated. Existing facilities that handle all waste regardless of the specific industry cannot easily be upgraded in the near future to handle treatment independently according to the specific industry.

Questionnaire Statistics (local governments)
Eight local governments, four wards in metro areas

Item 1 Actual Status of Surface Treatment Industry

A) Status of Waste Water Treatment Facilities

Government		No. of Companies	"Yes" on Facility	"No" on Facility
		companies	companies	companies
Metro Areas & Wards	1	130	111	19
	2	464	236	228
	3	13	13	0
	4	138	138	0
Sub-total		745	498	247
		companies	companies	companies
Regional Cities	5	130	106	24
	6	52	43	9
	7	259	205	54
	8	6	6	0
	9	68	68	0
	10	10	9	1
	11	46	42	4
	12	68	49	19
Sub-total		639	528	111
Total		1,384	1,026	358

B) Number of Companies and Number of Persons

Government		No. of Companies	5 and less	5 - 10	10 - 30	30 - 50	100 and more
		companies	companies	companies	companies	companies	companies
Metro Areas & Wards	1	130	19	89	22	0	0
	2	464	228	170	42	24	0
	3	13	0	0	0	9	4
	4	138	0	99	35	4	0
Sub-total		745	247	358	99	37	4
Regional Cities	5	130	24	34	52	20	0
	6	52	9	21	15	7	0
	7	259	54	83	96	0	26
	8	6	0	3	1	2	0
	9	68	0	0	35	0	33
	10	10	1	2	4	0	3
	11	46	4	11	26	0	5
	12	68	19	0	19	19	11
Sub-total		639	111	154	248	48	78
Total		1,384	358	512	347	85	82

Item 4 Loan Incentives to Waste Water Treatment Investment

Government		Fiscal 1973		Investment avg.	Fiscal 1974		Investment avg.	Remarks
		Responses	Investment		Responses	Investment		
			thousand yen	thousand yen		thousand yen	thousand yen	
Metro Areas & Wards	1				4	8,200	2,050	
	2	17	27,010	1,590	19	32,820	1,730	JPY 2 million (non-int. bearing)
	3							
	4	2	3,560	1,780	4	7,500	1,880	
Sub-total		19	30,570	1,610	27	48,520	1,800	
Regional Cities	5	26	163,220	6,280	9	42,300	4,700	APR 7.6% (int. subsidy 3.65%)
	6	4	24,600	6,150				
	7	37	284,500	7,690	11	87,000	7,910	
	8	1	8,000	8,000				
	9	2	6,160	3,080	1	5,190	5,190	
		2	Aid 4,000	2,000	1	Aid 2,000	2,000	
	10							2.5% subsidy of 8% int. for prefectural pollution elimination funds
	11	1	5,000	5,000	1	3,000	3,000	
	12	5	28,800	5,760	6	34,390	5,730	
Sub-otal		78	524,280	6,720	29	173,880	5,990	
Total		97	554,850	5,720	56	222,400	3,970	

Item 5 Sludge Emissions (t/mo)

Government		No. of Companies	"Yes" on Facility	Sludge Emission (t/mo)	Emission Volume (t/mo)
Metro Areas & Wards	1	130 co.	111 co.	8.5 ton	0.077 ton
	2	436	236	134.6	0.301
	3	13	13	1.5	0.115
	4	138	Responding companies 100	52.5	0.525
Sub-total		745	(460)	(201.6)	(0.638)
Regional Cities	5	130	106	200.0	1.887
	6	52	43	333.5	7.756
	7	259	205	202.0	0.985
	8	6	6	6.3	1.050
	9	68	68	714.0	10.500
	10	10	9	16.4	1.822
	11	46	42	70.0	1.667
	12	68	49	665.0	9.777
Sub-total		639	(528)	(2,207.2)	(4.180)
Total		1,384	(988)	(2,408.8)	(2.438)

Item 8 Desire to Establish Joint Treatment Facility by Using the Constuction and Transfer Program in the Environmental Pollution Control Service Corporation?

Government	Yes	No	No Response
1			
2	○		
3	○		
4	○		
5	○		
6	○		
7	○		
8	○		
9			○
10			○
11			○
12		○	

2) Summary of Oral Survey

Fourteen separate companies, three joint treatment facilities, three local governments and two plant complexes were answered verbally to the following areas of inquiry. However, we decided only to extract each company's answers and tried to grasp the present situation in waste water treatment.

Surveyed Items

a) Scale
b) Products
c) Waste water treatment facilities
d) Operation-related factors
e) Environmental problems
f) Economic factors
g) Factors related to inter-company cooperation and administration

a) Target of Survey (Scale of companies)

All 14 answered companies held capital of JPY 5 million or less and employed 50 or fewer employees. Excluding six companies with employee dormitories, four companies were in plant-designated areas and four were in residential areas.

Gross annual sales differed greatly, between JPY 15 and JPY 310 million, according to the number of employees, the nature of the company and regional characteristics. Given the disparity in sales, generalization was impossible.

b) Products

Only two of the 14 companies limited their acceptance of orders to special products. The other remaining 12 companies took orders for a variety of products.

A look at types of plating reveals that four companies handled either zinc plating (galvanizing) only or copper, nickel and chromium plating. Two companies handled chrome-related plating only while two handled primarily zinc, and some nickel and chrome.

Only one company in our verbal survey handled a wide variety of plating.

Hydrochloric acid, aqua fortis, caustic soda, soda cyanide and zinc cyanide products were typical in zinc plating. At companies handling copper, nickel and chrome plating, hydrochloric acid, aqua fortis, caustic soda, chromic acid and copper cyanide products were largely used. For chrome-related plating, products of chromic acid, nickel chloride, copper cyanide and sulfuric acid were typical.

Because of the use of various chemicals for many plating products, as well as the absence of any direct connection between products and sales, we could not determine the overall amount of water used through this verbal questionnaire survey.

c) Waste water treatment systems

All 14 companies answered that they have waste water treatment systems. They explained that they use a mixed treatment process of neutralization, sedimentation and filtering. They perform the intermediate treatments of oxidization and reduction per waste water flow line.

Most used conventional treatment methods; only one company used the ion exchange method.

Ten companies that keep analytical data showed that they successful by controlled emissions with concentrations below designated environmental standards. However, the other four companies failed to analyze their emissions despite record-keeping.

Most companies did not provide straightforward answers as to whether supervisors were hired full-time or part-time.

Four of eight companies, excluding six companies in an industrial park, reported that they have no idea how much sludge they emit, regardless of its small amount. They also avoided clearly answering how they treat sludge by themselves. These facts show such companies have been conducting waste water treatment in an irresponsible way with a poorly-organized supervisory system, eventually resulting in no sludge production. Meanwhile, of the remaining four companies producing sludge, three said that they treat sludge by temporary storage located at the company site. Only one company said that it consigns a service company to treat sludge. Sludge amounts differ per company, depending on the use of chemicals as well as on the amount and concentration of waste water. This has contributed to our difficulty in completing a successful sludge survey on a per unit basis.

d) Opinions on future management

Most surveyed companies claimed that the prospects for their plating business looked grim, largely due to possibly intensified regulation for waste water and the subsequent high cost of capital investment, which would eventually demand that they increase production costs. Nine companies said that they would face their business crisis, if such tightening occurred. Only one company, a large corporate affiliate, answered that it enjoyed a robust sales performance, thanks to a rearrangement and expansion of treatment systems with improvement of production lines.

Companies in an industrial park collectively use concentrated large treatment systems for waste water treatment. They therefore are urged to raise production costs that accompany increases in treatment costs. By contrast, independent companies mostly located in urban areas maintain low production costs because of insufficient treatment.

To get rid of such unfairness, industrial park-based companies claim that customers that place plating orders choose companies equipped with better waste water treatment systems, rather than independent companies with poor treatment systems, even if their production costs and the following market price are higher than those of independent companies.

Through these facts, we can conclude that environmental pollution control costs have posed a heavy financial burden on the plating industry.

e) Opinions on environment problem

Most companies responded that concrete measures to improve current treatment systems must be taken immediately. The ideas of the plating industry include the necessity of devising a plan guided by the plating industry, relocation of their businesses, reconsideration of the current high costs of consigned treatment, an increase in each company's responsibility for sludge emission*, and the introduction of a full-fledged efficient production system designed for environmental pollution control and recycling (Cleaner Production System).

* PPP = polluter pays principle

f) Opinions on environmental preservation and financial burden

While all the companies said that they have a duty to cover the costs of environmental preservation by themselves, they simultaneously claimed that it is almost impossible to bear the further investment costs for anti-pollution measures. In addition, others demanded better techniques for environmental protection, as well as fair payment among companies for waste water treatment systems.

g) Opinions on joint treatment, joint operation, grouping and assistance from government

Despite the difficulty of joint operation thorough extensive cooperation, most companies expect public organization to offer them some sort of financial assistance, or to direct a construction of joint treatment facilities, because they assume such actions to be the most feasible approach at present. They also clamored for intensified administrative guidance and a supervisory system to eliminate the current unfair business practice whereby companies lacking any treatment device continue to profit through lower production costs compared to well-equipped plating companies.

One noteworthy opinion focused on the drastic mechanical improvement of treatment systems aimed at sludge disposal and resource recycling.

Item	Companies	Company A	Company B	Company C	Company D	Company E
Size	1. Capital (thousand yen)	2,000	5,000	2,000	2,000	2,000
	2. Sales (thousand yen)	1973 75,936	1974 310,312	1973 29,588	1973 45,451	1973 63,931
	3. Employees	17	47	8	11	20
	4. Application location	Industry-oriented	Industry-oriented	Industry-oriented	Industry-oriented	Industry-oriented
Product	1. Main product	Various kinds	Various kinds	Various kinds	Various kinds	Various kinds
	2. Plating type	Copper, nickel, chrome	Copper, nickel, chrome, zinc, alumite processing	Zinc	Zinc	Zinc
	3. Type of used chemicals	Hydrochloric acid, aqua fortis, caustic soda, sodium cyanide, chromium acid, copper sulfate	Hydrochloric acid, aqua fortis, caustic soda, sodium cyanide, chromium acid, chromic compound	Hydrochloric acid, aqua fortis, caustic soda, sodium cyanide, zinc cyanide	Hydrochloric acid, aqua fortis, caustic soda, sodium cyanide, zinc cyanide	Hydrochloric acid, aqua fortis, caustic soda, sodium cyanide, zinc cyanide
	4. Water amount (m^3/mo.)	1,780	3,290	1,860	1,460	2,053
Waste water treatment system	1. Yes/No (waste water treatment system)	Yes	Yes	Yes	Yes	Yes
	2. Type and amount of waste water	Complete separation	Complete separation	Complete separation	Complete separation	Complete separation
	3. Treatment method	Joint comprehensive treatment—oxidization-reduction treatment —neutralization—depression—dewatering — sludge—discharge	Same as left	Same as left	Same as left	Same as left
	4. Analytical data of treated water	Copper 0.6 ppm Zinc 1.5 Iron 0.3 Hexavalent chromium 0-0.07	Same as left	Same as left	Same as left	Same as left

Waste water treatment system	5. Regulatory value of treated water	Cadmium 0.1 Cyan 1.0 Lead 1.0 Hexavalent chromium 0.5 Arsenic 0.5 Mercury -				
	6. Supervisor Yes/No	Yes	Yes	Yes	Yes	Yes
	7. Sludge emission (1) Qty. and quality (2) Treatment method (3) Disposal method	700 kg/day moisture 80% Vacuum dehydration At trader's disposal				
Opinions on environmental preservation and financial burden		1. Costs involved must be fairly shared 2. Sludge treatment costs have reached limit				
Opinions on future management		1. Demand consistent technical instructions 2. Demand fair guidance to prevent gap between independent companies and group companies				
Opinions on joint treatment, joint operation, grouping and assistance from government		1. Will become difficult 2. Offer more jobs to companies equipped with treatment systems 3. Will become disadvantageous due to gap in production costs				
Opinions on environmental problem		1. Will become more difficult in due course of time 2. Sludge treatment costs must be a huge financial burden 3. Cost : 400,000 yen - 500,000 yen/month				

Item	Companies	Company F	Company G	Company H	Company I	Company J
Size	1. Capital (thousand yen)	2,000	5,000	3,000	2,000	4,000
	2. Sales (thousand yen)	1974 64,487	1973 179,000	1973 79,530	1973 32,580	1974 112,240
	3. Employees	13	38	14	7	21
	4. Application location	Industry-oriented	Pre-commercial	Residence	Residence	Pre-commercial
Product	1. Main product	Various kinds	Auto parts	Various kinds	Various kinds	Auto parts
	2. Plating type	Alumite processing	Copper, nickel, chrome	Copper, nickel, zinc	Copper, nickel, chrome	Hard chromium
	3. Type of used chemicals	Sulfate, caustic soda, phosphoric acid soda, aqua fortis, brightener	Chrome acid, sulfuric acid, hydrofluosilic acid, selenic acid	Soda cyanide, caustic soda, nickel sulfate	Chrome acid, copper cyanide, selenic acid, nickel chloride	Hard chrome, chrome acid, nickel chloride, copper cyanide, others
	4. Water amount (m^3/mo.)	750	1,850	930	480	1,200
Waste water treatment system	1. Yes/No (waste water treatment system)	Yes	Yes	Yes	Yes	Yes
	2. Type and amount of waste water	Complete separation	Mixed sewage	Mixture	Mixture	Separation
	3. Treatment method	Joint comprehensive treatment oxidization-reduction treatment — —neutralization—depression—dewatering —sludge—discharge	Oxidization—reduction— —neutralization—depression—filtering	Oxidization— —neutralization— —depression	Oxidization— —neutralization— —depression	Ion exchange
	4. Analytical data of treated water	Copper 0.6 ppm Zinc 1.5 Iron 0.3 Hexavalent chromium 0-0.07	Cadmium 0.4 Lead 0.05	Cadmium 0.04 Lead 0.07	Unknown	Copper 0.2 Nickel 0.12 Chrome 0.01 Zinc 0.89

Waste water treatment system	5. Regulatory value of treated water	Cadmium 0.1 Cyanogen 1.0 Lead 1.0 Hexavalent chromium 0.5 Arsenic 0.5 Mercury -	Based on criteria for water pollution control	Same as left	Same as left	Same as left
	6. Supervisor Yes/No	Yes	Yes	Yes	Yes	Yes
	7. Sludge emission (1) Qty. and quality (2) Treatment method (3) Disposal method		560-980 kg/mo. Green-white colored Gel, water content 87% Dewatering Storage at company site	150-300 kg/mo. Storage at company site	Unknown	240-420 kg/mo. Green-white colored gel, water content 82% Dealers consignment
Opinions on future management			1. Slim chance to expand sales profits 2. Cannot expand business because of location in urban area	1. Cannot run business due to increased prevention equipment costs		1. Increasing sales as big corporate-affiliate with complete treatment system 2. Need to create technique for complete treatment and collection
Opinions on environmental problem			1. Need to take prompt action to stop emission into sewage	1. Acknowledge seriousness		1. Must be considerate as emission producer 2. Need to create consistent and comprehensive measures to control environmental pollution
Opinions on environmental preservation and financial burden			1. Financial burden influenced by easily-changed regulation for treatment systems 2. Demand complete technical guidance to prevent water pollution	1. Cannot pay huge sums; small amount might be possible		1. Indispensable for environmental protection
Opinions on joint treatment, joint operation, grouping and assistance from government			1. Cannot operate joint systems without hefty financial help 2. Cannot compete with companies without treatment systems	1. Local government must establish joint treatment systems and take care of disposal		

Item	Companies	Company K	Company L	Company M	Company N	
Size	1. Capital (thousand)	3,000	1,000	1,500	500	
	2. Sales (thousand)	1973 129,000	1973 14,800	1973 48,900	1973 57,000	
	3. Employees	30	4	12	12	
	4. Application location	Pre-commercial	Pre-commercial	Residence	Residence	
Product	1. Main product	Various kinds	Various kinds	Various kinds	Various kinds	
	2. Plating type	Zinc, nickel	Chrome	Zinc	Zinc, nickel, chrome	
	3. Type of used chemicals	Zinc white sodium cyanide, nickel chloride, others	Chrome acid, hydrogen acid fluoride, copper sulfate, others	Sodium cyanide, zinc chloride, others	Sodium cyanide, zinc chloride, others	
	4. Water amount (m³/mo.)	1,380	Unknown	860	Unknown	
Waste water treatment system	1. Yes/No (waste water treatment system)	Yes	Yes	Yes	Yes	
	2. Type and amount of waste water	Separation	Mixture	Mixed sewage	Mixed sewage	
	3. Treatment method	Oxidization treatment	Reduction treatment	Oxidization treatment	Oxidization treatment	
	4. Analytical data of treated water	Mercury 0.002 ppm Cadmium 0.005 Lead 2.1 Chrome - Arsenic -	Unknown	Unknown	Unknown	
	5. Regulatory Value of Treated Water	Based on criteria for water pollution control	Same as left	Same as left	Same as left	
	6. Supervisor Yes/No		Yes	Yes	Yes	

7. Sludge (1) Amount and type (2) Treatment technique (3) Disposal method	260-400 kg/mo. Brown slurry Water content 95% Dewatering drying Storage at company site	Unknown	Unknown	Unknown	
Opinions on future management	1. Will become unprofitable as promoting prevention measures 2. Cannot keep business unless ignores prevention measures	1. Labor shortage due to poor working environment	1. Cannot expand business due to location in residential area 2. Cannot sustain business due to strong resistance from residents		
Opinions on environmental problem	1. Group-oriented solution is necessary	1. Acknowledge necessity of prevention of environmental pollution	1. High time to think about relocation and changing businesses		
Opinions on environmental preservation and financial burden	1. Necessary to some extent	Impossible to spend more	1. Useless to keep spending costs in current location in residential area		
Opinions on joint treatment, joint operation, grouping and assistance from government	1. Joint system must be only possible solution 2. National government needs to offer financial assistance and create joint treatment systems		1. Need site rearrangement designed for industrial park		

1.1.5 Analysis of Survey Results

A comprehensive summary of the questionnaire and verbal survey follows.

1) Many companies are small-scale in terms of capital and their number of employees. Most of them were established quite a long time ago, and they have a long history both of achievements and continuity in management. Therefore, they are located mostly in residential areas, especially in the center of large metropolitan areas, and this allows them ready access to product orders.
   In these areas, waste water is emitted into public sewers (in Kawasaki City and Toyohashi City that are the targets of this survey). Therefore, standards for waste water emission are somewhat lax compared to other areas.
   The verbal survey reveals that this greatly influences how managers approach environmental pollution control and their awareness of the level of waste water treatment.
   Two facts make this influence clear. First, the disparity in production cost caused by site-specific conditions, which affects water treatment, makes many companies think that they cannot compete with larger companies in receiving product orders. Second, many small company plants do not even generate sludge because their level of operation technology at the treatment facility has diminished, consciously or unconsciously. The result is that they emit waste water into public sewers.
   Emissions of large amounts of harmful sludge from the metal plating industry into the public sewers lie ahead, presenting an urgent treatment problem. Therefore, the status quo of responsibility for waste expenses and the realities of environmental pollution and environmental preservation measures needs to be examined in detail according to the actual condition of the metal plating business world.

2) On the other hand, small-scale companies have an advantage in terms of production mobility. This is clear from the fact that many of the companies who cooperated in the verbal survey order many kinds of metal plating from many different sources, regardless of the type, amount, or appearance of the plating. They do not actually specify the type of metal plating, such as chrome, nickel, zinc, or copper in terms of processing technique. Rather, they process it at some facility and treat waste water in some unspecified way because many managers order bolts and nuts, plastics, and auto parts. In other words, they order whatever they can use. Moreover, they sometimes change the metal plating bath that can be used without any problem to others according to the plating types they order or the designated delivery date. In this aspect as well, the management of treatment is ignored. Many managers think that if they specify a specific type of plating, they cannot make the order and compete with other companies. This is part of the economic problem (the meeting of supply and demand) with orders by smaller companies.

This key problem is a conflict between two options, to spend on the treatment of generated sludge, or to close heavy metals (abandoning energy and resources) and spend on recycling it in production.
Therefore, it is very important to design a joint treatment facility to analyze the mechanism of waste water treatment of sludge.
The trends in law and regulations and in the social economy are equally significant. These trends require greater examination, since the technical aspects of sludge and waste water treatment are always influenced by society and the law.

3) Waste treatment facilities are in place. Many problems, however, exist in operation and management. In this survey, a few facilities were far from the treatment facility. Many companies have methods of waste water treatment that are mixed and concentrated because of the conditions mentioned above. Especially when it comes to company complexes, they own a joint treatment facility because it would cost too much were they to treat waste individually. They nevertheless consign the treatment and disposal of sludge to industrial waste treatment businesses because they can perform mixed treatment.
This is attributed to the fact that treatment systems are organized to address waste water treatment methods only to protect water quality and not to eliminate harmful heavy metals (sludge), at least not yet. Therefore, environmental protection and pollution control should be established as a complete system that takes resource protection into consideration as well. Based on the results of this survey, it is clear that future technological systems need to be examined via a deeper evaluation of present treatment technologies.

4) Many companies find it difficult to deal with sludge treatment. Large companies that introduced quality waste water treatment facilities, that maintain excellent management, and that are making efforts to prevent pollution also have troubles with sludge. Some managers claim that they are causing secondary pollution by consigning treatment to industrial waste treatment services or by involuntarily storing it on land owned by their companies.

5) Two joint treatment centers for larger areas deal with the treatment of cyanide concentrated waste liquid and are operated by large companies. However, both of them treat sludge after treating waste liquid. One of them makes resources by returning it to the mine smelter for recycling. The other also returning it to other mine smelters for recycling on a commission basis, but it faces financial problems because of high treatment costs.
In addition, the No. 3 center operated by the prefectural treatment public corporation is reducing the amount of waste only to reduce the treatment cost in returning it to a mine smelter, by hydrating and drying pre-treatment. As noted in Chapter 5, the results of this survey clarify that it is difficult to adopt sludge treatment techniques that produce resources in the face of such obstacles as safety, economy, the scale of the facility, and

operation, despite the development of these techniques. Moreover, the establishment of a treatment facility is difficult in and of itself. The metal plating industry lacks sufficient capital, its plants are located in overpopulated metropolitan areas, and land is hard to obtain.

Effective sludge treatment techniques should be compact and inexpensive. In addition, the development of techniques that are easy to operate and that offer high safety will be necessary in the future. These aspects of waste water treatment are essential to accomplishing this research project and will be addressed in future research.

6) Opinions freely offered in the oral survey revealed a number of interesting points.

① Many companies said that pollution problems would hinder the metal plating business of the future. Metro-area companies in particular expressed this view. However, the affiliated companies of the business group place their orders to the selected companies based on whether or not there was a pollution control facility at hand. In fact, such selected companies in this survey increase the orders. On the other hand, smaller companies answered that the cost increase of installing a facility would prevent them from operating at all. Throughout the entire metal plating industry, how this problem is addressed depends on the disparity in business scale.

② This difference can be seen in managers' awareness of pollution control and environment problems. The disparity of scale could be the cause; however, the treatment cost of sludge seems to be a burden regardless of company size. Thus, the economic problem, the problem of who bears the burden of costs, public participation, and information management should be carefully examined and evaluated when a joint treatment system is later designed.

③ Each enterprise recognizes that preventive and economic burdens must be borne, but all hope there will be fairness in the sharing of those burdens. For example, there are differences between areas with sewerage and those without, and differences between companies that are implementing pollution control measures and those that are not; so, all enterprises are desirous for the pollution control authorities to be centralized and consistent and for the establishment of technical guidance to be speedily promoted.

④ Some managers, nevertheless did not agree with joint treatment and cooperation because they did not understand their responsibilities as waste producers. Some have begun to reconsider. Some companies claimed that cooperation would be difficult, although most of the companies polled agreed that they should consider more drastic waste water treatment methods in the years to come. They conceded that joint complexes would probably be the only way to handle the problem because of management difficulties at a single location. Closing down a production system to avoid sludge generation was another consideration. This view has gained popularity, even on the government side.

According to the results of these surveys, the design of a treatment system in the future requires evaluation and analysis technically, socially, and economically. It should not be merely an extension of a treatment technique, but an establishment of a closed system whose precondition is recycling with a view towards environmental and resource protection. What is required is the development and research of a multi-process treatment system whose main purpose is to prevent the spread of polluted substances into the environment.

1.2 Report Summary

Summary of Chapter 2 Sludge Emission

Sludge emitted by the surface treatment industry often contains harmful substances, such as heavy metals. Since the metal plating industry consists of small companies, it lacks proper sludge treatment. In addition, there remain many unclear points from the viewpoint of treatment and management techniques, such as the types of harmful substances sludge contains.

Therefore, in this survey, the metal plating industry, which is representative of the surface treatment industry, is mainly discussed. In order to find an actually effective plan towards a system to treat sludge emitted by the metal plating industry, substances related to water pollution must be understood consistently. Therefore, the mechanism of how pollution substances are emitted is solved in the technical process of water pollution control.

Summary of Chapter 3 Analysis of Sources of Plating Sludge Emission

Chapter 3 clarifies the actual condition of the metal plating industry. The survey covered the technical standards of treatment, management criteria for water quality, the reality of sludge treatment, etc. Data, however, were insufficient. Problems came to light through the verbal polling. According to the analysis of the results of the questionnaire sent to local governments, key issues were the reinforcement of emission regulations, awareness of sludge not simply as some countermeasure such as a joint treatment plan, but as a problem threatening the entire industrial structure, and awareness of resource protection in the future for the whole environmental water system.

Summary of Chapter 4 Examination of Examples of Large (Joint) Treatment Systems

It is clear that an easygoing way of planning joint treatment systems have caused the primary obstacle to their operational management.

While large treatment and joint treatment are partially effective to control pollution and protect the environment, they also make it easier to blame others for being the source of emissions. This conceptual environment causes a lack of responsibility for emissions, which, in turn, limits a centralized treatment, technically and socially.

As is clear in Chapter 3, a complete system is desirable. It is proved that sub-systems only shift the pollution source. The need for technical development as a recycling system was clearly brought out.

Summary of Chapter 5 Analysis of Emission Control System Technologies

Based on the problems revealed in the analysis of the actual condition of the industry, this chapter analyzes and evaluates current techniques in order to design a complete recycling system.

This analysis and evaluation examine how to develop sludge treatment, the main subject in this report, the kinds of techniques and ways of thought required for that development, and affinity with the social system.

Summary of Chapter 6 Fundamental Concepts of Sludge Treatment and Disposal Systems

This survey of the state of the industry made abundantly clear the problems of sludge treatment in the surface treatment industry, especially in the metal plating industry.

First, sludge treatment technology should target recycling and resource production again. Mere treatment (reclamation) will lead to other forms of pollution, such as secondary pollution, and prevent the effective use of resources (by collecting for reuse).

Second, when joint treatment is carried out, management's awareness of environmental protection must be sincere. Managers need to understand fully that their goals can be achieved only by making satisfactory management possible.

Third, financial incentivies and assistances from government are expected.

Fourth, metal plating techniques need to focus on converting the industrial structure into a closed system where harmful substances cannot escape at the polluting source. The closed system is stated herein as the future basic plan for sludge treatment and disposal.

Chapter 2 Sludge Emission

2.1 Waste Water According to Process Used in Plating Industry

There are three major sources of water pollution.

1) Rinsing water emission
2) Water recovered from plating
3) Aged treated water (small amounts but concentrated)

2.1.1 Plating Industry Processes

A) Preliminary treatment process

In preliminary treatment, barrel polishing and chemical polishing remove burrs from the surface of materials when, for example, too much oil adheres to it or rust and scales are hard to remove.

Emitted waste water is rich in chemical activity — it contains numerous bases from heavy metals, oils (surface oil as well as oil residue in mud), surface-active agents that abstract sedimentation, and abrasive sediments and metal waste that cause blinding in pipes.

Table 2-1 shows the components in waste water and types of concentrated waste in the preliminary treatment process.

Table 2-1 Waste Components and Types of Concentrated Waste Water

Bath Type	Usual Waste Water Components	Types of Concentrated Waste
Solvent cleaning		Aged waste water (Organic solvents, solid materials)
Emulsion cleaning	Strong acid, strong alkali, oil, surface-active agents, iron	Aged waste water, Gas scrubbing waste water
Acid cleaning	Strong acid, metal ions	Aged waste water, Gas scrubbing waste water
Barrel polishing	Abrasives, metallic dust, surface-active agents	Aged waste water
Chemical polishing	Strong acid, metal ions	Aged waste water, Gas scrubbing waste water

Base metals: steel, copper, copper alloys, zinc alloys, etc.

a) Solvent cleaning

Trichloroethylene or pachloroethylene are usually used for solvent leaning although kerosene and light oil are also sometimes used.

Since these are used by a device with a condenser, cooling water is used as circulating or cleaning.

Caution must be taken since the acid-proof lining of concrete poles and synthetic resin pipes and pumps are eroded away by in these solvents when discharged in waste water routes.

b) Emulsion cleaning

Emulsion cleaning includes the water-in-oil type and oil-in-water type. The former is a system in which the water is dispersed into a large amount of oil and used when there is extensive oil adhesion. The latter is a system in which the oil is dispersed into a large amount of water and is used when adhesion is light.

Emitted waste water contains large amounts of floating oil and suspended oil. Unless removed through floatation, adsorption or coagulation, they may cause various problems in treating the water. Oil deposits on electrodes may reduce sensitivity; these materials may also cause blinding of the filter and dehydrator.

c) Acid cleaning

In addition to the use of sulfuric acid, hydrochloric acid and nitric acid either separately or together, an inhibitor is added to prevent hydrogen brittleness. Surface-active agents are also added in order to avoid misting.

Emitted waste water is rich in heavy metals such as iron, copper and zinc and is highly acidic. When concentrations of these metals increase, the water ages, but if the water has been used for cleaning surface on iron and steel, it contains a large amount of ferrous salt.

d) Barrel polishing

Barrel polishing includes the octagonal rotating type and the oscillating type. In either case, the material, medium, and compound are put into a machine.

Emitted waste water is rich in alkaline and solid inorganic and organic substances. Due to the surface-active agents in the water, it often foams.

Due to the structure of abrasives, the metal to be treated often becomes suspended as a particulate, but the amount of the compound to be used may be reduced significantly if the suspended matter is removed from the water and reused.

At facilities where the compound and rinsing water are constantly emitted, these compressible solid substances are deposited in a temporary sedimentation basin or a waste water storage tank, and the process of removing these substances from the facilities is quite costly.

The suspended medium also wears out the pump.

e) Chemical polishing

For copper or copper alloys, a mixture of sulfuric, nitric, and hydrochloric acids is used as mixing acid liquid for chemical polishing, and for the aluminum brightener treatment, a mixture of phosphoric and nitric acids is used.

In recent years, however, chemical polishing using hydrogen peroxide has been used more often in order to combat various problems. These include the production of exhaust gas during the process and deterioration of the working environment due to nitrogen oxides that are also produced, caused by the use of strong acids such as nitric acid and chromic acid. However, waste water emitted by this process produces a large amount of sludge due to its high acidity and the large amount of metal ions it contains.

B) Pre-treatment Processes

Pre-treatment processes are as follows.

a) Degreasing process to remove grease and oil adhering to the element before beginning the plating process.
b) Acid cleaning process to eliminate oxides on the surface.
c) Rinsing process to perform (a) and (b) simultaneously.
d) Activation process to improve plating adhesion by activating metal surface.
e) Surface treatment process to intensity adhesion of the electroless plating by etching and sensitizing plastic surface without conductivity.

Although acid, alkali and other cyanide baths are often used, cyanide has recently been replaced by large amounts of EDTA, gluronic acid soda, amines, hydroxy acetate and other organic chelating agents. It has become more difficult, therefore, to eliminate heavy metals from waste water with sufficient sedimentation solely by adjusting the pH. Moreover, since surface-active agents abound in cleaning solutions, emitted water often foams when n-hexane soluble substances (resins) increase. Particular caution must be taken when handling aged waste water and cleaning solutions soaked into filter cloths.

The following table shows the components in waste water and types of concentrated waste in pre-treatment processes.

Table 2-2 Waste Components and Types of Concentrated Waste Water

Bath Type	Usual Waste Water Components	Types of Concentrated Waste
Alkali cleaning	Strong alkali, oil, surface-active agents, SS	Aged waste water, cleaning solutions soaked into filter cloths
Emulsion cleaning	Strong acid, oil, surface-active agents, heavy metal ions	Aged waste water, cleaning solutions soaked into filter cloths,gas scrubbing waste water
Electrolytic cleaning	Strong alkali, oil, surface-active agents, chelating agents, cyanide	Aged waste water, cleaning solutions soaked into filter cloths,gas scrubbing waste water
Activation (neutralization)	Strong acid, strong alkali, chelating agents	Aged waste water
Surface-smoothing	Strong acid, hexavalent chromium, all chrome	Aged waste water, recovered water, gas scrubbing waste water
Sensitization	Strong acid, tin, palladium	Aged waste water

Surface: steel, copper, copper alloys, zinc alloys, plastics

a) Alkali cleaning (degreasing) solution

Small amounts of surface-active agents are added to caustic soda or ortho sodium silicate soda to clean steel surfaces. They are added to sodium carbonate, trisodium phosphate, or ortho sodium silicate, either alone or in combination, to clean surfaces of copper and zinc alloys.

Since most products begin with this process, large amounts of surface oil are present. If oil separation and continuous filtration using differences in specific gravity are carried out, then the new cycle is greatly improved. Moreover, although aged waste water is treated by a separate process or by diluting the alkali system, preliminary cleaning or treatment of particularly dirty products after using emulsion is more efficient and economical.

b) Emulsion cleaning

Acidic emulsion baths of hydrochloric acid and sulfuric acid are often used. Cleaning and derusting are performed through emulsification, dispersion, penetration, and wetting. This process is used often for barrel zinc plating over iron steel. Due to the re-plating of defective products and zinc dissolution of resistance welding on the metal fittings for electrodes inside of the barrel, there is a large amount of zinc present in the emitted waste water in addition to ferrous ions that are produced during the process. Particular caution must be taken when treating the water in this process since it contains suspended oil as well as surface-active agents.

c) Electrolytic cleaning

This process is carried out in order to remove light residue after the processes previously explained in a) and b) have been completed. Depending on the element, anode electrolysis, cathode electrolysis, or both, or PR electrolysis is performed to clean the surface using oxygen or hydrogen gas bubbles. In this process, oxide films, etching and electrocoating of dissolved metals sometimes will be formed.

The baths are divided into two groups. The first is a cyanide bath consisting primarily of caustic alkali and chelating agents. The second is a non-cyanide bath consisting primarily of caustic alkali, carbonate, light acid, phosphate chelating agents and surface-active agents. The effluent from the first bath cleaning with steel, iron melted from elements or smut generates ferrocyanide. Since the usual method of such effluent treatment cannot adapt to the pollution control standards the second bath type is more often used. Since such chelating compounds as iron, copper and zinc are generated, caution must be observed even when using the second bath type.

In addition, the bath generates a heavy alkali mist. Although cleaning equipment to address exhaust air and gas is normally installed, problems may still arise if the circulating cleaning water is not sufficiently treated.

d) Activation, neutralization and acid dipping

A bath of sulfuric acid, hydrochloric acid and caustic soda is normally used. The amount of metal ions in the emitted water is relatively small and can easily be rendered harmless by adjusting the pH.

Concentrated waste water can be used to adjust the pH.

e) Pre-treating plastics

This pre-treatment facilitates surface cleaning and deposition of electroless plating. It cleans, smooths surface treatment, sensitizes and neutralizes to improve adhesion.

Bath types include cleaning solutions (sodium carbonate, tertiary sodium phosphate and surface active agents), etching fluids (chromic acid anhydride, sulfuric acid and phosphoric acid) and sensitization solutions (stannous chloride, palladium chloride and hydrochloric acid).

Etching fluids are particularly problematic. Since chromic acid is highly concentrated, much hexavalent chromium must be extracted. Moreover, since the chromic acid oxidizes the resin itself becomes trivalent chromium, the addition of organic substances and trivalent chromium ages the solution.

This, then, is the largest source of sludge in plating plastics. Although a recovery vessel is usually in place, as long as concentrated impurities are not forcefully eliminated, recovery is meaningless.

Since the air is stirred, recovery using a cyclone recovery tank is better than wet cleaning in terms of mist recovery.

C) Plating Processes

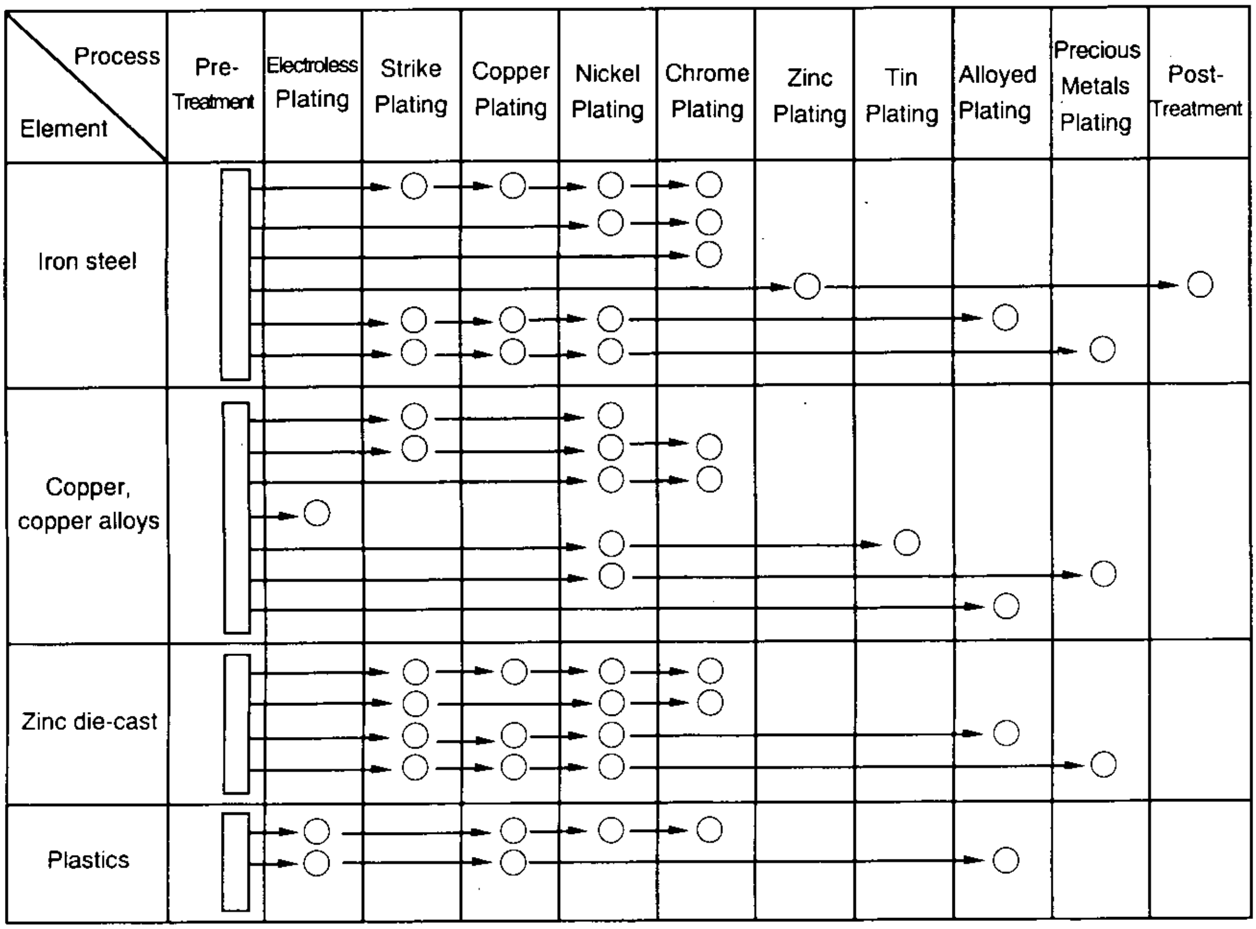
Table 2-3 shows the main industrial plating processes.

Although industrial chrome plating and zinc plating of iron steel are single-layer plating, all others are multi-layer plating. In multi-layer plating, rinsing is always performed between processes. Neutralization and activation are sometimes interjected as well. This is the source of ordinary waste water, and sludge, in the plating process. Table 2-4 shows the components in waste water and types of concentrated waste.

a) Electroless plating

Although copper and nickel are largely used in electroless plating, since many reducers and chelating agents are also included, neutralization alone will not separate out heavy metal sedimentation.

Table 2-3 Typical Plating Process Table



Process Element	Pre-Treatment	Electroless Plating	Strike Plating	Copper Plating	Nickel Plating	Chrome Plating	Zinc Plating	Tin Plating	Alloyed Plating	Precious Metals Plating	Post-Treatment
Iron steel	▯		○	○	○	○					
					○	○					
						○					
							○				○
			○	○	○				○		
			○	○	○					○	
Copper, copper alloys	▯		○		○						
			○		○	○					
					○	○					
		○									
					○			○			
					○					○	
									○		
Zinc die-cast	▯		○	○	○	○					
			○		○	○					
			○	○	○				○		
			○	○	○					○	
Plastics	▯	○		○	○	○					
		○		○					○		

The main products used when performing electroless plating are copper sulfate, formalin, potassium sodium tartrate, gluconic acid, sodium citrate, thiourea, and organic amines.

Types of electroless nickel baths include nickel sulfate, hypophosphoric acid soda, ammonium chloride, tartaric acid soda, hydrazine, EDTA, glycolic acid, hydrated boron, and acetic nickel. Electroless baths are fundamentally different from electroplating baths in that the chemicals are not supplied from the metal plate to be plated, but by the state of the ions.

With electroless plating baths, the temperature is generally unstable, bath control is difficult, and aged waste water is easily generated. Concentrated waste water is treated separately by thermal decomposition or by dilution injection. Since chelating agents abound, separating heavy metals is difficult. With an increase in BOD and COD, offensive odors are sometimes released and treatment and colorless treated water is difficult to obtain.

b) Strike plating

A recent transition towards non-cyanide baths has prompted a move towards non-cyanic strike plating.

Since copper cyanide strike baths are plating baths with low-concentration, when a cyanide bath is used in copper plating, in most cases, copper plating is performed directly without rinsing after strike plating.

Table 2-4 Waste Components and Types of Concentrated Waste Water in Plating Processes

Types of Plating Baths		Emitted Components	Types of Concentrated Waste Water
Electroplating	(nickel, copper)	Nickel, copper, alkali, reducers, chelating agents	Aged waste water, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
Strike plating	(copper cyanide, nickel)	Copper, cyanide, alkali, nickel	Recovered liquids, when eliminating sodium carbonate, Waste water from gas cleaning tower
Copper plating:	Cyanide bath	Copper, cyanide, alkali	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
	Sulfur bath	Copper, acid	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
	Pyrophosphoric acid bath	Copper, pyrophosphoric acid, ammonia	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
Nickel plating:	Ordinary nickel	Nickel, acid	Recovered liquids, cleaning solutions soaked into filter cloths
	Semi-gloss nickel bath	Nickel, acid	Recovered liquids, cleaning solutions soaked into filter cloths
	Gloss nickel bath	Nickel, acid	Recovered liquids, cleaning solutions soaked into filter cloths
	Tri-nickel bath	Nickel, acid	Recovered liquids, cleaning solutions soaked into filter cloths
	Black nickel bath	Nickel, zinc, cyanide	Recovered liquids, cleaning solutions soaked into filter cloths
Chrome plating:	Ordinary bath	Chromic acid, acid	Recovered liquids, waste water from gas cleaning tower
	Fluoride bath	Chromic acid, acid, fluorine	Recovered liquids, waste water from gas cleaning tower
	Hydrofluosilic bath	Chromic acid, acid, fluorine	Recovered liquids, waste water from gas cleaning tower
	Industrial chrome bath	Chromic acid, acid, fluorine	Recovered liquids, aging solutions, waste water from gas cleaning tower
	Black chrome bath	Chromic acid, acid, zinc	Recovered liquids, waste water from gas cleaning tower
Zinc plating:	Cyanide bath	Zinc, cyanide, alkali	Recovered liquids, cleaning solutions soaked into filter cloths, when eliminating sodium carbonate, waste water from gas cleaning tower
	Zinc chloride bath	Zinc	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
	Zinc sulfate bath	Zinc, acid	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
	Zincate bath	Zinc, strong alkali (cyanide)	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
Tin plating:	Alkali bath	Tin, alkali	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
	Acid bath	Tine, strong acid, fluorine	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
Precious metal plating: (gold, silver, rhodium,etc.)		Gold, silver, rhodium, cyanide	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
	Copper-zinc alloy	Copper, zinc, cyanide	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
Alloy plating:	Copper-tin alloy	Copper, tin, cyanide	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower
	Lead-tin alloy	Lead, tin, fluorine	Recovered liquids, cleaning solutions soaked into filter cloths, waste water from gas cleaning tower

Ordinary nickel bath and nickel chloride bath non-cyanide baths. Non-cyanide copper baths are also marketed. Therefore, treatment that suits the liquid properties of the following plating baths is, necessary. It generates waste water.

c) Copper plating

Copper plating baths generally include copper cyanide baths, copper pyrophosphoric acid baths and copper sulfate baths. Since each plating bath includes much copper metal, it is therefore necessary to decrease drawing the solution from the bath as little as possible

◎ The alkali-chlorine oxidation method is usually used in treating waste water from copper cyanide baths. After the cyanide is oxidized, copper sediment is separated as a hydroxide.

It is difficult to protect the waste water standard because an iron cyanide complex salt is generated and this does not separate in the normal alkali-chlorinie oxidation method. Also the installation place of the plating bath should be carefully chosen, and the greatest care must be taken to prevent the outflow of the plating bath when handling the filtrator used in continuous filtration.

◎ Copper in waste water from the pyrophosphoric acid bath does not sink even if the PH is adjusted. Therefore, the waste water should be treated by joining it with chromic acid waste water or by adjusting the PH after converting the waste water into strong acid and then into copper orthophosphoric acid to separate sedimentation as copper hydroxide. Furthermore, potassium pyrophosphate sedimentation can sometimes be separated by using hydrated lime.

◎ The waste water from a copper sulfate plating bath can be separated sufficiently by adjusting the pH. However, it is difficult to return it to the recovery tank because the bath temperature is at room temperature.

Several ways of eliminating electrolytic mist are available — increasing the static pressure of the ventilation to increase the amount of waste water returned to the recovery tank after most of the plating bath evaporates or by using a forced concentration. Some such method must be upplied.

In addition to the above, boric-fluoride baths are also used for higher speeds. In addition to copper fluoborate and fluoboric acid, potassium sodium tartrate, thiouria, potassium rhodanate, and organic additives are also used as additives. In any case, the treatment of waste water and concentrated waste water is fraught with problems.

d) Nickel plating

Multi-layered nickel plating is on the rise.

Semi-gloss nickel plating, gloss nickel plating, and chrome plating improve corrosion-resistant.

These are, basically, Watt baths using nickel sulfate, nickel chloride and boric acid. As the nickel concentration inside the bath rises due to the plating speed, the drawing amount from the bath must be decreased.

Moreover, black nickel plating is used for special applications. Caution must be taken when handling waste water from the black nickel bath since it also contains zinc and cyanide.

e) Chrome plating

Chromic acid is usually the primary component in chrome plating, although small amounts of sulfuric acid or fluoride are also included.

Most of the chrome exists as hexavalent chromium in this bath, although a touch of trivalent chromium is also present.

The metal concentration is much higher than in other plating baths and the extracted amount is unusually large. Since the plating bath is strongly acidic, much raw metal is eluted from the bath. In particular, the raw metal is intentionally eluted from the bath in industrial chrome plating. This poses the problem of handling aged waste water.

There is no problem in recovering liquids after plating for industrial chrome plating in which the amount drag out is small. The converse is true, however, in decorative chrome plating in which the amount drag out is large, even with a normal bath of relatively high bath temperatures.

This is easily seen in baths that use fluoride because the bath temperature is lower than usual.

Therefore, a variety of methods are necessary for forcible concentrated recovery. A process consisting of the elimination of impurities and concentration is essential to complete recovery and recycling.

In addition to the chemical treatments above, some normal waste water can be discharged after absorbing chromic acid by using ion exchange resin.

Batch treatment in which the bath separation of absorbed chromic acid is entrusted to the mine smelter and separated at the plant site is sometimes used.

f) Zinc plating

Zinc chloride, zinc sulfate and zincate (low-cyanide baths of non-cyanide) baths have come into greater use in recent years. Cyanide baths, however, have several advantages over non-cyanide baths, whose use still prevails.

In addition to still plating, barrel plating is widely used in zinc plating. Care must be taken, however, since drags out.

Emitted waste water contains many fats and oils and solid substances, in addition to heavy metals. Conversion to non-cyanide baths is only possible by having equipment that can carry out full pre-treatment and by a through-going bath control.

One characteristic of zinc plating is a low bath temperature. This makes it difficult to return recovered waste water to the recovery tank.

Waste water must be returned through the concentration process. At present, waste water is diluted or jointly treated. Moreover, care must be taken when handling filter cloth cleaning solution, sodium carbonate removed by the cooling method, the circulating water of non-gaseous cleaning tower, etc.

Treating waste water from non-cyanide baths is easy. Either by converting it into zinc hydroxide by adjusting the pH or by absorbing the zinc using cation exchange resin, the resultant sludge and bath separating solution can easily be recycled as a metal resource.

g) Other plating

◎ Tin plating

Alkali, sulfuric acid, and boric-fluoride baths are on the process of tin plating. The neutralization and sedimentation methods are used to treat waste water from alkali and sulfuric acid baths. Hydrated lime is used for sedimenting the waste water from boric fluoride baths as calcium fluoride. Residual fluorine is eliminated by ion exchange resin.

◎ Precious metals plating

Since gold, silver, and rhodium plating offer excellent physical and chemical properties, they are often used in ornaments and electronic parts. Since most of these composition liquids are bought as concentrated plating solutions sold on the market, the bath in liquid structures are not clear.

Some waste water contains cyanide. Since the fluid itself is extremely expensive, however, critical attention is paid to preventing extraction. Moreover, since the plating tanks are relatively small, pollution problems are rare.

◎ Alloy plating

Typical alloys include brass plating of copper and zinc and bronze plating of copper and tin. These have been used as decorative plating for building hardware, lighting equipment, and miscellaneous articles.

These are highly concentrated cyanide baths. The use of lead-tin and tin (boric fluoride baths) for tinning has grown in recent years with the development of the electronics industry.

Unlike the cyanide baths described above, boric-fluoride baths contain lead and fluorine so caution must be exercised.

D) Post-treatment Processes

Electroplating post-treatment processes include zinc plating and copper and copper alloy chromate treatments, peeling operations on defective and scratched products, etc., and coating of the chromate films of electric parts.

Table 2-5 shows the types of waste components concentrated effluents from post-treatment processes.

Table 2-5 Types of Waste Components and Concentrated Effluents from Plating Post-treatment Processes

Bath Type		Usual Waste Water Components	Concentrated Effluent	
Chromate treatment		Hexavalent chromium, all chrome, zinc, strong acid, (cyanide)	Aging solution	
Tin washing		Hexavalent chromium, all chrome	"	
Coating			Water booth waste water (SS, COD, BOD)	
Plating stripping:	Chrome stripping	Hexavalent chromium, strong alkali, all chrome, strong acid	Aging solution	Waste water from gas cleaning tower
	Copper and nickel stripping	Copper, nickel, strong acid, cyanide, chelating agents	"	
	Zinc stripping	Zinc, strong acid	"	
Jig stripping:	Chrome stripping	Hexavalent chromium, strong alkali, all chrome, strong acid	"	
	Other metal stripping	Copper, nickel, zinc, tin, lead, strong acid,chelating agents	"	
Coating stripping		Strong alkali, organic substances, strong acid	"	

a) Chromate treatment

Chrome plating and highly concentrated chromic acid baths have been equally used in chromate treatment baths after zinc plating for some time. Recently, however, in order to reduce the discharge of chromic acid, baths of low concentration have grown in use. Moreover, bichromate and chromate are often used instead of chromic acid anhydride for dark chromate.

Plating cleaning is incomplete and often produces cyanide in the chromate bath with zinc plating from a cyanide bath. When this occurs, the cyanide is not treated, but diluted by waste water from other water routes and discharged. Furthermore, the cleaning water of the chromate treatment contains a considerable amount of zinc in addition to chromic acid, and at times, the zinc content sometimes exceeds that of chrome.

Chromate baths in which a large amount of zinc has been dissolved, is added, as aged effluent, to dilute chromic acid-based waste water. Since the chromic acid concentration is low, zinc is extracted from the chromate bath by cation exchange resin. This partially serves as a way to prevent the generation of aged solutions.

b) Plating stripping

Like acid cleaning and other pre-treatments, stripping causes the metal layers to be dissolved in the solution. Thus, the waste water, besides containing large quantities of heavy metals, is often strongly acidic or strongly alkaline.

Table 2-6 shows the usual peeling methods.

Table 2-6 Examples of Plating Stripping Methods

Plating	Base Material	Peeling Method
Copper plating	Steel	Electrolysis in mixed chromic acid and mixed sulfuric acid
	Copper, copper alloys (Copper carbonate + aqueous ammonia)	Brushing after soaking in sodium sulfide and caustic soda solutions
	Zinc die cast	Brushing or NaCN dipping after soaking in sulfur and sodium sulfide solutions
	Aluminum	Soaking in concentrated aqua fortis
	Plastics	Dipping in ferric chloride solution
Nickel plating	Steel	Soaking in hydrochloric acid after electrolysis in sulfuric acid solution
	Copper, copper alloys	Electrolysis in hydrochloric acid
	Zinc die cast	Electrolysis in sulfuric acid
	Plastics	Dipping in hydrochloric acid and hydrogen peroxide solutions
Zinc plating	Steel	Dipping in hydrochloric acid or sulfuric acid, electrolysis in caustic soda solution
Chrome plating	Steel	Electrolysis in caustic soda or sodium carbonate solution
	Copper, copper alloys	Dipping in hydrochloric acid
Tinning	Steel	Electrolysis in sodium nitrate solution
	Copper, copper alloys	Dipping in glacial acetic acid and hydrogen peroxide solutions

Stripping of chrome plating is done by soaking in hydrochloric acid and by electrolysis in a caustic soda or a sodium carbonate bath. Since the latter dissolves the plating as hexavalent chromium, great care must be taken when discharging the waste water.

Cyanide and non-cyanide baths can be used for copper and nickel stripping. Strong chelating agents are present in both. As for aged effluents in cyanide baths, great care must be taken by diluting with normal waste water or by requesting joint treatment.

Stripping of copper and nickel from jigs is dissolved by soaking in concentrated nitric acid. Care must be taken to prevent a deterioration of the work environment and complaints from the neighborhood because of the generation of nitrogen oxides and acid fumes.

Zinc plated defective on scratched products, and electrified hardware of barrel are usually removed in the pre-treatment acid cleaning process without a special stripping operation. Since acid cleaned waste water is generally treated mixed with chromic acid based waste water, zinc stripping in a special stripping bath is preferred to avoid injecting chrome and iron into the zinc sludge.

c) Coating and coating stripping

There are many plating products, such as zinc chromate electric parts and brass- and bronze-plated decorative products that are coated with a transparent film after they are coated. Both water-based and oil-based paints are applied as the transparent coating by dipping, spraying, and electrostatic coating. None of these methods emit waste water, making it difficult to treat water booth circulating cleaning water.

Scum compositions are organic polymers and many contain flammable solvents. If incinerated, black smoke will erupt. If allowed to flow into a waste water treatment facility, clogging of the filter or erosion of the lining materials by the solvents will occur. Coating that is dispersed in the water increases the COD and BOD in the waste water. Moreover, strong acid and alkali baths are used to peel defective products; precaution must be taken in handling the waste water and waste fluids.

2.2 Chemicals Used and Sludge Amount

2.2.1 Chemicals Used in Plating

Various types of chemicals are used for metal plating. Not only the inorganic chemicals of heavy metals, but also organic chemicals, oils, solvents and others, that include heavy metals, are used. A list of the waste chemical compositions of these follows.

Note that buffing compounds are used in each process so they are summarized in the following tables. (2-7, 2-8).

Table 2-7 Types and Uses of Long Cylindrical Buffing Compound

Type	Name (Popular Name)	Buffing Compound	Use	
			Applicable Process	Processed Materials
With Fat and Oil	Buffing compound for sisal buffing (Sisal compound)	Fused alumina (Al_2O_3)	Rough polishing	Carbon steel, stainless steel, non-ferrous steel
	Emery paste	Fused alumina (Al_2O_3) Emery (Al_2O_3, Fe_3O_4)	Rough polishing (Main polishing)	Carbon steel, stainless steel
	Tripoli	Tripoli (SiO_2) Silica rock (SiO_2)	Main polishing	Iron, brass, aluminum, zinc die-cast, plastic, etc.
	(Crocus)	Iron oxide (non-refined) (Fe_2O_3)	Main polishing, finish polishing	Copper, brass, aluminum, Cu plating, etc.
	Lime (Matchless)	Baking dolomite (MgO, CaO)	Finish polishing	Copper, brass, aluminum, Cu plating, Ni plating, etc.
	White bar	Fused alumina fine (Al_2O_3) Kiln alumina (Al_2O_3)	Main polishing, finish polishing	Carbon steel, stainless steel, etc.
	Blue bar	Chromium oxide (Cr_2O_3)	Finish polishing	Stainless steel, brass, Cr plating, etc.
	Red bar	Iron oxide(refined) (Fe_2O_3)	Finish polishing	Gold, silver, platinum, etc.
	Buffing compound for plastic	Microlite silica (SiO_2)	Finish polishing	Plastic, ebonite, ivory, etc.
	Grease stick* (Grease bar)	---	(Rough polishing), (Solid processing oil)	Each type of metal, plastic (as processing oil for lubricating polishing wheel, abrasive belt, flap wheel)
Without Fat and Oil	Polishing compound (Greaseless	Silicon carbide (SiC)	Greaseless finish, (Satin finish, matte finish) These are used for rough polishing as well.	Each type of metal and non-metal materials: stainless steel, brass, zinc die-cast, aluminum, Cu plating, Ni plating, Cr plating, plastic, etc.

Note: * This belongs to processing oils rather than buffing compounds. In many cases, however, it is treated as a buffing compound because it is generally produced by buffing compound industries.

Table 2-8 Types and Uses of Emulsion Type Liquid Buffing Compounds (examples)

Type	Name	Buffing Compound	Use	
			Applicable Process	Processed Materials
For Air Spray	S-110	Fused alumina (Al_2O_3)	Rough polishing	Carbon steel, stainless steel
	S-115	Fine fused alumina (Al_2O_3) Baking alumina (Al_2O_3)	Rough polishing	Carbon steel, stainless steel
	C-310	Fine silica rock (SiO_2)	Main polishing	Brass, aluminum, zinc die-cast, plastic, etc.
	C-315	Tripoli (SiO_2)	Main polishing, main, finish polishing	Brass, aluminum, zinc die-cast, plastic, etc.
	M-520	Iron oxide (non-refined) (Fe_2O_3)	Main polishing, finish polishing	Brass, Cu plating, etc.
	M-520	Fine fused alumina (Al_2O_3)	Main polishing, finish polishing	Stainless steel, non-ferrous metal
	M-525	Baking alumina (Al_2O_3)	Finish polishing	Brass, aluminum, zinc die-cast, Cu plating, etc.
	F-810	Fine fused alumina (Al_2O_3) Baking alumina (Al_2O_3)	Finish polishing	Stainless steel, non-ferrous metal
	F-815	Chromium oxide(Cr_2O_3)	Finish polishing	Stainless steel, non-ferrous metal
	F-825	Iron oxide (refined) microlite silica (SiO_2)	Finish polishing	Plastic
For Airless Spray	No.1004	Fine silica rock (SiO_2)	Main polishing, main, finish polishing	Brass, aluminum, zinc die-cast, plastic
	No.1006	Tripoli (SiO_2)	Main polishing, main, finish polishing	Brass, aluminum, zinc die-cast
	No.1008	Baking alumina (Al_2O_3)	Main polishing, main, finish polishing	Stainless steel, aluminum, zinc die-cast
	No.1010	Baking alumina (Al_2O_3)	Main polishing, main, finish polishing	Stainless steel, brass, aluminum, Cu plating
	No.1012	Chromium oxide(Cr_2O_3) Baking alumina (Al_2O_3)	Finish polishing	Stainless steel, non-ferrous metal

The following is a list of chemicals used according to the treatment processes.

a) Chemicals used in the preliminary process

Table 2-9

Process		Chemical Name
Acid cleaning process		Sulfuric acid, hydrochloric acid, nitric acid, phosphoric acid
Degreasing process	Alkali degreasing	Caustic soda, sodium carbonate, ortho sodium silicate, tripoli sodium phosphate, surface-active agents, glucoric acid soda, other organic acids
	Solvent degreasing	Trichloroethylene, parchloroethylene, other organic halogen system solvents
	Electrolytic degreasing	Sodium cyanide, EDTA, caustic soda, surface-active agents, gluconic acid soda, other organic acids

b) Chemicals used in metal plating process

Table 2-10

Type of Metal Plating	Chemical Name
Zinc plating	Soda cyanide, caustic soda, sodium carbonate, zinc cyanide, zinc bloom, zinc sulfate, zinc chloride, zinc acid soda ($Na_2Zn(OH)_4$), chromic acid anhydride, nitric acid, organic brighter, ammonia, organic amine, EDTA, other chelating agents
Copper plating	Soda cyanide, caustic soda, sodium carbonate, potassium sodium tartrate, copper cyanide, copper cyanide soda, potassium copper cyanide, potassium pyrophosphate, ammonia, copper sulfate, electroless copper plating (copper sulfate, formalin, potassium sodium tartrate, gluconic acid soda, citric acid soda, thiourea, organic amine, surface-active agents, others), potassium rhodanate, organic brightener, selenic acid, boric copper fluoride, boric hydrofluoric acid
Nickel plating	Nickel sulfate, nickel chloride, boric acid, nickel ammonia sulfate, ammonia chloride, sodium copper, sulfonic acid, electroless nickel plating (acetic soda, hypo phosphoric soda, citric acid soda, succinic acid soda, malic soda, ammonia chloride, tartaric acid soda, hydrazine, EDTA, glicolic acid, citric acid nickel, etc.), organic brightener, formic acid nickel
Chromium plating	Chromic acid anhydride, sulphuric acid, boric hydracid fluoride acid, selenic acid, hydrofluoric acid, surface-active agents, fluoride ammonia
Tinning	Stannic acid soda, potassium stannum, stannum sulfate, cresol sulfonic acid, phenol sulfonic acid, stannum chloride, potassium ferrocyanide, caustic soda, caustic potassium. brightener, glue, acetic soda, boric stannum fluoride, boric hydracid fluoride
Cadmium plating	Cadmium cyanide, cadmium oxide, cadmium oxide soda, cadmium carbonate, caustic soda, caustic potassium, soda cyanide, cadmium chloride, cadmium sulfate
Solder plating	Boric stannic fluoride, boric lead fluoride, fluoboric acid, lead nitrate, lead oxide, stannic chloride, sodium stannic acid, caustic soda, stannic sulfomine acid, lead sulfomine acid
Alloy plating	Copper cyanide, zinc cyanide, sodium stannic acid, others
Noble metal plating	Potassium gold cyanide, potassium carbonate, potassium dihydrogen phosphate, potassium cyanide, potassium hydroxide, potassium pyrophosphate, EDTA, phosphoric acid, citric acid, potassium silver cyanide

Table 2-11 Amount of Chemicals Related to Metal Plating According to Use

Use	Qty. (kg/mo)	(%)	Examples (Numbers in Parentheses = Amount of Use in kg/month)
Metallic salt	747,000	29.8	Chromic acid anhydride (7,800), nickel sulfate (4,920), copper sulfate (1,120), nickel chloride (850)
Reducer	6,100	0.24	Hyposulphuric sodium (125), potassium pyrophosphate (394), formalin (40.6), boric acid (13.1)
Improver	70,300	2.80	Sodium bichromate (272), chromic acid anhydride (1,150), phosphoric acid (564), oxalic acid (375)
Cleaner	1,020,000	40.6	Sodium hydroxide (101,000), sulphuric acid (377,000), nitric acid (252,000), hydrochloric acid (178,000), fluoric acid (90,000)
Waste treatment	561,000	22.4	Coagulant (3,350), sodium hydroxide (129,000), hypochlorous acid soda (53,900), sulphuric acid (23,700)
For demineralized water	288		Sodium hydroxide (67.5), hydrochloric acid (160)
Dehydration	600		Acetone (600)
PH adjuster	11,800	0.47	Sodium hydroxide (8,880), nitric acid (2,260), aqueous ammonia (418)
Etching	40,000	1.59	Secondary iron chloride (31,200), iron liquid (1,000)
Degreasing	347		Inhibitor ① (346), inhibitor ② (1)
Inhibitor	23,300	0.93	Trichleae (4,640), sodium hydroxide (705), cleaner (2,650)
PH buffer	1,360	0.05	Boric acid (1,160), ammonia chloride (116)
Adjuvant	24,900	0.99	Soda cyanide (4,740), potassium cyanide (1,180)
Heat treatment	1,440	0.06	NS_1, NS_2
Fixture	1,180	0.05	Sodium sulfide (70)
Acceleration	562		
Others	152		
Total	2,510,000	100	

* Sulfuric acid includes sulfurous acid and sulfide. Boric acid includes boric fluoride. Phosphoric acid includes pyrophosphoric acid, polymerized phosphoric acid, and inhibitor. Hydrochloric acid includes perchloric acid, hypochlorous acid, and heavy hypochlorous acid. Chromic acid includes dichromic acid. Tartaric acid includes EDTA. Fluoric acid includes silic fluoride.

** Basically, sodium hydroxide is for the PH adjuster and pre-treatment, and sulphuric acid, nitric acid, and hydrochloric acid are for pre-treatment.

2.2.2. Plating Industry Sludge

A) Estimate of Sludge

The following are the main substances considered to be sludge.

1) Hydroxide of each type of metal
2) The substance emitted when insoluble substances such as oil and fat coagulate and precipitate.
3) Polymer coagulant
4) Calcium sulfate and calcium hydroxide (the substance that results when lime is used in the neutralization process)

It is very difficult to estimate the amount of sludge. In general, however, sludge emitted in the plating process mostly occurs during the neutralization, coagulation, and sedimentation processes.

An experiment to estimate the amount of sludge is given below.

<Experiment>

All the samples except for chrome are cut by a drill. One gram of each sample of drillings is melted by nitric acid and hydrochloric acid to make a one-liter solution.

The amount of sludge is found when 0.1 g of each solution is extracted from the liter and adjusted to its optimal pH value with 1N of caustic soda.

In addition, the amount of sludge in chrome is estimated by weighing 1 g of chrome from anhydrous chromic acid, reducing it by acid sulfite soda ($NaHSO_3$), and then neutralizing it.

Figure 2-1 shows the time series variations in the amount of sludge emitted from 0.1 g each of copper, nickel, chrome, zinc, iron, and aluminum.

Figure 2-2 shows the time series variations in the amount of sludge consisting of two different components (zinc-chrome, alminum-iron, copper-nickel, and copper-iron). The mixture ratio is 1:1, and the indicated amount is from 0.1 g. The procedure is the same as the one above.

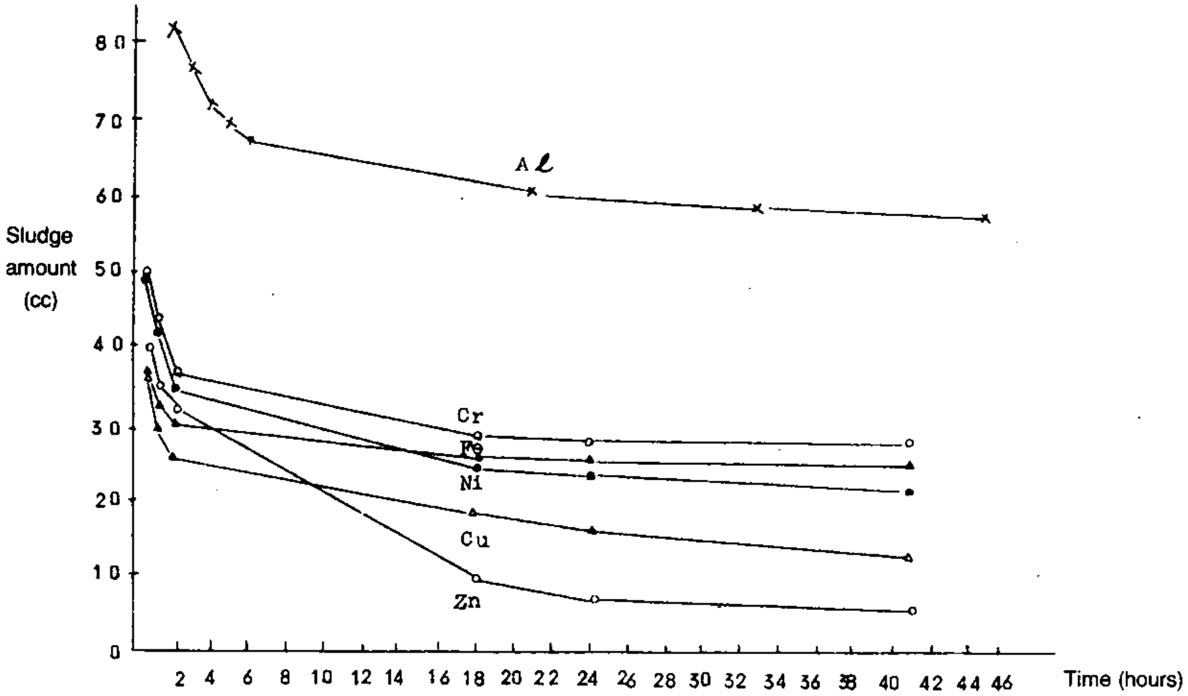


Figure 2-1 Amount of Sludge Emitted When Acid Solution with 0.1 g of Each Metal is Neutralized by Caustic Soda (IN)

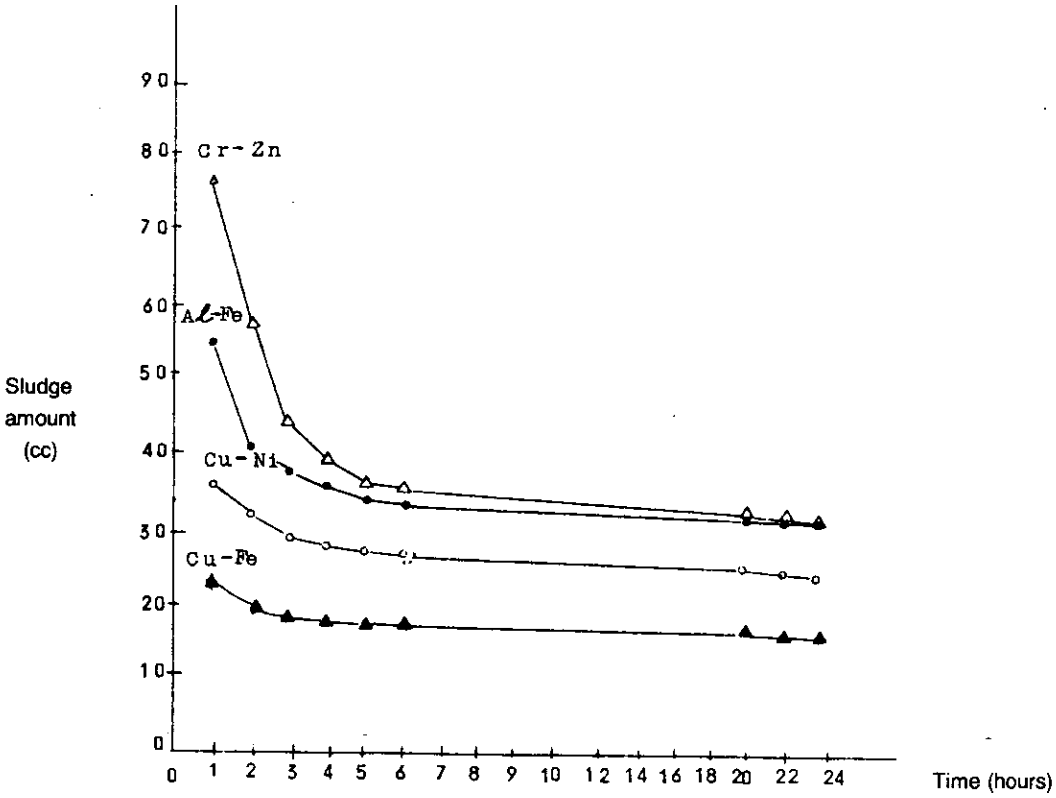


Figure 2-2 Amount of Mixed Sludge Emitted by Melting 0.1 g of Mixed Metal (1:1) and Applying Neutralization Process (Secular change)

The amount of sludge depends on each metal. However, it is obvious from the figures that the amount is tremendous.

Among six types of metal, zinc sludge was minimal, its total being less than 10% that of aluminum.

However, aluminum sludge decreases when iron is mixed in it, and zinc-chrome exhibits the same figure as aluminum-iron.

Metal hydroxides themselves serve as coagulants for these metals. The amount of sludge decreases when two types of metal have a coagulating effect on each other.

As is clear from the previous figures, sludge from metals is emitted even from 0.1 g of metal. In order to convert these into volume, each metal should be multiplied by its specific gravity.

The following table shows the amount of sludge emitted from 1 m^3 of six types of metal.

Table 2-12 Amount of Sludge Emitted from 1 cm^3 of Metal

Name	Specific Gravity	Amount of Sludge Emitted from 1 g (cc)	Amount of Sludge Emitted from 1 cm^3 of Metal (cc)
Cu	8.96	120	1,075
Ni	8.60 - 8.90	205	1,763 - 1,824
Cr	6.92	275	1,900
Zn	7.04 - 7.16	50	352
Fe	7.85 - 7.88	245	1,925
Al	2.70	575	,552

The amount of sludge varies greatly depending on the temperature of the solution, pH, types and added amounts of coagulant, the density of waste water, the type of neutralizer, churning condition, and the shape and capacity of the sedimentation tank.

The following table shows the variations in the amount of sludge emitted.

Table 2-13 Relationship Between Neutralizer and pH in Sludge
(metalof 0.1 g, after 7 hours, unit: ml)

Type of Metal	Type of Neutralizer pH	NaOH	Na_2CO_3	$Ca(OH)_2$
Cu	7.0	53 ml	47 ml	-
	7.5	-	-	30
	8.0	47	-	45
	10.0	38	47	40
Ni	9.0	28	20	29
	9.5	32	52	37
	10.0	32	-	33
	10.5	-	52	-
Cr	7.0	-	27	21
	7.5	-	14	15
	9.0	20	-	-
Zn	8.0 - 9.5	36 - 44	28	-
Fe	4.0 - 10.0	38 - 50	34 - 45	-
Al	5.0 - 8.5	140 - 165	125 - 140	-

In order to examine the relationship between the type of alkali and pH variation, salt containing 0.1 g/l of sludge was extracted into a measuring cylinder of one liter from each of six types of metal, and the pH was adjusted by a neutralizer (three types of alkali of 0.5N).

This amount of sludge was measured after seven hours.

Cu emitted the least amount of sludge (30 ml) when the pH was adjusted to 7.5 by lime, and the most amount of sludge (53 ml) when the pH was adjusted to 7.0 by caustic soda.

The ratio was slightly greater than 1:1.7.

Similarly, nickel had a ratio of minimum and maximum amounts of sludge of just over 1:1.8. Chrome was slightly over 1:1.9. The ratio of zinc was slightly over 1:1.5. Iron was just over 1:1.4 and aluminum slightly greater than 1:1.3.

Therefore, the amount of sludge emitted by neutralization with lime is smaller than average.

This is due to the coagulating effect of lime. In the co-precipitation system with this effect, the amount of sludge is not as large as that emitted by other neutralization methods as long as the pH adjustment by lime is suitable.

From the above, it is possible to estimate the amount of sludge emission. Conversely, it is possible to estimate from the amount of sludge how much metal is flowing out through the process.

Zinc and copper do not emit much sludge because their moisture content is smaller than that of other types of metals in the process of sludge emission. This also explains why filtration and dehydration can be performed easily.

B) Estimate of Amount of Sludge by Process

The amount of sludge is estimated based on the three processes below.

1) Sludge in the pre-treatment process
2) Sludge in the plating process (available metal sludge emitted by water cleaning after plating, and sludge emitted in chromate treatment and other so-called post-treatment processes)
3) Aged waste water sludge

Since the main component of sludge is metal hydroxide in the drag-out processes 1) and 2), the amount of sludge is based on the amount of solution drag out and the metal density.

In the acid cleaning process of 1), when the acid is still new, metal density is low. Therefore, the amount of sludge from the solution is small. As the acid ages, however, metal density increases sharply. Therefore, the amount of sludge emitted by extraction increases sharply as well.

In the plating solution in 3), the amount of sludge is proportionate to the amount of solution drag out because the density is almost constantly under control. Therefore, a countermeasure to reduce the amount of the solution drag out is needed to decrease the amount of sludge.

After iron and steel pass through acid cleaning and mixing acid liquid for chemical polishing of copper and copper alloys, 60 g/l of sludge will usually be found dissolved in these materials during the aging process. This concentration is higher than the metal concentration of the other general plating solutions except for that of chrome plating. This means that the amount of sludge emitted in the process of acid cleaning is extremely large. Moreover, the amount of sludge emitted when all of the acid cleaning solution is renewed will be enormous.

As to the acid cleaning solution in the aging liquid of 3), plants whose main work is zinc plating frequently discharge the waste water containing the sludge that exceeds the standard value, unless the aging liquid receives optimum treatment.

The following table shows major sources of sludge emission and their amounts.

Table 2-14 Estimate of Major Sources of Sludge Emission and Amount of Sludge

Source	Metal Density in Normal Condition g/liter	Metal Density in the Aging Process g/liter	Amount of Sludge from 1 Liter	Amount of Sludge when 1000 Liter of Solution is Renewed in the Aging Process
Cu plating A	60	-	7,200	-
Cu plating B	50	-	6,000	-
Ni plating	45	-	9,200	-
Cr plating	130	-	35,700	-
Zn plating	28	-	1,400	-
Acid cleaning solution for iron steel	0 - 100	60 ±	7,350 (When amount is 30 g/liter)	1,470 (When amount of sludge is 60 g/l)
Mixing acid chemical polishing solution for copper	0 - 100	60 }	3,600 (When amount is 30 g/liter)	720 (When amount of sludge is 60 g/l)
Low concentration chromate liquid	1-10 (as Cr)	Cr 2 - 20* Zn 5 - 20	Cr 550 - 5,500 Zn 250 - 1,000	Zn 500 Cr 2,750 (When metal is 10 g Zn and 10 g Cr)

The numerical value of the amount of sludge per one liter of the solution drag out is calculated by multiplying the sludge from 0.1 g of each metal by the metal density. The asterisk (*) mark indicates that the numerical value of the chromate solution varies. When the bath is set-up, the density is initially low (for example, 5 g/liter for $Cr0_3$), however, the density of $Cr0_3$ becomes several times as high as the initial value because chemicals are added during the operation.

In this table, Cu plating A is an example of a high-speed copper cyanide bath, B of a copper sulfate bath, and Zn of an ordinary cyanide bath.

Even though the amount of sludge from Zn plating is small, the total amount of sludge, including some by acid cleaning before and after Zn plating, chromate treatment, and renewing these solutions, is tremendous. It is difficult to recycle these as the mixed sludge. Therefore, techniques for recovering and recycling the metals before they turn into sludge are necessary.

C) Condition of Sludge by Emission Pattern

The compositions of sludge differ according to the type of plating, waste water treatment method, and the type of basic metal, even if the type of plating is the same. It also differs according to combinations of multi-layer plating.

Thus, the following table shows as examples the compositions of the mixed sludge of copper, nickel, chrome, and plating.

Table 2-15 Composition of Copper, Nickel, and Chrome Sludge

Water content (%)	Composition (dry base %)				
	Cu	Ni	Cr	Zn	Fe
98.5	6.0	13.0	15.7	0.1	-
91.9	6.0	13.2	14.0	0.1	-
96.5	4.4	12.9	4.6	14.0	7.0

The following table shows the composition of the mixed sludge of copper, nickel, and plating.

Table 2-16 Composition of Copper, Nickel, and Plating Sludge

Water content (%)	Composition (dry base %)				
	Cu	Ni	Cr	Zn	Fe
91.9	13.2	11.2	0.5	5.2	0.5
88.5	22.5	4.0	1.0	8.4	1.0
84.6	20.0	10.0	2.0	12.9	1.3

The following table shows the composition of the mixed sludge from the zinc chromate treatment liquid.

Table 2-17 Composition of Zinc Plating Sludge

Water content (%)	Composition (dry base %)			
	Cu	Cr	Zn	Fe
79.8	1.0	21.5	15.1	1.0
74.1	3.0	30.7	12.9	1.6
68.8	3.0	20.0	23.9	1.0

The following table shows the components of sludge and the results of the elution test, even though no relation is found between these two.

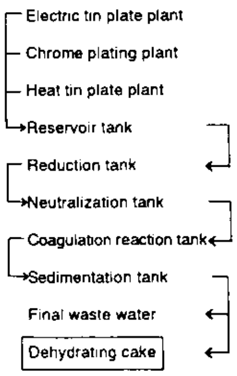
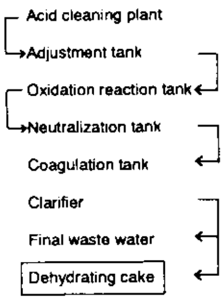
Table 2-18 Components Of Sludge and Results of Elution Test

Sample	Sludge	Water Content	T- CN	T - Cr	Pb	Cd	Cu	Ni	Zn
EX - 1	Composition (%)	98.5	0.08	15.7	0.23	Tr			
	Elution value (ppm)		-	0.02	0.08	0.01			
EX - 2	Composition (%)	85.9	0.03	34.1	0.04	Tr			
	Elution value (ppm)		-	-	-	-			
EX - 3	Composition (%)	86.7	2.7	13.8	0.13	0.02			
	Elution value (ppm)		0.20	0.14	-	-			
EX - 4	Composition (%)	75.8		0.33			42.0	1.3	7.6
	Elution value (ppm)			-			0.02	-	-
EX - 5	Composition (%)	91.9		14.4			6.05	13.2	0.09
	Elution value (ppm)			-			0.02	-	-

Note: The dashes (-) in the above table mean that no trace was detected.

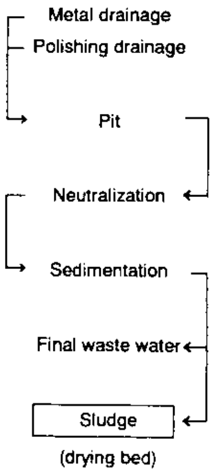
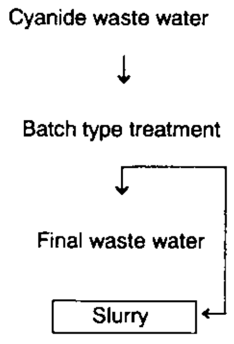
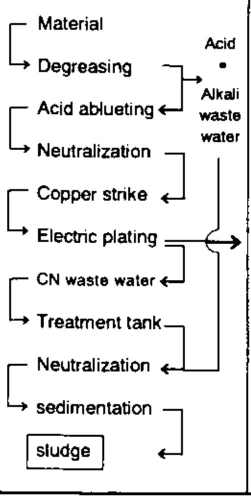
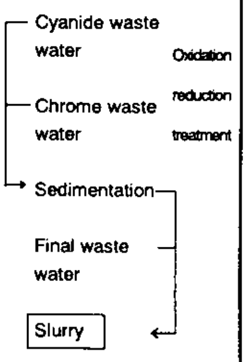
As is mentioned earlier, the components of sludge differ according to the type of plating. Actual examples are shown below to understand the nature of sludge from the manufacturing process perspective.

Table 2-19

Type of Plating / Condition		Iron Thin-Board Plating	Same as Left	Hard Chromium Plating	Same as Left
Plant No.		1	1	2	3
Area		Kyushu	Same as left	Chubu	Same as left
Place of emission		Coagulating sedimentation cake	Same as left	Waste water treatment sludge	Polishing chip
Amount of emission (Mo.)		2,000 t	1,500 - 1,800 t	1.5 - 2.0 t	0.05 t
Treatment measure		Reclamation of company-owned land	Same as left	Accumulation by company	Reclamation after burning
Appearance		Brown muddy condition	Light brown powdery condition	Green white gel	Grayish black metal powder
pH		10.6	7.4	6.8	6.4
Burned residue (%)		92.7	66.2	74.0	12.3
Water (%)		71.2	51.2	87.3	5.0
Hg	In sample	-	- (-)	0.004 (0.03)	-
	In solution	-	-	-	Not detected
Cd	In sample	Not detected	0.83 (1.7)	0.52 (4.1)	2.1 (2.2)
	In solution	Not detected	Not detected	Not detected	Not detected
Pb	In sample	49 (170)	15 (30)	43 (340)	43 (45)
	In solution	Not detected	Not detected	Not detected	Not detected
Cr	In sample	Not detected	Not detected	1,200 (9,800)	66 (69)
	In solution	-	Not detected	0.03 [VI]	Not detected [VI]
As	In sample	-	-	7.4 (58)	Cu - 280, Ni - 590
	In solution	-	-	Not detected	-
Process indication				-	Polishing chip ↓ Burning ↓ Reclamation

In sample	mg/kg	( )	Dry provision conversion value
In solution	mg/l	▭	Sample extraction

Type of Plating / Condition		Hard Chromium Plating	Electric Plating (Cu, Ni, Zn, Cr)	Same as left	Same as Left
Plant No.		4	5	6	7
Area		Chubu	Same as left	Same as left	Same as left
Place of emission		Waste water treatment sludge	Storage tank	Sedimentation sludge	Same as left
Amount of emission (Mo.)		0.05 t	0.006 m^3	0.08 m^3	0.02 m^3
Treatment measure		-	In waste water	Accumulation by company	Same as left
Appearance		Blue green clay	Brown gel	Gray brown gel	Black brown sandy
pH		10.2	10.6	8.2	8.2
Burned residue (%)		82.0	79.0	79.7	99.2
Water (%)		77.0	91.2	90.4	0.92
Hg	In sample	-	-	-	-
	In solution	-	-	Not detected	-
Cd	In sample	1.4 (6.0)	0.66 (7.5)	0.39 (4.1)	1.1 (1.1)
	In solution	Not detected	Not detected	Not detected	Not detected
Pb	In sample	940 (4,100)	68 (770)	35 (360)	150 (150)
	In solution	0.05	Not detected	Not detected	Not detected
Cr	In sample	53,000(230,000)	63 (720)	8,500 (89,000)	350 (350)
	In solution	Not detected (VI)	Not detected (VI)	Not detected (VI)	Not detected [VI]
As	In sample	Cu - 1100 Zn - 340 Ni - 73	-	Cu - 14,000 Zn - 830 Ni - 25,000	Cu - 5,300 Ni - 1,600
	In solution		Not detected		
		Chrome plating abluent water ↓ Reduction ↓ Coagulation sedimentation ↓ Decantation ↓ Sludge	No treatment ↓ Drainage	Waste water ↓ Reduction ↓ Coagulation ↓ Sedimentation ↓ Sludge	Materials ↓ Reeling polishing ↓ Polishing chip

Type of Plating Condition		Electric Plating Sn Stainless Steel Polishing	Same as Left Zn	Same as Left Cu, Zn, Pb, Sn	Same as left Die-Cast Foundation Cu, Ni, Cr
Plant No.		8	9	10	11
Area		Kanto	Same as left	Same as left	Same as left
Place of emission		Sand bed sludge	Storage tank	Drying bed sludge	Sedimentation sludge
Amount of emission (Mo.)		1 m³	0.1 m³	0.3 t	10 t
Treatment measure		Consignment treatment	Same as left	Accumulation by its company	Consignment treatment
Appearance		Yellow green clay	Brown slurry	Gray brown clay	Blue green slurry
pH		6.2	10.6	9.0	7.5
Burned residue (%)		82.2	66.6	78.5	77.4
Water (%)		83.7	95.4	83.3	97.5
Hg	In sample	3.9 (24)	0.13 (2.7)	0.73 (1.7)	0.02 (0.67)
	In solution	Not detected	0.002	Not detected	Same as left
Cd	In sample	0.69 (4.2)	0.44 (9.5)	2.0 (12)	Not detected
	In solution	0.040	0.005	Not detected	Same as left
Pb	In sample	5.2 (3.2)	0.84 (1.8)	9.6 (57)	Not detected
	In solution	0.07	2.1	Not detected	Same as left
Cr	In sample	-	-	-	-
	In solution	Not detected [VI]	Same as left	Same as left	Same as left
As	In sample	0.17 (1.1)	1.3 (2.7)	Not detected	0.03 (1.3)
	In solution	Not detected	Same as left	Same as left	Same as left
Process indication					

Type of Plating Condition		Electric plating chromate	Same as left (Zn, Sn, Cr, Ni)	Same as left (Cu, Ni, Cr)	
Plant No.		12	13	14	
Area		Kanto	Kyushu	Kanto	
Place of emission		Sedimentation tank	Dehydrating cake	Sedimentation tank	
Amount of emission (Mo.)		7 t	0.6 t	3 t	
Treatment measure		Consignment treatment	Company storage	Same as left	
Appearance		Gray green slurry	Brown cake	Brown mud	
pH		7.2	8.0	8.9	
Burned residue (%)		69.3	73.9	77.7	
Water (%)		96.1	74.7	38.0	
Hg	In sample	0.05 (1.2)	-	0.21 (0.34)	
	In solution	Not detected	-	0.032	
Cd	In sample	Not detected	-	95 (150)	
	In solution	Not detected	-	0.13	
Pb	In sample	0.26 (6.5)	240 (940)	1,100 (1,700)	
	In solution	Not detected	Same as left	1.4	
Cr	In sample	-	Not detected (VI)	3,400 (5,600)	
	In solution	Not detected	-	Not detected (VI)	
As	In sample	0.19 (5.0)	-	15 (24)	
	In solution	Not detected	-	Not detected	
Process indication		Chrome plating ↓ Waste water reduction treatment ↓ Sedimentation Final waste water ← Slurry ←	Zinc plating Copper plating Nickel plating Chrome plating → Cyanide reaction tank Chrome reaction tank ← ↓ Sedimentation tank ↓ Concentration tank ↓ Dehydrating equipment Final waste water ← Dehydrating cake ←	Cyanide waste water Chrome waste water Acid/Alkali waste water → Mixture ↓ Neutralization ↓ Sedimentation Final waste water ← Sludge ←	

Chapter 3 Analysis of Sources of Plating Sludge Emission

3.1 Industry Scale and Site Environment

In general, most of the metal plating industry consists of small and medium-size companies. This chapter discusses the scale of these companies and their on-site environment, using survey areas as examples.

The following table summarizes the 18 companies chosen as objects of the survey.

Table 3-1 Summary of Companies In Metal Plating Industry Survey

Name	Capital	Number of employee	Type of metal plating	Site area	On-site environment
A	thousand yen 8,000	56	Cr	(m^2) 7,405	Semi-industrial area
B	4,200	28	Cr, Zn	1,043	Prearranged area for park
C	5,000	35	Cr	1,320	Semi-industrial area
D	10,000	15	Cr	1,201	Industrial area
E	2,000	15	Cr, Ni	594	Residential area
F	10,000	35	Cr, Zn, Others	2,310	Residential area
G	10,000	86	Noble metal, Ni, Ci	1,406	Semi-industrial area
H	2,000	35	Cr, Others	660	Semi-industrial area
I	5,000	65	Zn	604	Semi-industrial area, but actually residential area
J	6,000	28	Zn	924	Residential area
K	3,000	30	Zn, Ni	495	Semi-industrial area
L	500	12	Zn, Ni, Cr	165	Residential area
M	2,000	10	Zn	132	Residential area
N	Principal 8,000	3	Zn, noble metal	66	Residential area
O	1,500	6	Noble metal, Zn	66	Semi-industrial area
P	Principal 44,300	14	Zn, Ni	1,036	Residential area
Q	1,000	15		145	Semi-industrial area
R	6,000	7	Metal plating flaking	165	Industrial area
Total (18 companies)				19,737	

3.1.1 Scale

A) Summary of metal plating industry

a) Many small-sized companies

According to the capital scale, ten of the companies (66%) are capitalized at below JPY 5 million, and 12 of them (67%) employ less than 30 people.

b) Long operating history

Only four companies have been operating less than ten years. Most of them have been operating more than ten years. Thus, small size and longevity of operation are common to most of the companies surveyed.

Table 3-2

Less than 10 years	10-15 years	15-20 years	More than 20 years	Total
4 22%	3 17%	4 22%	7 39%	18 100%

c) Type of metal plating

Members of plating associations are only those dealing exclusively with metal plating. Except for the 12 companies that deal with either zinc or chromium only, the others deal with two or more types of metal plating.

Table 3-3

Type of Metal Plating	Number of Companies
Zinc	6
Chromium	6
Zinc and chromium	2
Chrome and nickel	1
Noble metal plating	1
Zinc and nickel plating	1
Metal plating peeling	1
Total	18

d) Labor shortage

The lack of labor is a common problem for all types of companies. Twelve companies in the metal plating field (67%) claim a shortage in the labor force. Among the 18 companies, 32 employees are needed to meet the shortage. In addition, these companies experience other problems with personnel management, including salary raises, employee ability, and education and public welfare.

e) Active plant investment

Plant investment, and costs, from 1972 to 1975 are as follows:

Table 3-4

1972 (completed)	11 companies	61%	JPY 311,132 thousand
1973 (completed)	12	12	144,997
1974 (completed)	9	50	166,527
1975 (planned)	5	28	67,500

Plant investment was active during the bull market period from 1972 to early 1973. Even in tight-money lulls, however, plant investment remains active. Some JPY166.5 million is scheduled for investment in 1974.

B) Financial scale

a) Low growth percentage

According to sales trends over the past four years, average growth in 1972 was 75.8% (with 1968 sales at 100%). The annual growth rate is nominally 15.2%. Only two companies doubled in growth rate, while growth rates for two others were under 100%. Most of their customers belong to the transportation machinery and equipment manufacturing industry and the electric machinery and appliance manufacturing industry, both being growing fields. Such low growth rate is due to a posture and policy that failed to face growth amidst a lack of understanding of costs, other factors that push prices higher, and sales power.

Table 3-5 Sales Growth by Type of Metal Plating

Type / Year	1969	1970	1971	1972	1972/1968
Zinc companies	25.8%	8.7%	6.8%	7.0%	56.2%
Chrome companies	27.9	7.3	△7.3	5.3	51.6
Metal plating companies of many types	21.9	23.8	△9.9	27.2	73.1
Average	25.3	19.1	△5.0	13.1	75.8

Table 3-6 Sales Growth by Capital

Capital / Year	1969	1970	1971	1972	1972/1968
JPY 3 million and below	13.2%	12.5%	0.4%	14.5%	46.4%
JPY 5 million and below	81.4	15.2	△0.3	2.5	213.4
JPY 10 million and below	24.6	△16	37.2	19.0	71.1
Average	35.0	△ 2.2	17.4	13.4	75.8

b) Low profitability

Total capital turnover that reflects profitability indicates that the profitability of seven companies (39%) is below 2.3%, which is the average profitability of the plating industry in this prefecture. The capital revolving rate indicates that the rate at four companies is less than one time, which is the average of the prefecture, and the rate at nine companies (50%) is below 1.2 times.

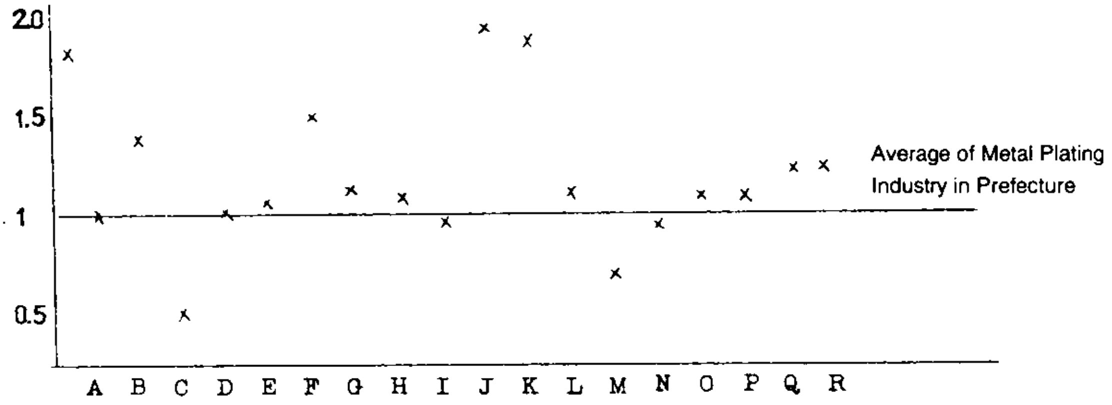


Figure 3-1 Capital Turnover

c) Financial affairs and differences among companies

Generally, all companies show high productivity, though some disparities exist. According to the monthly processing volume per employee, which expresses productivity, 12 companies (67%) have more volume than that of the average of the prefectural plating industry. The processing volume of six companies (33%), however, is below average. A clear disparity between high and low processing volumes exists.

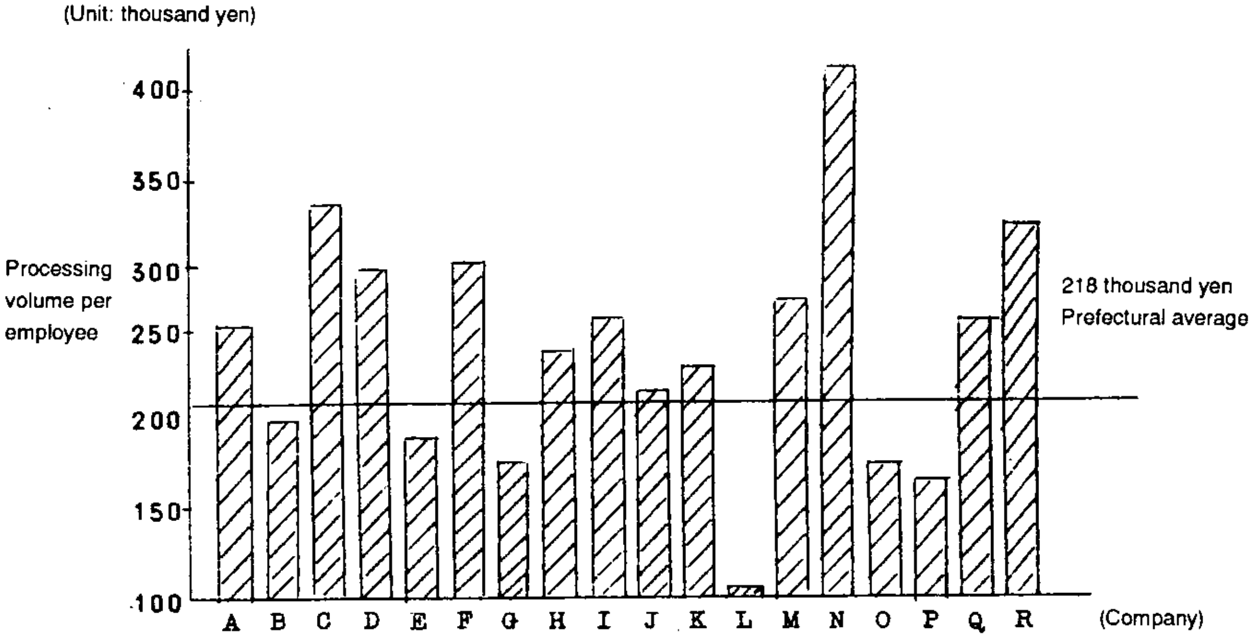


Figure 3-2

◎ Disparity in net worth ratio

Net worth ratio expresses the rate against total capital. Six companies (33%) are below 20.3%, which is the prefectural average, whereas ten companies (56%) are over 30% in net worth ratio. Therefore, disparity exists here as well.

The loan dependence ratio, on the other hand, is generally high. Nine companies exceed 36%, which is the prefectural average. The companies whose net worth ratios are low tend to have high loan dependence ratios. (See Total Capital Net Worth Ratio and Total Capital Loan Dependence Ratio in the Management Ratio per Member List.)

◎ Disparity in machine equipment ratio

The machine equipment ratio reflects machine equipment cost per employee. The prefectural average is JPY 525,000., with seven companies (39%) below the average. Seven other companies are above JPY 700,000., which is extremely high. This disparity is due to differences in labor-saving and rationalization through automation. (See Machine Equipment Ratio in Management Ratio per Member List.)

◎ Disparity in current ratio

The current ratio is the rate of current liabilities and current assets and expresses payment ability towards current liabilities. While the prefectural average in manufacturing industries is 113.5%, that of the metal plating industry is 82.9%. There is only one industry whose current ratio is below the prefectural average. In 1972, the economic environment was fortunate thanks to the easing in money. Capital liquidity was high. The disparity nevertheless remains. Ten companies (56%) have more than 150% for the current ratio, whereas four companies (22%) have less than 100%. (See Current Ratio.)

◎ Disparity in earning rate

The earning rate before depreciation indicates that more than half of the members have reached a standard above the prefectural average. The prefectural average is above 8.9%, but 11 industries (61%) exceed 10%. Despite maintaining a high earning rate, some companies whose earning rates are below the prefectural average have extremely low earning rates. Again, the disparity is conspicuous.

Table 3-7 Management Ratio List by Company

Manegament Ratio Name of Company	Operating Profit Rate of Total Assets	Turnover Ratio of Total Assets	Operating Profit Rate	Return on Total Assets before Depreciation	Current Ratio	Equity Ratio of Total Assets	Loan Ratio of Total Assets
	%	Turns	%	%	%	%	%
A	27.6	1.0	25.6	32.0	351.1	78.7	16.8
B	12.5	1.5	8.1	20.9	101.2	2.65	23.6
C	△ 2.8	△ 0.4	△ 6.5	1.3	203.4	7.4	60.6
D	8.4	1.0	8.2	15.3	101.9	27.4	43.0
E	4.1	2.0	2.0	8.7	131.3	38.6	16.8
F	17.4	1.1	15.8	31.5	130.2	33.8	41.0
G	11.0	1.6	6.7	17.3	280.9	56.5	18.7
H	7.5	1.2	5.8	12.3	221.0	30.9	46.2
I	△ 20.5	1.1	△ 17.1	△ 6.4	96.7	△ 0.6	80.2
J	2.3	0.9	2.5	8.6	97.8	12.1	54.4
K	19.5	2.2	8.6	27.3	191.4	65.5	9.0
L	2.2	1.1	2.0	1.6	56.0	0.4	83.8
M	11.9	0.6	19.9	19.2	262.0	51.9	32.0
N	24.1	0.9	28.1	15.2	95.0	46.6	33.5
O	1.1	1.2	0.9	9.8	159.7	15.4	52.1
P	7.5	1.2	6.0	19.5	375.9	78.6	0.3
Q	0.8	1.3	0.6	6.7	183.4	10.4	50.2
R	20.2	1.3	15.0	26.5	173.7	59.0	10.8
Member average	10.3	1.3	7.3	14.8	155.3	27.7	31.8
National average	10.8	1.6	7.1	10.5	133.1	29.6	-
Prefectural average of manufacturing industries	6.3	1.6	4.0	11.9	120.6	26.2	30.0

◎ Disparity in processing cost to personnel cost ratio

The average prefectural ratio of processing cost to personnel cost is 45.5%. Seven companies (39%) are below 40%, and six companies (33%) are above 50%. If this ratio exceeds 60%, profit growth rises more slowly because of personnel costs.

Table 3-8

Processing Cost of Each Employee per Month (thousand yen)	Machine Equipment Ratio (thousand yen)	Return on Investment of Machinery Turns	Material Cost Rate of Sales %	Processing Cost vs Personnel Cost %	Processing Cost vs Depreciation Cost %	Processing Cost vs Operating Profit Rate %	Total Assets vs Net Profit Rate %
262.7	783.2	6.4	22.7	28.0	5.3	33.2	24.7
204.4	395.4	10.8	7.8	35.2	6.8	10.2	9.2
333.6	1,452.1	3.2	20.4	42.3	12.0	△ 8.1	2.1
295.2	1,091.5	3.6	45.5	24.5	12.4	15.1	9.4
193.6	288.4	15.0	12.9	61.3	4.7	4.2	3.8
297.5	863.4	5.0	13.3	41.0	16.3	20.0	16.1
181.2	243.0	15.6	15.2	60.4	4.6	8.1	13.3
244.8	514.4	7.2	13.6	55.3	4.9	7.6	7.5
266.8	198.4	51.2	15.9	81.3	14.1	△ 20.5	△ 30.0
221.6	620.9	5.0	12.6	38.4	10.3	3.9	2.7
239.2	373.5	9.0	23.7	42.7	6.5	15.2	20.0
104.6	581.8	2.3	19.2	55.3		2.5	1.6
274.6	1,428.5	19.2		31.4	14.0	23.0	11.9
414.4	1,319.0	3.8	9.0	27.2	14.1	24.7	16.4
181.6	646.8	3.4	17.5	59.6	10.3	1.1	0.1
171.9	386.8	5.3	16.9	47.6	6.2	0.9	14.0
265.8	469.8	6.8	37.3	42.4	5.0	7.9	1.5
320.8	747.5	5.2	18.7	38.3	8.9	23.5	18.8
238.8	689.1	7.5	17.9	42.9	9.2	9.6	10.2
179.5	533.0	4.0	-	40.9	-	16.7	-
202	523	7.0	32.8	43.8	7.0	8.0	5.6

3.1.2 Site Environment

a) On-site environment of each company in the same area

According to the current on-site environment of these companies, nine companies (50%) are in residential areas. If the companies that are not supposed to be, but actually are, in residential areas, are included, then 16 companies (89%) are in residential areas. Most companies, then, are actually built in residential areas. As a result, they can easily receive complaints about pollution issues.

Table 3-9

Residential Area	Semi-industrial Area	Industrial Area	Total
9	7	2	18
50%	39%	11%	100%

b) Real estate

Both the land and buildings are owned by the companies in nine cases (50%). Either the company or the president of the company owns the land in 13 cases (72%). Three companies lease both land and buildings.

c) Site-specific awareness towards pollution issues

Twelve members (67%) mentioned anti-pollution measures as a management problem. Many members believe that investment in and management of pollution control equipment will increase costs. The more completely the company tries to profit from pollution control, the more money they lose, and no profit is ultimately realized. However, most members say that continued management will be difficult unless companies attack pollution control to clean up the environment, and pay less attention to profits.

d) Narrow industrial sites

According to many members, companies are actually in areas where houses stand close together. Site restrictions would prevent companies from expanding in the future were they to try. Moreover, companies possess a high proportion of pollution control equipment, some 20 - 25% of the entire industrial site.

3.2 Treatment Costs

As can be seen from Table 3-10 Plating-related Waste Treatment, 75% of waste is treated by the companies themselves and 25% is consigned.

Materials discharged into the water area after passing through the treatment facility, however, are also considered waste. The quality of the treatment, therefore, is unknown. Given the harm being caused to underwater life, the cost of providing and managing treatment facilities cannot be considered as being too high.

Consignment treatment is shown below.

Concentrated cyanide waste fluid:	55 yen/l	-	85 yen/l
Sludge (harmful):	3,500 yen/t	-	35,000 yen/t
Collecting and transportation:	3,500 yen/t	-	5,500 yen/t
Final disposal:	2,500 yen/t	-	5,000 yen/t
Collecting, treatment, and disposal:	25,000 yen/t	-	35,000 yen/t

The investment cost for the pollution control facility by the Kawasaki Metals Industrial Complex Plan is JPY 500 million. Eighteen companies are included in the complex and the precondition is that it be a closed system. If the average monthly discharge per company is 100 m^3, the depreciation fund and payment interest are calculated as follows:

[With depreciation over 10 years]
Facility depreciation cost JPY 500 million ÷ 10 years = JPY 50 million
Cost, interest (10%) = JPY 30 million
Total = JPY 80 million

Therefore, the monthly investment cost is JPY 6 - JPY 7 million. Since the discharge volume is 2000 m^3, the company pays 3000 - 3500 yen/m^3.

Although the ability of any treatment equipment in this complex plan is unclear, this is the minimum treatment cost required to prevent pollution and preserve the environment. These are balanced against consignment costs for the treatment of sludge and concentrated waste fluid.

Table 3-10 Plating-related Waste Treatment

Name of Waste	Amount			Treatment Measure*												
				Waste Treated by Company						Waste not Treated by Company						
						Individual Processing		Joint Processing				Dealer Consignment Processing		Recycling, Disposal by Sale		Others
	No. of Companies	Amount (t/mo.)	Rate (%)	Amount (t/mo.)	Rate (%)	No. of Companies	Amount (t/mo.)	No. of Companies	Amount (t/mo.)	Amount (t/mo.)	Rate (%)	No. of Companies	Amount (t/mo.)	No. of Companies	Amount (t/mo.)	
Concentrated cyanide waste fluid	33	802	0.09	796	99.0	18 (2)	584 (16,700)	4	212	6	1.0	15	5.97	2	(29)	
Concentrated metal plating waste fluid	29	6,060	0.71	6,060	99.9	12	2,600 (46,500)	15	3,460	221	0.1	4	2.2	1	(5)	
Acid waste fluid	87	545,000	63.7	545,000	100	48 (2)	181,000 (54,100)	37 (2)	364,000	904		10	68.6	6 (2)	21.8	
Alkali waste fluid	70	81,700	9.55	81,700	100	30 (1)	18,900 (14,700)	37 (4)	62,800	1.54	-	5	1.54			
Waste acid and alkali mixed fluid	16	202,000	23.5	197,000	97.5			14	197,000	5,000	2.5			1	(100)	1 co. 5,000
Waste acid and metal plating mixed fluid	5	8,250	0.96	8,250	100			5 (1)	8,250							
Waste metal plating acid and alkali mixed fluid	1	1,700	0.2	1,700	100			1	1,700							
Waste acid, alkali, and metal plating sludge mixed fluid	2	25		25				2 (1)	25							
Waste acid, alkali, metal plating, and metal plating sludge mixed sludge	1	1,000	0.12	1,000	100			1	1,000							
Sludge	76	9,790	1.14	9,500	97.4	55 (4)	9,500 (11,000)			292	2.6	20 (2)	291	1	(55)	
Total	320	856,000	100	851,000	99.4	163 (10)	213,000 (143,000)	116 (7)	638,000	5,390	0.6	54 (2)	369	11	22	1 co. 5,000
Remarks	* The numbers in parentheses in the amount of treatment show the treatment ability, and those in parentheses in the number of companies mean the number of companies that do not know the amount. * There is a gap between the amount of waste treatment of concentrated cyanide waste fluid and ability. That is due to the 3% density of cyanide waste fluids; it is diluted several tens of times when treated. * The number of companies is the total number for each item. * The unit of the numbers in brackets is kg.															

Chapter 4 Examination of Examples of Large (Joint) Treatment Systems

4.1 Examples of Joint Enterprises

As is obvious from the results of the research on actual conditions, most of the waste in the metal plating industry is the source of environmental pollution and environmentally polluted substances. Managers in the metal plating industry, therefore, should not focus on past rivalries. Rather, they must strive for cooperation, complex development, and the establishment of joint treatment facilities.

A case study of actual conditions, such as a complex, cooperation, and the actual establishment of a joint treatment facility will now be examined.

The Takasaki Metals Industrial Complex and the Ageo Metals Industrial Complex were surveyed. The Kawasaki Metals Industrial Complex plan will be examined.

4.1.1 Examination of Takasaki Metals Industrial Complex

In the survey of the Takasaki Metals Industrial Complex Cooperative, it was very difficult to obtain a plant site because the residents had an image that the metal plating industry was certain to cause pollution. Thus, they objected to plant establishment. There were actually three site-proposal changes.

This plan is superior to the others in that it systematizes related small-to-medium-size companies related to the metal plating industry, press working industry, metal processing industry, and machine manufacturing industry as essential to improving business structure.

One other remarkable aspect is the plan's effect on environmental pollution control. The plan distinguishes environmental polluting substances such as heavy metals, metal finishing chemicals, solvents, and waste oil from municipal waste.

[Financing]

Participating companies' funds	21.4%
Funds from the Environmental Pollution Control Service Corporation	30.7%
Funds from the Association for the Promotion of Small and Medium-size Businesses	23.3%
Funds from the Modernization of Small and Medium-size Prefectural Business Equipment	1.9%
Funds from the Corporation for Urban Advancement	5.8%
Funds from government and local banks	18.8%

The complex was constructed for JPY 1,287,695,000. The inauguration took place in November, 1972.

The following duties are to be performed as a cooperative:

1. Management of operation of joint waste water treatment device
2. Joint purchase of main chemicals
3. Joint management of utilities such as fuels
4. Joint insurance affiliation
5. Others, such as employment. In addition, company housing, dining halls, and gymnasiums are constructed as joint facilities.

1. Joint purchase of main chemicals

The joint purchase has some advantages beyond receiving a discount for blanket purchases. By adopting a joint purchase approach, the quality of waste water can be understood clearly in terms of waste water treatment techniques. Moreover, a fairer allocation of costs based on the amount of use can be expected as well.

The construction cost of the joint waste water treatment facility is determined in proportion to the funds and the number of employees. Operation costs include costs for industrial water, waterworks, electricity, chemicals, and the processing cost. However, it is not necessarily managed smoothly. Even though joint purchase is the policy, it is limited to those used jointly, and materials used only by each company are purchased individually.

2. Sludge treatment

Even with a successful joint waste water treatment, sludge is taken to reclaimed land. Therefore, the fundamental problem remains unsolved.

4.1.2 Examination of Ageo Metals Industrial Complex

The Ageo Metals Industrial Complex was constructed for two reasons. First, each company could not handle the responsibility for funds and techniques due to the enforcement of pollution restrictions; there was a need to solve this problem by comprehensive waste water equipment. Second, this construction not only solved the pollution problem, but also met the corporation's demand to extend production.

In the beginning, 12 companies in the city were scheduled to join, but only six ultimately participated.

Relatively small 6,600 m^2 site

Funds from the Corporation for Urban Advancement	29.6%
Funds from the Association for Structural Improvement of Small and Medium-size Businesses	32.5%
Funds from the Modernization of Small and Medium-size Prefectural Business Equipment Own funds	7.8%
Participating companies' funds (including bank loans)	30.1%

Total JPY 239.644,000. The inauguration took place in June, 1973.

Management is similar to that of the Takasaki Metals Industrial Complex. The key difference, however, is that the complex consists of the metal plating industry only, and does not include any related industries, such as those handling raw materials in need of surface treatment. There are some disadvantages, given the current low economic growth of the country.

1. Sludge treatment

Waste water treatment is dealt with as joint treatment. Emitted sludge is treated by consignment. The amount of emission is 700 kg/day (water content 80% after vacuum dehydration), and the composition is as follows:

Zinc	12.50 Wt%	Iron (bivalent)	0.30 Wt%
Chromium	5.94	Barium	0.24
Aluminum	4.12	Manganese	0.14
Silicon	4.00	Potassium	0.07
Calcium	3.38	Lead	0.07
Nickel	3.03	Titanium	0.02
Copper	2.44	Cobalt	0.01
Iron (trivalent)	1.90	Tin	0.01
Magnesium	1.07	Others	60.33
Sodium	0.43		
		Total	100%

"Others" stand for the chemicals used for coagulation sedimentation in the waste water treatment process.

Costs are as follows:

Waste water treatment: Rate by quantity of water
Equal rate

The criteria of the rate by quantity of water are the amounts of sludge and electricity, and those of the equal rate are personnel costs, management costs, and incidental costs. Moreover, the cost of chemicals is allocated according to the amount of use.

Sludge: 12,000 yen/t

Even though the operation rate has decreased to 40-50% currently, the cost is still 120,000 - 400,000 yen/month.

The amount of water use is 420 tons/day, which is approximately 80% of the estimated maximum value.

4.1.3 Examination of Kawasaki Metals Industrial Complex

Since many of the metal plating companies in Kawasaki City lie scattered in residential areas, they are having a difficult time dealing with anti-pollution measures. Many companies were small-scale with less than JPY 5 million in capital. Therefore, they could not keep up with the modernization of management and the rationalization of equipment. The complex was established because of little progress in sales and profits. It was established as a cooperative corporation in December, 1973 in order to work on modernization and pollution control in a positive, cooperative manner.

The complex is made up of 18 companies that have a corporation in the city and belong to the Prefectural Metal Plating Industrial Association. About 200 companies, however, were in the city according to the above-mentioned questionnaire. Therefore, the actual rate of participation in the complex is 10%, which is quite low.

Summary of group complex construction plan and problems

Land:	39,600 m^2
Building:	23,100 m^2
Other:	1,650 m^2

These are the advantages that are expected with grouping.

① Elimination of industrial pollution in Kawasaki City
② Promotion of rationalization by grouping and intensification
③ Reduction of amount of water waste treatment and running cost by concentration of pollution elimination facilities
④ Merits of accumulation, such as obtaining labor force by promoting joint business, joint order of metal plating processing, joint purchase of raw materials.
⑤ Adoption of closed system according to water treatment equipment system

On the other hand, financial factors depend largely on the unit price of the land. For example, when the unit cost is JPY 660,000/m^2:

Cost of land:	JPY 2,400 million
Cost of building plants:	JPY 1,500 million
Cost of machine device:	JPY 878 million
Company welfare facilities:	JPY 52 million
Moving cost:	JPY 94 million
Cost of pollution elimination equipment	JPY 100 million
Allotment of facilities for common use	JPY 132 million
Total:	JPY 5,156 million

The procurement funding plan is as follows:

- Own funds: JPY 1,025 million
- Loans
  - Funds for advancement: JPY 3,680 million
  - Credit institutions: JPY 451 million

The cost of the annual payment will be JPY 416 million for ten years on average. An estimate reveals that the necessary sale volumes and the yearly growth rate of a company are 6.04 times for 1972 and 22.2%, respectively.

4.2 Examination of Large Treatment System (I)

As treatment of effluent individually by the plating plants is difficult because of the medium to small size of the plants, joint treatment plants are being built by private groups to treat the waste liquids generated by plating enterprises spread over a wide area. The following are one or two examples of this.

4.2.1 Examination of Jonan Treatment Center

The main function of the Jonan Treatment Center is the treatment of concentrated cyanide waste fluid, which is emitted by companies that belong to the Tokyo Electroplating Industrial Association.

The center was established with the founding of the Tokyo Cyanide Treatment Cooperative Association in April, 1970. The center was established by NISSO Metal Chemical Co., Ltd. taking charge of building and managing the actual joint pollution control association, and the Tokyo metropolitan government providing the land.

The sludge emitted by this waste liquid treatment is treated and collected as metal resources by NISSO Metal Chemical Co., Ltd.

The following describes the center's management.

- Center's land: Purchased from the Tokyo metropolitan government 1,318 m^3
- Owner of buildings and facilities: Control Association
- Technology: Nippon Soda
- Construction: NISSO Engineering Co., Ltd.
- Management: NISSO Metal Chemical Co., Ltd.
- Collection: Omori Kosan

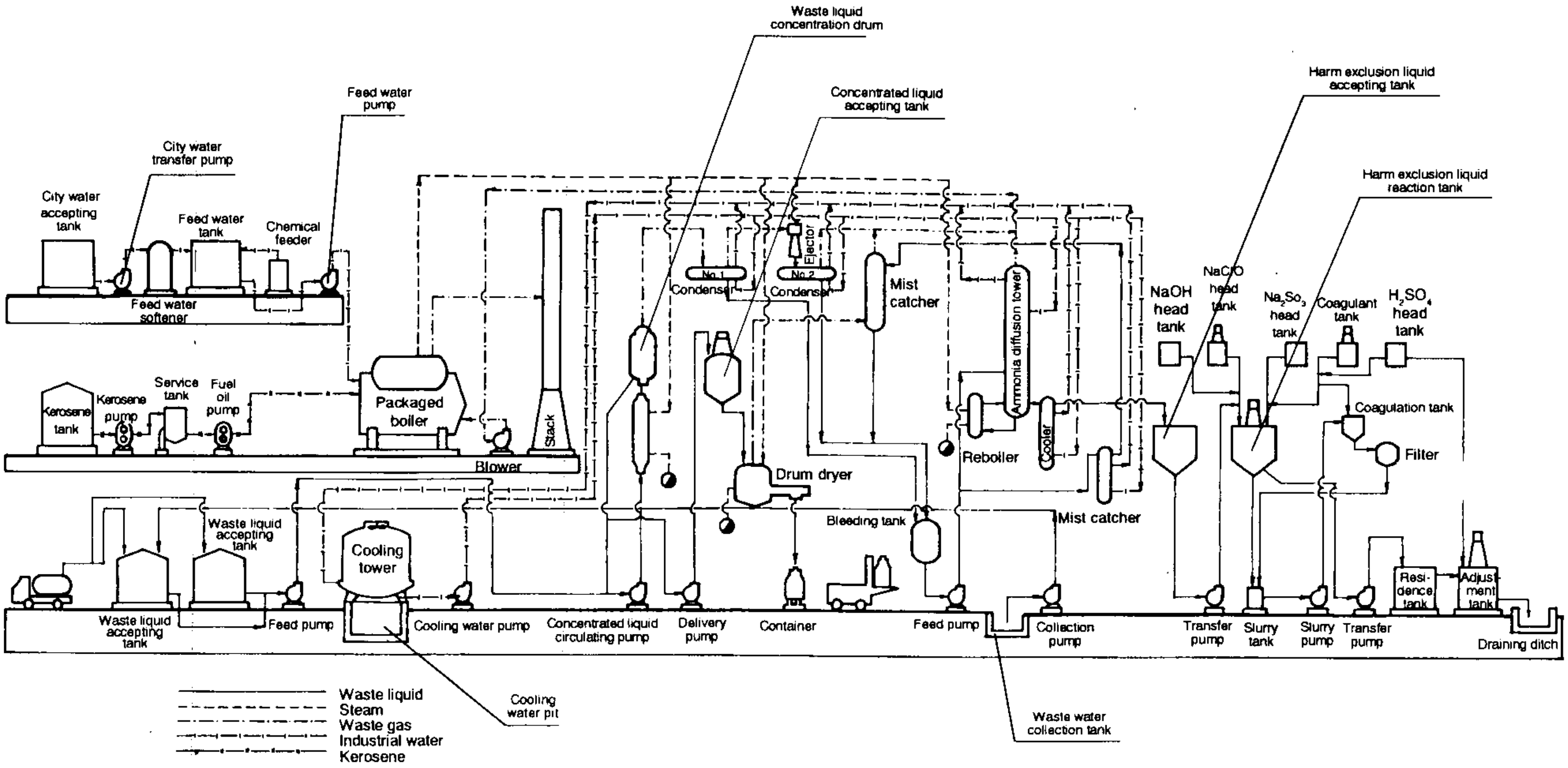


Figure 4-1 Concentrated Cyanide Waste Fluid Treatment Processes

• Construction cost:	JPY 200,140,000.-
• Treatment capacity:	200 kl/15 hours, 25 days
• Number of employees:	14 (management 3, collection 2)
• Collection cars:	Three trucks equipped with vacuum hose

- Construction cost

  Collection and treatment cost: 55 yen/l for members; 85 yen/l for non members

- Collection cost, center management cost, the cost of transferring waste to Nisso Metals Corporation, and the cost of consigned treatment are paid from this cost. Nisso should adjust any imbalance between income and expenditure.
- Agreement between Association and Nisso
- Minimum guaranteed amount: 200 kl/M

  Even though the Tokyo metropolitan district does not participate in the agreement, it actively supports the Center with regulation and aid.

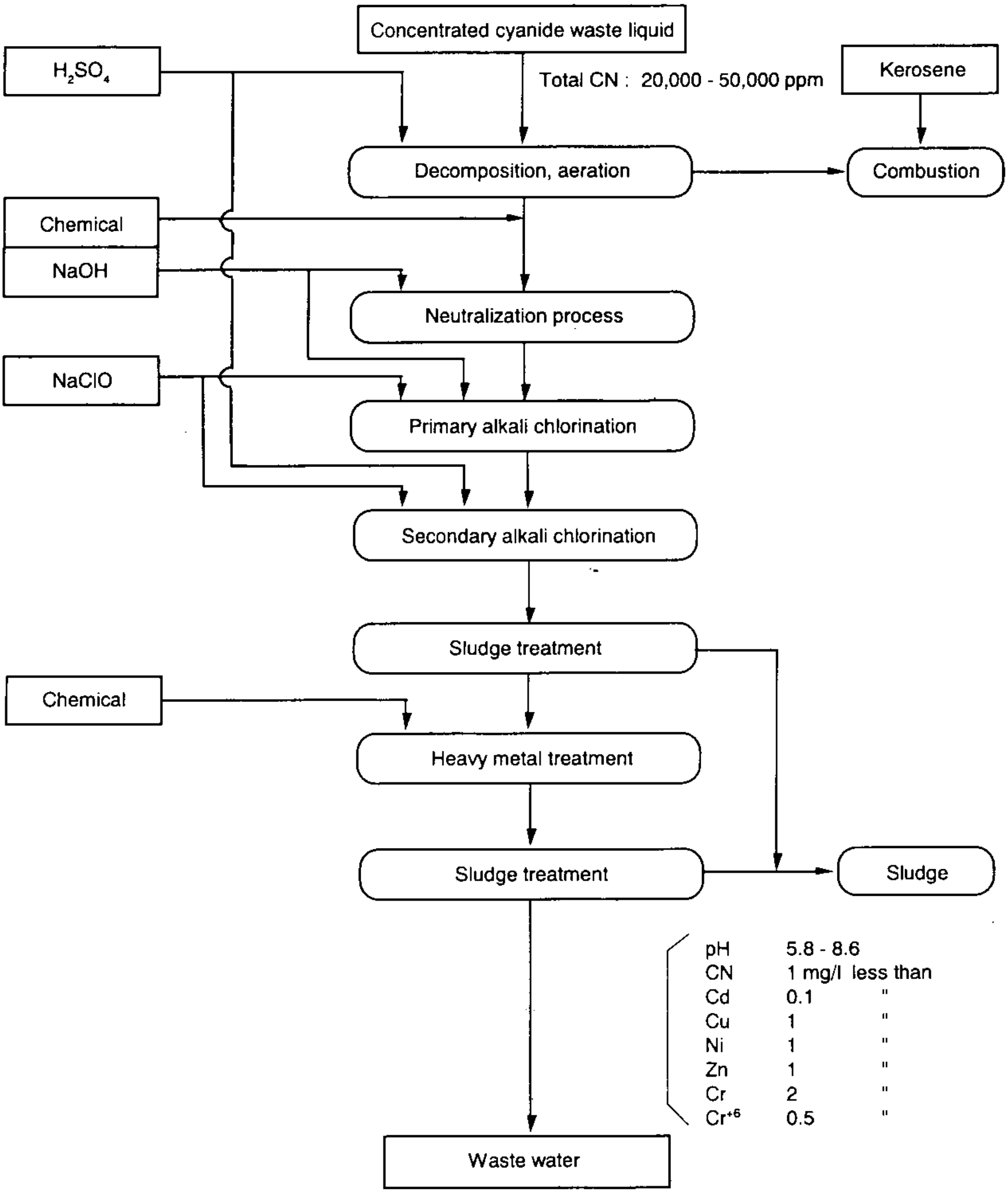
- Operations

  Full operation began approximately eight months after the center became operational. However, operation was cut back by 60% because of the depression in the metal plating industry. The targets were the industries that have main offices either in Tokyo, Saitama or Chiba. The total number is approximately 700. A look at the limits on income and expenditures for the Center's management reveals that treatment costs 55 - 70 yen/l for 120 - 160 kl/M. A treatment of 200 kl/M generates 25 tons of waste (includes 20% CN).

4.2.2 Examination of System at Showa Denko K.K.

Use of the decomposition-combustion process to treat concentrated cyanide waste liquid began in March, 1970. The facility, which targeted the treatment of concentrated waste liquids by the Kanagawa Prefectural Metal Plating Association members, was established in Showa Denko's plant in Kawasaki. Operation began in July 1972.

The treatment system for concentrated cyanide waste liquid is shown below (Figs. 4-2 and 4-3):



pH	5.8 - 8.6	
CN	1 mg/l	less than
Cd	0.1	"
Cu	1	"
Ni	1	"
Zn	1	"
Cr	2	"
Cr^{+6}	0.5	"

Figure 4-2 Summary of SDK Method

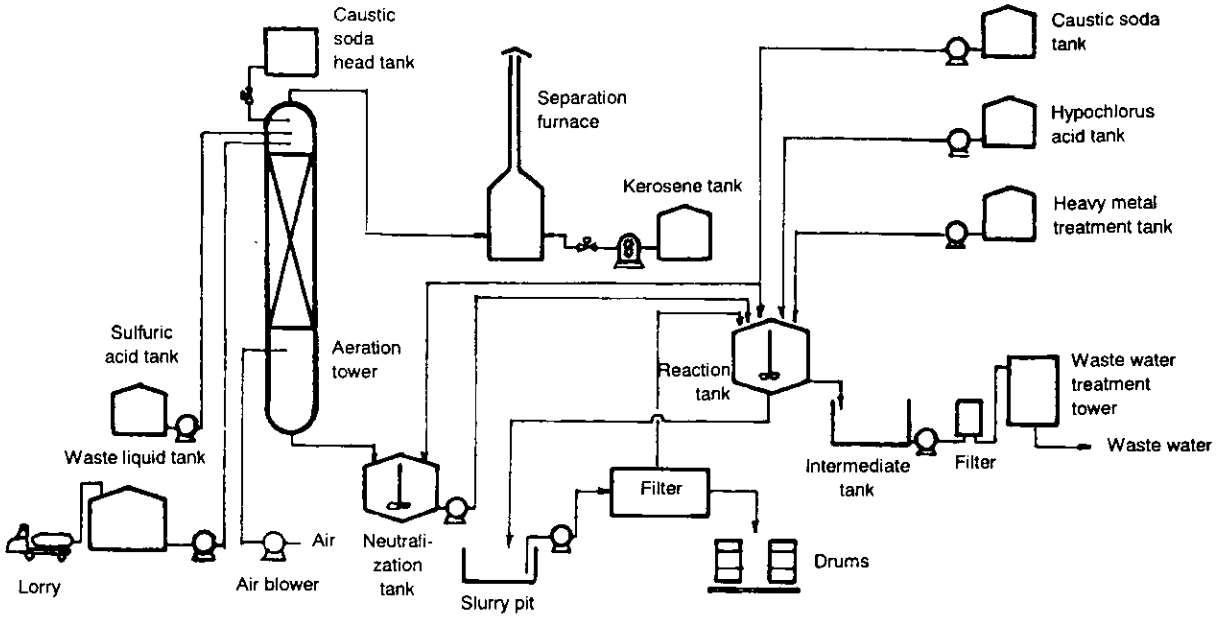


Figure 4-3 Flow Chart of SDK Method

The management of the system is as follows:

- Land, buildings: Showa Denko plant in Kawasaki (400 m^2)
- Technology: Showa Denko
- Management: Showa Denko
- Collection: Consign industrial waste treatment agency, and adjust to pH 12.
- Treatment capacity: 100 kl/M in 25 days
- Employees: 10 (collection 4, analysis 2, management 4)
- Collection car: 2 special trucks equipped with vacuum hose
- Treatment cost

  Collection and treatment cost: 50 yen/l for members; 85 yen/l for non members

- Operation

  Just after the system began operation, collection was performed at approximately 30% of actual capacity. After six months, however, it began full operation. Operation currently stands at 60-70%. The targets are 130 companies not only from Kanto but also from Chubu and Kansai. Those companies have relatively large waste sources. Companies that produce small amounts of waste, however, for treatment are responsible for its transport.

4.3 Examination of Large Treatment System (II)

(The Nagano Public Corporation for Environmental Conservation)

The Nagano Public Corporation for Environmental Conservation, a foundation established in July 1993 and operated by Nagano Prefecture, is the nation's first wide area treatment system for processing inorganic sludge containing harmful metals.

To cope with urgent issues surrounding such inorganic sludge containing harmful metals, the Nagano prefectural government launched its five-year political reform plan in March 1971. Following the plan, the government set up a large-scale development project in April 1971, focusing on the treatment of industrial waste. Under the project, in 1971 and 1972, the government conducted region-wide research on the actual industrial waste situation, paying close attention to manufacturing industries since they most tended to cause environmental pollution through emission.

Through this research, in 1972, the government created a large treatment system, focusing on the following five kinds of industrial waste, the main causes of environmental pollution necessitating advanced technological treatment.

a) Sludge
b) Waste oil
c) Waste plastic
d) Animal or plant residue
d) Rubber

Mindful of huge costs required for construction of a comprehensive treatment center and underdeveloped technology in conventional sludge treatment systems, the government finally decided to build, for the time being, a wide-area treatment center dealing with highly polluted inorganic sludge that contains harmful metals and other industrial waste.

A) Responsibility for treatment of inorganic sludge including harmful heavy metals

However, treatment of the sludge including harmful metals (hereinafter called inorganic sludge) discharged from metal-plating and glass polishing-related plants in Nagano makes it difficult for companies to treat it by themselves because of special circumstances shown below.

B) Environmental issues

a) Because it contains harmful substances like heavy metals, inorganic sludge can cause serious disease through the food chain unless any proper action is taken, Minamata Disease and Itai-itai Disease to name only a few.

b) In Nagano, socially serious environmental issues like polluted tap water (through metal plating effluent) and harmful inorganic chemical plants (they emit cadmium compounds) have already arisen in some areas, creating greater concern for the treatment of sludge among local residents.
To prevent this and further environmental pollution, the government must set up stricter guidelines and thoroughly monitor inorganic sludge treatment.

C) Technological issues

At present, it is difficult for each company to dispose of sludge, since it contains much harmful substance and water, requiring not only advanced technology but also considerable cost.

D) Site-securing issues

Waste disposal requires land-reclamation (ocean restoration), but it is growing more difficult to secure sites largely due to residents' opposition to disposal locations, as well as to increased land prices.

E) Economic issues

In Nagano, sludge treatment by individual companies is costly since most enterprises are small to medium-sized companies.

Therefore, in most cases, such companies relied on temporary on-site sludge storage at that time. Limited space, however, has brought this solution to its end. Mindful of the situation, the Nagano government, urged by industrial companies, finally decided to handle the treatment of inorganic sludge to protect residentsÕ health and the natural environment.

F) Treatment facility

Table 4-1
Emission and Number of Companies

(as of Dec. 31, 1972)

Section	Emission		Number of Companies	
	Amount (ton/day)	Ratio (%)	Number	Ratio (%)
North Nagano	2.0	20.0	58	20.9
East Nagano	1.1	11.0	39	14.0
Central Nagano	1.2	12.0	45	16.2
South Nagano	5.7	57.0	136	48.9
Total	10.0	100.0	278	100.0

(Note) Amount (tons/day) is calculated based on a water content of 85%.

Given the region's geographical confines, as well as local companies' regional distribution and emission, the government at first divided the entire region into two blocks: central and south Nagano, and east and north Nagano. It planned to build an environmental conservation center in each block. In July 1973, the environmental conservation Suwa center, was built in the central and south Nagano area where much emission and large number of companies are concentrated, thanks to cooperation from city government. Construction on the east and north Nagano center will begin in 1975.

G) Summary of Suwa-based environmental conservation center

a) Construction summary

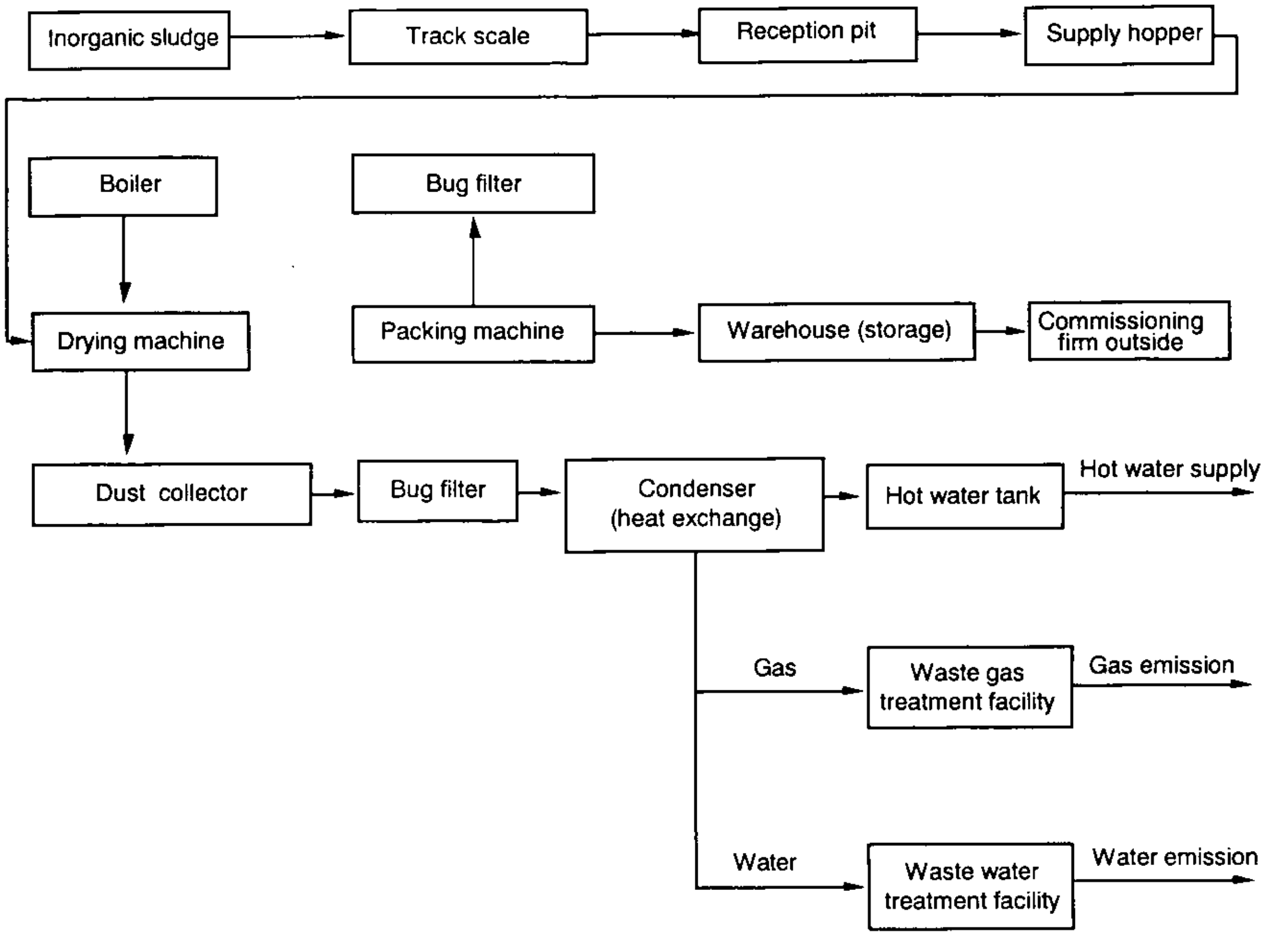
Facility name: Nagano Environmental Conservation Center Suwa Office
Location: 4790-2, Aza-soneda, Oaza-nakasu, Suwa-shi, Nagano
Construction site: 2,187 m^2
Completion: July 1973
Total construction cost: JPY 150 million
Treatment capability: 5 tons per day of Inorganic sludge (water content, 85%)

b) Sludge to be disposed

Metal plating sludge, glass polishing sludge, surface treatment sludge

c) Summary of treatment system

The facility receives inorganic sludge that has been pre-heated and dewatered by the waste-discharging enterprises to a water content of less than 85%. The sludge is dropped into a dryer where it is subjected to low temperature drying (140℃) by indirectly heating it with steam so that its water content is reduced to less than 30%, and its weight and volume to about 1/5. The resultant sludge is then sent to mine refineries for resource recovery and recycling.



Inorganic Sludge Disposal Flow Chart

Figure 4-4

Waste gas, produced through the drying process, is cooled by the condenser and divided into liquid and gaseous phases. The liquid phase goes through the waste water treatment process (to remove cyanogen, chrome, and oil). The gaseous phase goes through the waste gas treatment process (incineration at 1,000℃).
A government-operated test center regularly checks post-treatment emission quality.

d) Summary of facility

		Qty
Reception pit:	Concrete vessel, volume: 3 m^3	1
Hoist-equipped basket crane:	Hoisting load: 710 kg, basket volume: 0.3 m^3	1
Sludge supply hopper:	Steel plate, two-wheel screw, volume with fitter: 5 m^3	1
Drying machine:	Continuous double-disc band pressure, volume: 7.5 m^3	1
Dust collector:	Single cyclone	1
Bug filter:	Vertical cylindrical system, filter space: 10 m^2	2
Condenser:	Horizontal multi-tubular type, surface area: 40 m^3	1
Fuel tank:	Underground storage tank, volume: 10 m^3	1

Hot water tank:	BLP vertical, cylindrical type, volume: 4 m^3	1
Track scale:	Capacity: 10 t	1
High voltage current control system:	Transformer capacity 85 kW	1
Waste water treatment system:	Treatment capacity: 4 m^3, two-story iron frame building, total floor area: 53 m^3	1
Waste gas treatment system:	Treatment capacity: 4 m^3	1
Boiler:	Natural circulation-type package boiler, surface area: 16.75 m^2	1
Boiler room:	Block-loaded one-story building, floor area: 24 m^2	1
Plant:	Iron-frame one-story building, floor area: 261 m^2	1
Warehouse:	Iron-frame one-story building, floor area: 240 m^2	1

e) Facility control and management

The Nagano Public Corporation for Environmental Conservation, a foundation established in April 1972, was commissioned by ordinance to control and manage a regional industrial waste treatment facility. Currently, five staff members are engaged in operating the facility.

The industrial waste treatment center may charge treatment costs to waste producers. The current treatment cost is 280 yen/10 kg, thanks to cost-cutting efforts. Users of the facility first need the governor's permission. Thereafter, they may bring in inorganic sludge to the treatment center and pay the fee on their own responsibility.

At present, environmental pollution and the destruction of nature have become more serious social issues. Therefore, a clear and sure solution for industrial waste must be devised as early as possible.

In this sense, the Nagano government's strenuous achievement of having established a large treatment system for inorganic sludge including harmful metals is quite significant.

The completed treatment facility, however, is not perfectly effective in terms of technology; its potential is still limited to the drying function aimed at decreasing the volume and weight of sludge. It is impossible to render sludge harmless at present, although technology to cope with sludge has been developed to some extent. Sludge remains harmful even after treatment. Therefore, government regulations are still required to conserve the environment, and effective technological solutions are expected to materialize in the near future.

Concrete solidification is regarded as one sludge treatment solution. Unfortunately, it requires a reclamation site. Moreover, this method still poses the danger of sludge leakage. There is no guarantee that concrete solidification is perfectly safe despite successful experiment results. Thus, it is quite reasonable and sensible for the Nagano government to have decided to establish a weight-reducing treatment system and to return the sludge to mine refineries.

The system's drawback, however, is treatment cost. Sludge treatment cost went up to 280 yen per 10 kg in November 1974, since the facility changed its disposal system from the initial packing and stockpiling process to the transportation required for commissioning firm outside for recycling. Unlike the initial process, the new process necessitates not only transportation expenses but also disposal expenditures for the sludge.

In the former bagging and stockpiling process system, the cost was 100 yen per 10 kg. Because of cost increases, the total amount of sludge brought into the facility has been decreasing. To stave off the ongoing decrease, some measures must be taken immediately.

According to the current survey, another prefecture, which uses concrete solidification, estimates disposal cost at 200 yen per 10 kg. Industrial companies, however, claim that this is still costly, making them hesitant to use the system.

Several technological breakthroughs are needed, all of which are possible, at the Suwa-based central and south Nagano regional treatment facility. First, the supply system for the drying machine can be improved by making the sludge feed smoothly. To this end, the current technical problem of bridging muddy sludge needs to be resolved. Second, it is necessary to develop a more efficient drying system (at low cost). Third, it is important to introduce sell-off oriented recycling systems. By analyzing the content of sludge, for instance, sludge can be separated into some categories, such as chrome- and nickel-dominant sludge. This less complex sludge can be sold off for recycling. Finally, more advanced chemical technology that refines separated sludge to render it more harmless is needed to activate sell-off projects. To this end, developing a more sophisticated sludge treatment system that targets efficient cost-cutting and recycling is essential to environmental conservation. This solution will allow both the Nagano Public Corporation for Environmental Conservation and local companies to advance towards a viable means of ending environmental pollution and the destruction of nature.

Chapter 5 Analysis of Emission Control System Technologies

In Chapter 2, we explained what chemicals are used in the plating process, how they are discharged through waste water, and finally what minerals remain in sludge after waste water treatment. In this chapter, we are going to reveal problems in sludge treatment through the analysis of several treatment methods.

5.1 Problems and Technical Limits of Plating Sludge Treatment Systems

So far, a narrow-sighted notion focusing solely on water quality and its regulation value has been prevalent among waste water treatment service companies as well as treatment device manufacturers. For instance, to prevent environmental pollution, clarifier carry-over prevention and improvement of sludge dewatering systems have been developed in sedimentation treatment systems. Yet they are never technologically new and innovative. In today's technology, it is impossible for waste water treatment system manufacturers to produce new types of treatment device and operate them. Although they ostensibly agree to try to change waste water into clean water through comprehensive treatment, they fail to create the methods to do so. Therefore, even if people unfamiliar with waste water treatment systems strive to improve and develop a system, their efforts appear to be of no avail. The result is that sludge containing heavy metals remains a technically unresolved issue.

With this fact in mind, in waste water treatment technology, we need to seek further development focused on the manufacturing process aimed at no water or pollution-free water, rather than focusing on improving treatment techniques.

In fact, in the plating industry, new challenges of developing cluster ion plating, pH plating and dry type plating techniques are under way. The rinsing treatment system demonstrates its new technique: by juxtaposing the water flow and product flow directions, high concentrated acid water can be cleaned gradually as it passes through several water tanks. This counter-current rinsing method can reduce water. The new technique is estimated to cut rinsing water down to 1/40 to 1/200 in total when using four water tanks.

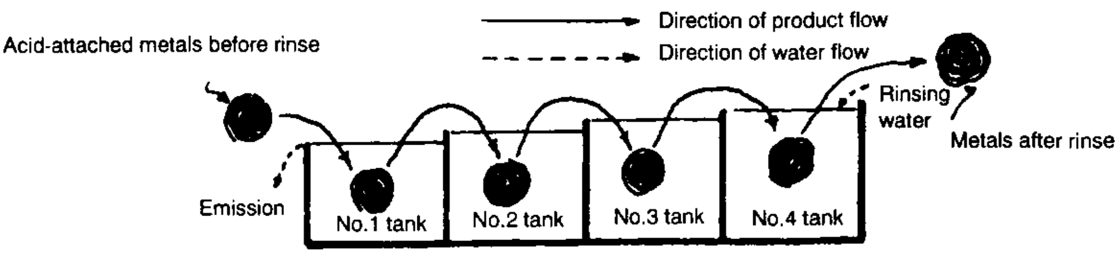


Figure 5-1

Counter-current Rinsing Method in Acid Cleaning Process (using four water tanks)

Waste water with heavy metals needs treatment devices for each process. In most cases, electric plating, except special alloy plating such as brass metal plating Cu + Zn and tinning Pb + Sn, tends to avoid mixture of different types of metals. To be sure, plating liquid under the well-controlled process does contain virtually no different metals. Today's waste water treatment systems, however, mix such metals, creating complex sludge containing different kinds of metals. As a result, sedimentation systems must use sedimentation tanks designed for each metal, a very expensive proposition for the facility and site. As a practical solution, it is possible to use ion exchange devices for each metal. Reproduction is to be done intensively at one place. In this case, leasing cartridge-type ion exchange devices is preferred. It is irrelevant whether reproduction is accomplished by pharmaceutical companies or in the form of joint treatment center systems. Desorption liquid for ion exchange resin, which is free of mixed metals, can be easily recovered for recycling.

Currently, plating industrial parks have been built, and emission from the plants has been treated collaboratively among companies. It is dubious, however, whether or not such joint treatment systems can be useful and effective in preventing environmental pollution.

By using such a treatment system, waste water mixed with different kinds of metals can pass the designated water quality regulation, producing unreasonable result. By way of example, plant A emits cadmium three times higher than its regulation value; plant B emits lead and plant C cyanogen. If emissions from each plant are equal in amount, these three minerals are diluted one third, which eventually enables the emission to pass water quality regulation. This comes as no surprise because the current water quality regulation adopts concentration-based criteria. An unwelcome result in the near future is that such elusive joint treatment systems will be rampant and free to cause environmental pollution "legally." The point is that, in principle, waste water must be treated at an early stage at each plant, the emission source. It is quite wrong to rely on joint treatment systems and public sewage services for disposal. Treatment for sludge with heavy metals and organic substances is technically difficult, even if basin sewage treatment facilities to remove heavy metals are installed. This is already true with public sewage treatment facilities everywhere.

5.1.1 Current Sludge Treatment Techniques

Current sludge treatment techniques can be divided into the following three types:

a) Dumping technique
b) Effective use technique
c) Circulating reuse technique

In addition, the freezing-dewatering technique and drying technique are available. These are not explained here because they are merely pre-treatment techniques, not full-fledged sludge treatment methods.

a) Dumping technique

The dumping technique, the most unsophisticated treatment technique in terms of economy and the prevention of environmental pollution, does not merit discussion in this chapter. It is solely a profit-making means for disposal contractors.

① Concrete solidification

This technique focuses on fixing sludge with concrete. The solidified sludge is used for reclamation and ocean dumping, but the strength of the solidified sludge can never be superior to that of normal concrete.

② Sintering solidification method

This technique burns sludge with clay and glass mixed in. Sludge mixed with such additives is burned at high temperatures and finally used for reclamation.

③ Plastic solidification method

This technique is designed to mix sludge with waste plastic. The mixed sludge is melted into solidification and used for reclamation.

The common denominator of these techniques is that they avoid making the best use of the chemical characteristics of metal compounds in sludge; they only use it as inexpensive materials for treatment. As a result, these techniques are still problematic - in the end, enormous energy is spent without producing anything of value, and creating the possibility of causing secondary environmental pollution. In terms of recycling, however, they can be effective in treating ash from incinerated public garbage and public sewage sludge, since both usually contain small amount of harmful heavy metals.

Japan has relied on the international market for more than 60% of its heavy metals. Nevertheless, it allows industries to irresponsibly discharge and illegally dump them, largely because of undeveloped treatment technologies. Consequently, to prevent the further expansion of environmental pollution, any sludge treatment technique that fails to make the best use of the chemical characteristics in heavy metals needs to be abolished.

b) Effective use technique

1) Lightweight aggregate artificial gravelization (H Corporation)
    a) Techniques to make heavy metals in sludge harmless

Basically, the following two treatment techniques are available to render sludge with heavy metals harmless.

1) There are techniques to physically seal in heavy metals to reduce the area of contact of the heavy metals with the outside and to make them dissolve resistant. Examples are "concrete solidification," "plastic solidification," and "asphalt solidification."
2) There are techniques to render sludge harmless by changing heavy metals into different chemical compounds, which are harder to melt. In concrete, heavy metals are burned with shale and clay, and changed into lightweight aggregates, artificial gravel, roof blocks, bricks, etc.

In either case, substances after the treatment must satisfy the criteria, Ordinance No. 4 issued by the Prime Minister's Office to prevent environmental pollution. To this end, solidified or burned heavy metals, for instance, must be treated carefully to avoid dissolution through accidental crushing or the binder's erosion by rain, ground water and sea water.

H Corporation's heavy metals treatment technique is designed to chemically change heavy metals in sludge into chemical compounds that are difficult to melt. Just as heavy metals used for colored glass and pottery are chemically stable, by burning heavy metal-containing sludge with glass substance added, heavy metals are sealed into glass and form glass to become chemically well-balanced. This makes them hard to dissolve and to solidify by glass acting as a binder. This further ensures no leakage of heavy metals due to damage during reclamation work. The company expects the substance to be effectively reused as artificial lightweight aggregates and road gravel.

b) Vitrifying heavy metals

Sludge with heavy metals cannot change itself into glass through burning. Glass substances are required for the conversion.

1) Burned heavy metals with glass must be chemically stable.
2) They must show as much viscosity as the binder through burning (for granulation effect and equalization of burned substance).
3) Additives must be easily available and inexpensive.
4) Heavy metals with harmful sludge must be changed into a glass substance at low temperatures, since they can turn volatile if burned at high temperatures.

To produce new chemical compounds, these conditions must be met.

Through its research, H Corporation has decided to use sodium silicate and clay as effective additives.

Silicate (SiO_2), mostly contained in clay, creates silicate glass through melting at high temperatures. The created object, silicate (fused quartz) glass, affords excellent heat and corrosion resistance. High temperatures exceeding 1500℃ are necessary, however, for the creation, and high temperatures tend to make heavy metals volatile and to shorten furnace longevity.

Silicate glass presents a three-dimensional mesh form based on the chemical structure of SiO_4, a chemical compound with a four-sided structure. Si^{4+}, mesh formation iron, is connected to each of four O atoms. Each O atom is connected to a Si atom, creating SiO_4. The following is a two-dimensional illustration of SiO_4. After adding sodium silicate (Na_2O. $3SiO_2$) to this silica glass, the Si-O-Si connection in the mesh formation of silicate glass (see Figure 5-3) is broken, changing into a chemically unstable glass, and becoming brittle. Then, silicate glass is changed into Na_2O-SiO_2 glass (soda glass) formed at low temperatures.

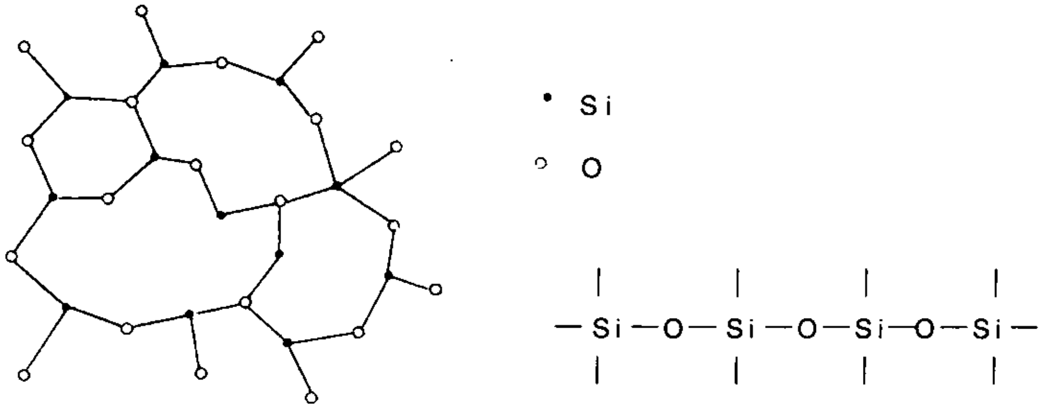


Figure 5-2 Two-dimensional Structure of Silica Glass Mesh Formation

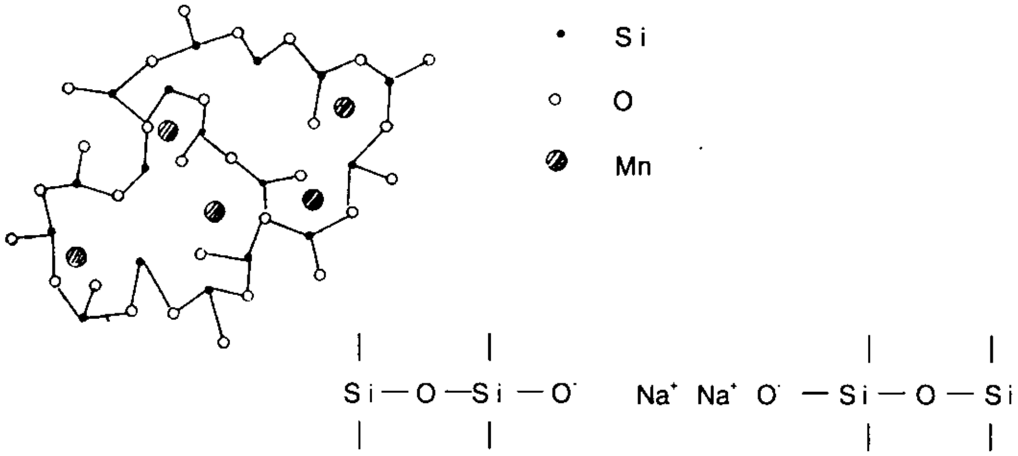
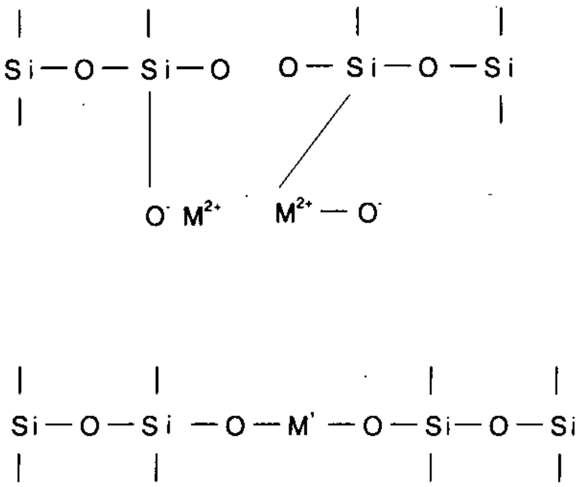


Figure 5-3 Two-dimensional Structure of Mesh Formation of Sodium Silicate Glass

Although sodium silicate itself is water-soluble, it can be changed into high-quality glass by being mixed with additives like Al_2O_3 and Fe_2O_3. The new product offers excellent water-proofing and corrosion resistance.

After being placed into sodium silicate, oxidized heavy metals, a major contributor to environmental pollution, enter the inside of the soda mesh structure. There, it displays intermediate chemical characteristics between skeleton formation ions and modifier ions and becomes refractory. (See Figure 5-4)



(M: Modifier ions & metals)

(M': Skeleton-forming ions & metals)

Figure 5-4 Two-dimensional Illustration of Glass Mesh Formation

Glass viscosity decreases as the burning temperature increases, prompting glass expansion among sludge particles, and finally upgrading the glass mesh function as a binder. In addition, the reaction speed increases, prompting glass formation, and eventually the dissolve resistance.

Figure 5-5 shows an example of the burning temperature and dissolution rates of heavy metals for a heavy metals-sodium silicate-combined substance.

The figure shows one experiment result: ammonium acetate water soluble at pH 4.5 is extracted after a burned substance is crushed into less than 100 mesh in size. As the data show, heavy metals can become resistant to dissolution through their glass formation at high temperatures. Figure 5-6 shows another experiment result: a $Cr(OH)_3 \cdot xH_2O + CaCO_3$ chemical compound is heated in the air. As the data show, hexavalent chromium is formed at temperatures between 600 and 1000℃, but the number decreases at temperatures higher than that.

Basically, its formation does not stop even at 1400℃. However, when the $Cr(OH)_3 \cdot xH_2O + CaCO_3$ compound is burned with clay (1:1 weight ratio), formation of hexavalent chromium cannot be seen at more than 1100℃, and the chrome's anti-oxidation effect which is caused by the clay was found. This proves that the chrome oxidizes in the presence of calcium salt in the sludge, forming calcium chromate.

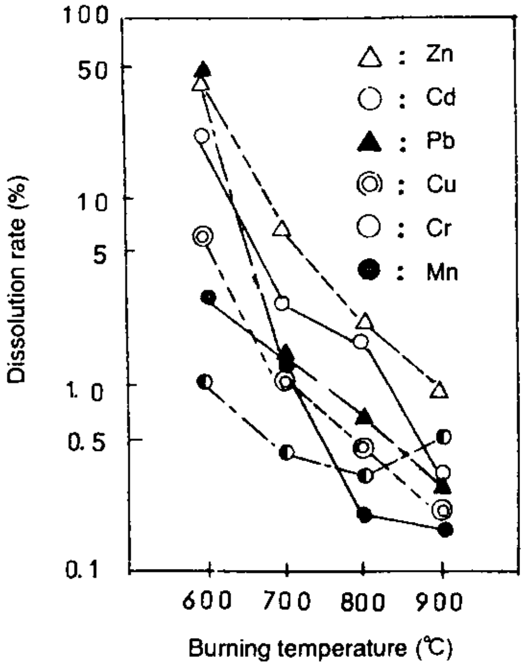
The mesh formation can never be developed by heavy metals in sludge alone; it usually requires $CaCO_3$, Al_2O_3 and Fe_2O_3 for its development. Na_2O-$CaCO_3$-SiO_2, Na_2O-Al_2O_3-Fe_2O_3, Na_2O-Fe_2O_3, Al_2O_3, and $CaCO_3$ can be easily burned in that order. In particular, sludge with Fe_2O_3 can be fully burned sufficiently without silicate soda. $CaCO_3$ blocks vitrification at low temperatures.

Figure 5-6 shows heavy metals' resistance to dissolution caused by calcium ions.

Calcium ions are assumed to work as mesh modifying ions that cut the glass skeleton, and to be hard to be glass.

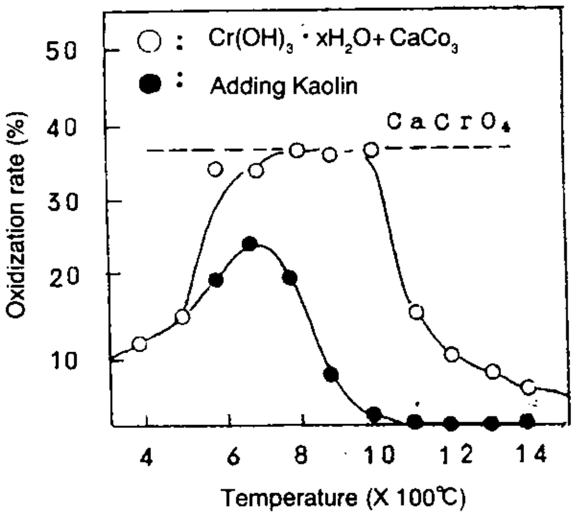
Calcium salt is used as a neutralizer in the treatment of the heavy metal-containing discharged water; sludge usually contains 5 - 20% calcium.

The following is another experiment result: dried sludge (Cr = 10.1, Ni = 10.7, Cu = 5.3, Cd = 13.9 WT %) is added to 1.5 parts kaolin and 0.75 parts silicate soda (JIS #3 water content: 60%), then burned in a rotary kiln (inside diameter: 700 mm, length: 7000 mm) at 1100℃. The substance is then crushed into 0.5 - 5 mm, and soaked at 10 wt/vol% for 48 hours. Finally, by atomic absorption, the soaked liquid is measured for its heavy metal concentration rate.



Extraction of MO-$Na_2Si_3O_7$ substance by NH_4AC at pH 4.5

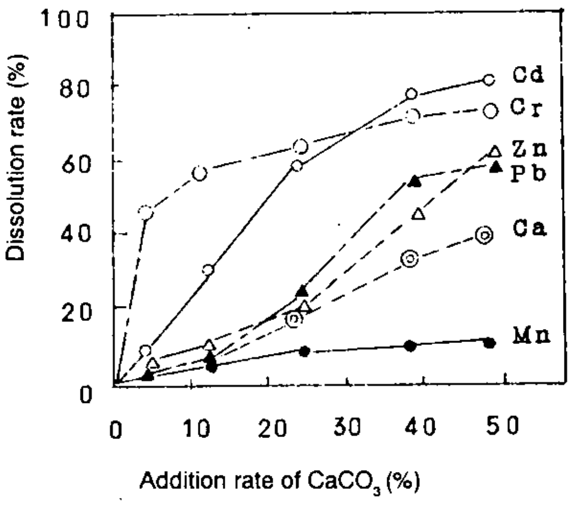
Figure 5-5



Oxidization of chrome through coexistence with calcium salt

Figure 5-6

As this table shows, the dissolution amount of heavy metals falls below the regulated concentration rates in Ordinance No. 5 "Criteria for Harmful Industrial Waste," issued by the Prime Minister's Office.



Effect preventing heavy metals from becoming hard-to-melt by adding Ca ion

Figure 5-7

Table 5-2 Experiment data of burned substance-soaked liquid (unit: ppm)

Soaking Liquid	After Soaking (pH)	Cr	Ni	Cu
H_2O	6.80	tr	tr	tr
NH_4AC	6.90	tr	tr	1.3
pH 4.5 NH_4AC	4.50	tr	tr	2.7
HCl	0.55	tr	tr	11.4

c) Behavior of heavy metals in burning process

The drawback of H Corporation's burning process is that it requires temperatures as high as between 800℃ and 1000℃, posing the possibility of volatility. Of course, heavy metals differ from each other in volatility depending on their type, chemical form, and coexisting substances. Therefore, the following conditions must be met for sludge to burn successfully.

1) Sludge without Hg and As

Chemical compounds with Hg or As can easily become volatile because of high steam pressure if burned at several hundred degrees centigrade.

2) Sludge with Cd, Zn or Ni

Sludge with these metals must not contain large amounts of reduced substances, including organic substances, since chemical compounds containing Cd or Zn can easily become volatile metal fumes.

3) Sludge with chlorides
   Chlorides, such as Cd, Zn, Cu and Pb, all have sufficiently high steam pressure to become volatile at 500℃.
4) Sludge without many chlorides, including sodium chloride
   Although unable to become volatile by themselves, some chemical compounds can become volatile where there are sodium chloride and calcium chloride.

The most economical burning conditions including clay (which changes sludge into a glass substance), the adding rate of silicate soda and the burning temperature must be determined based on the chemical characteristics of sludge, or the type of heavy metals, composition of coexistent substances, etc. To this end, H Corporation conducts various burning experiments, using a small batch-type kiln (inside diameter: 350 mm, length: 400 mm) for each sludge to be treated to determine the most suitable clay, silicate soda, and burning temperature. The company also conducts pilot-scale experiments by using a test kiln (inside diameter: 770 mm, length: 7000 mm) when necessary.

d) Device design

To prevent secondary environmental pollution, sludge treatment devices need to meet various environmental regulations.

Moreover, unlike production facilities, pollution preventing equipment tend to be economically limited, and therefore, the equipment need to be designed in a rational way, with simple and clear diagrams, installment, equipment selection, material selection and instrumentation method.

The sludge reservoir is designed based on transportation method and sludge type. For sludge with water, however, the reservoir must be carefully designed according to the sludge's adhesion and viscosity.

For instance, side walls of the hopper need to be stood at a right angle, or stood in a counter inclination position to form a trapezoid. With this form, the hopper's bottom widens, allowing a larger withdrawal device.

The burning reaction is similar to the solid phase reaction, which works better with finer particles in sludge. If sludge contains rough particles, pre-treatment, including crushing, is necessary. In this case, compressed and dried particles can be easily treated. If sludge contains too much water or too many organic substances, pre-treatment such as drying and burning is also necessary. In most cases, however, such per-treatment is unnecessary, since the sludge components are already dried and burned.

Measurement, mixing, and kneading are the most important processes in pre-treatment. In measurement, a hopper scale is used for each batch to check sludge viscosity. Then, sludge is kneaded by a pugmill-type mixer that sprays sodium silicate from the top to the sludge.

If kneading is insufficient, sludge cannot be evenly mixed. This prevents heavy metals in sludge from being resistant to dissolution. Granulation equipment is installed to granulate burned substances. This equipment can fix the granulation size and strength of substances so that they can be reused for frameworks and road materials.

Bread type or drum type pelletizers and briquetting granulating machines are available, and granulating characteristics are largely affected by the water content of sludge to be treated. Thus, machine selection needs to be done based on the substance's physical characteristics.

A rotary kiln, closely akin to conventional kilns, is basically used. Burned substances are emitted from the rotary kiln as particles, which are scattered in a wide range. Fire bricks inside the kiln must be selected carefully with their heat resistance and alkali resistance in mind, because the sludge to be treated usually contains silicate soda.

Granulated particles can cause explosions through pellet destruction and abrupt water evaporation, caused by kiln rotation if granulated substances are directly placed into the kiln. To avoid explosion, granulated substances must be cooled down gradually in advance through a grate-type preheater or band-type drying machine before being placed into the kiln.

Clinkers, burned substances emitted from the kiln, possess high temperatures. To be strengthened, clinkers must be gradually cooled by a rotary cooler, before being stored.

Waste gas generated by the kiln has a different temperature depending on the water content of sludge, but will usually rises to approximately 200 - 300℃ where the sludge containing 70 - 80% water is treated. Moreover, it contains dust composed of heavy metal fragments. An electric dust collector, therefore, is necessary to collect dust and prevent further environmental pollution.

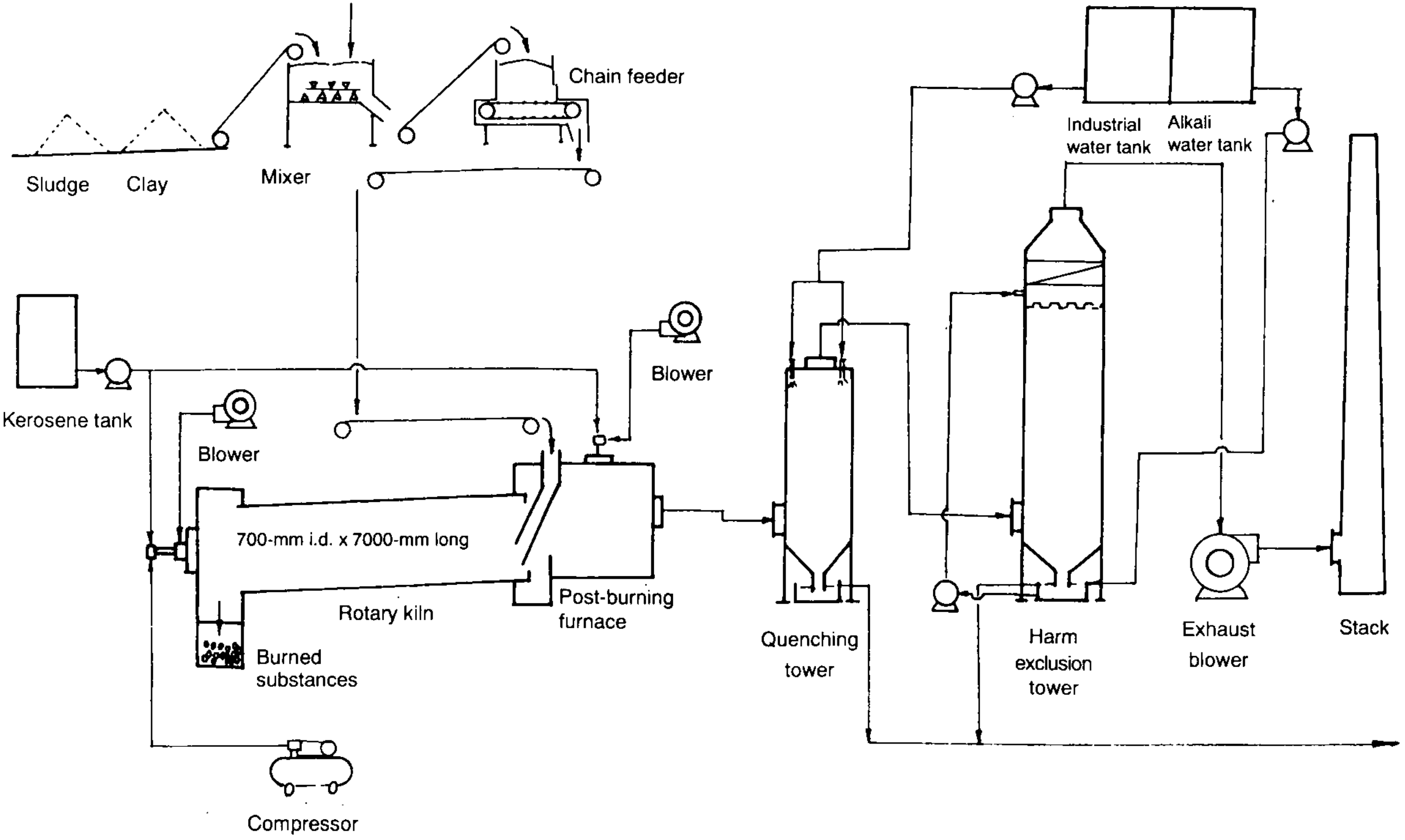


Figure 5-8 Rotary Kiln Pilot Plant

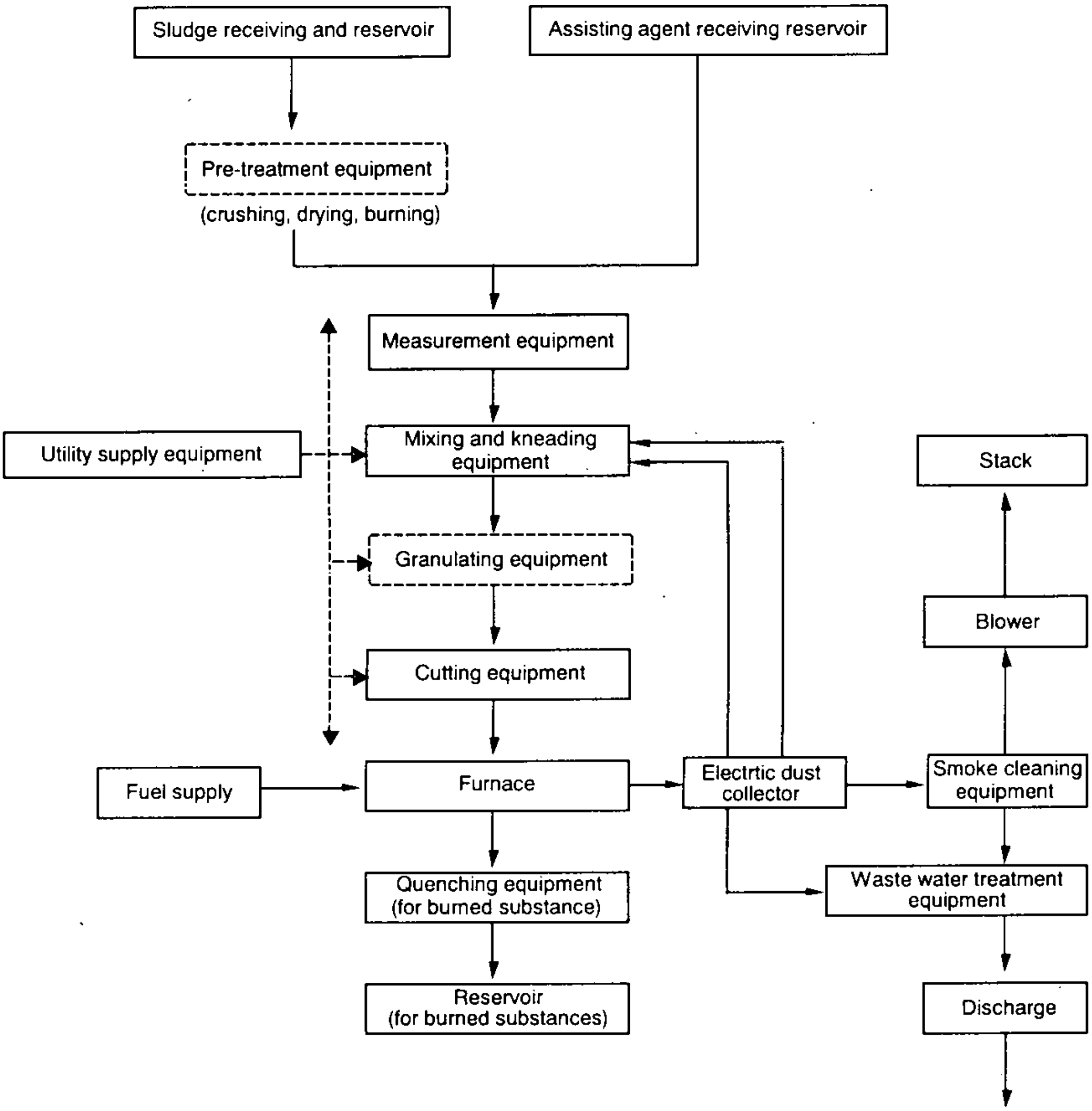


Figure 5-9

(Note) Requirement of equipment with ┌╌╌╌┐ depends on sludge type.

Where sludge contains harmful substances like sulfide and chloride or where waste gas contains harmful gases, like Sox and Hcl when there is an excess of sulfur in the fuel, gas cleaning equipment is necessary to eliminate them. When a wet type gas cleaning system is used, water treatment equipment is additionally required.

The following are typical subjects to be addressed.

Substance to be treated : Sludge with heavy metals, like plating sludge. Water content 70 - 90%. It must not contain combustible (flammable) substances or chloride that requires pre-treatment.

Treatment condition:

Mixture rate of assisting agent

Table 5-3

Sludge (dried weight)	Sodium Silicate	Clay
1	0.5 - 1	1 - 2

Burning condition: Burning temperature 900 - 1100℃.
Burning time 1 - 2 hours.

Flow: See Figure 5-8

Operation time: Continuously 24 hours

Burned subject: Can meet reclamation regulations in the Ordinance No. 5 of the Prime Minister's Office

Fuel oil additive:

Sodium silicate JIS#3 (liquid type) or equivalent

Clay constituent

Table 5-4

SiO_2	Al_2O_3	1g-Loss
Approx. 80%	Approx. 16%	Approx. 4%

Particle size: 46 μ or finer 99%

Operator: 2 people x 3 shifts

Utility: 200 - 300 kWH/ton sludge

Industrial water: 1 - 1.2 m^3/ton sludge

Supporting oil (kerosene): 0.13 - 0.15 m^3/ton sludge

Treatment cost: Estimate based on the following conditions:

* Depreciation: 8-year fixed amounts

Interest rate: 10%/year

Maintenance cost: 3% of machine equipment (annual rate)

Operating days: 300 days/year (24 hrs/day)

Personnel expenses: 2 people x 3 shifts (JPY 2.5 million/person per year)

Operating cost:
- Electric power: 250 kWH/ton (9 yen/kWH)
- Industrial water: 1.1 m^3/ton (5 yen/m^3)
- Kerosene: 0.14 m^3/ton (40,000 yen/m^3)
- * Sodium silicate: 0.15 ton/ton (40,000 yen/ton)
- * Clay: 0.3 ton/ton (20,000 yen/ton)

The treatment cost for the entire device is estimated based on the combined cost of conventional waste incineration equipment and additives. The total cost is almost the same as the cost of consigning the treatment to law-abiding disposal companies that do not create secondary environmental pollution, or the cost of using concrete pits at isolated landfills in their own company sites.

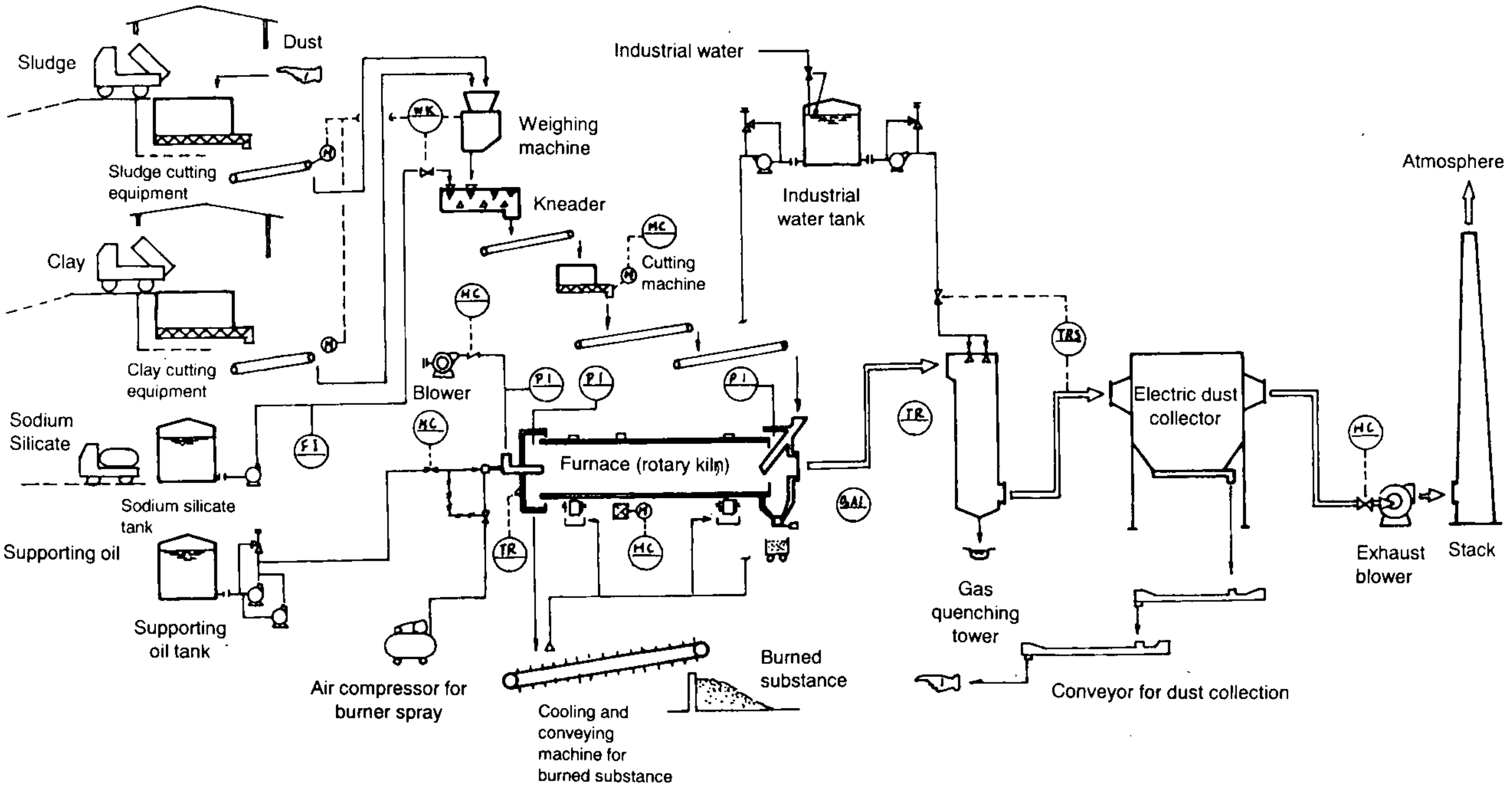


Figure 5-10 Flow Chart for Burning Sludge with Harmful Heavy Metals

ii) Dissolution and separation-based sludge treatment technique (M Corporation)

With this technique, additives are added to the harmful sludge containing the most problematic heavy metals and dissolved in an electric furnace to stabilize sludge. It tries to extract small amounts of heavy metals from sludge by dissolution and separation.

a) Target sludge

1. Dewatered sludge of plating waste water, waste acid, and waste alkali
2. Burned ash from public sewage
3. Burned ash from normal garbage
4. E. P ash (dust collected by electric dust collector)
5. Others (ash from industrial waste)

The main components of these wastes differ depending on the place of emission, type of company, and season. The following are examples.

Table 5-5

Example of industrial waste components (unit: %)

	SiO_2	CaO	Fe_2O_3	Al_2O_3	MgO	MnO
1	3.0 - 5.0	22.5 - 36.0	3.0 - 4.0	7.0 - 8.0	3.0 - 4.0	1.0 - 2.0
2	30.0 - 35.0	19.0 - 23.0	10.0 - 15.0	9.0 - 11.0	1.8 - 3.0	1.0 - 1.5

Table 5-6

Example of burned normal garbage ash (unit: weight %)

	Inflammable	Minerals	Glass・concrete	Ash
3	25 - 30	5 - 10	20 - 25	20 - 25

b) Types of treatment

The following are current possible sludge treatment techniques.

1) Concrete solidification method
2) Sintering (burning) solidification method
3) Plastic dissolution solidification method

4) Electric dissolution solidification method (M Corporation)
   - a) Stabilization treatment for harmful substances
   - b) Dissolution and separation treatment for harmful substances

c) Principles of treatment techniques

1) Electric dissolution

In this technique, the major components of waste are inorganic substances in which harmful substances like heavy metals exist as chloride and oxide.

By dissolving the inorganic substances along with traces of heavy metals, they are oxidized in the atmosphere created by base substances to form complex chemical compounds. They are also reduced to simple minerals and remain at the furnace's bottom.

2) Stabilizing harmful substances

This is the case when harmful substances in sludge are dissolved, and when either the sludge forms harmful substances and more stable chemical compounds, or oxidized harmful substances change into more stable chemical compounds as the following example illustrates.

$$\begin{array}{ccccc} Cr_2O_3 & + & SiO_2 & \rightarrow & Cr_2O_3\,SiO_2 \\ \text{(chromic oxide)} & & \text{(silicate)} & & \text{(green-colored glass)} \end{array}$$

3) Metal separation in reducing atmosphere

This is one of the most popular methods for extracting minerals. Each substance in the reducing atmosphere has formation energy ($\triangle G$), which helps substances remain stable under various conditions. The initially stabilized substances are transformed by the addition of highly active substances. For instance, the following relationship originally exists in uncontrolled atmosphere.

$$\begin{array}{ccccc} C & + & CO_2 & \rightleftharpoons & 2CO \text{ ....} \quad ① \\ \text{(carbon)} & & \text{(carbon dioxide)} & & \text{(carbon monoxide)} \end{array}$$

When the temperature exceeds 600℃, this reaction moves quickly to the right, causing the atmosphere to be reduced. Metallic oxides, whose activation is lower than that of carbon monoxide, separates as a single metal. Its transformation is as follows:

$3CO + Fe_2O_3 \rightarrow Fe + 3CO_2$ .... ②

$CO + CuO \rightarrow Cu + CO_2$ .... ③

$CO + NiO \rightarrow Ni + CO_2$ .... ④

As these formulas show, harmful metals in waste can be extracted in the form of metallic compounds by the use of such reactions.

d) Evaporation and oxide dispersion

These can be seen among metals with low-melting points, and these metals exist in sludge as simple substances or oxides. When the melting point of mixed inorganic substances which are sludge base is higher than the evaporation point of metals, these metals can be converted into gas and discharged into the air. This allows metallic dust to be contained in the gas. Therefore, facilities for capturing the heavy metals in the dust and processing the waste gas are necessary to prevent further environmental pollution.

Haploid arc method

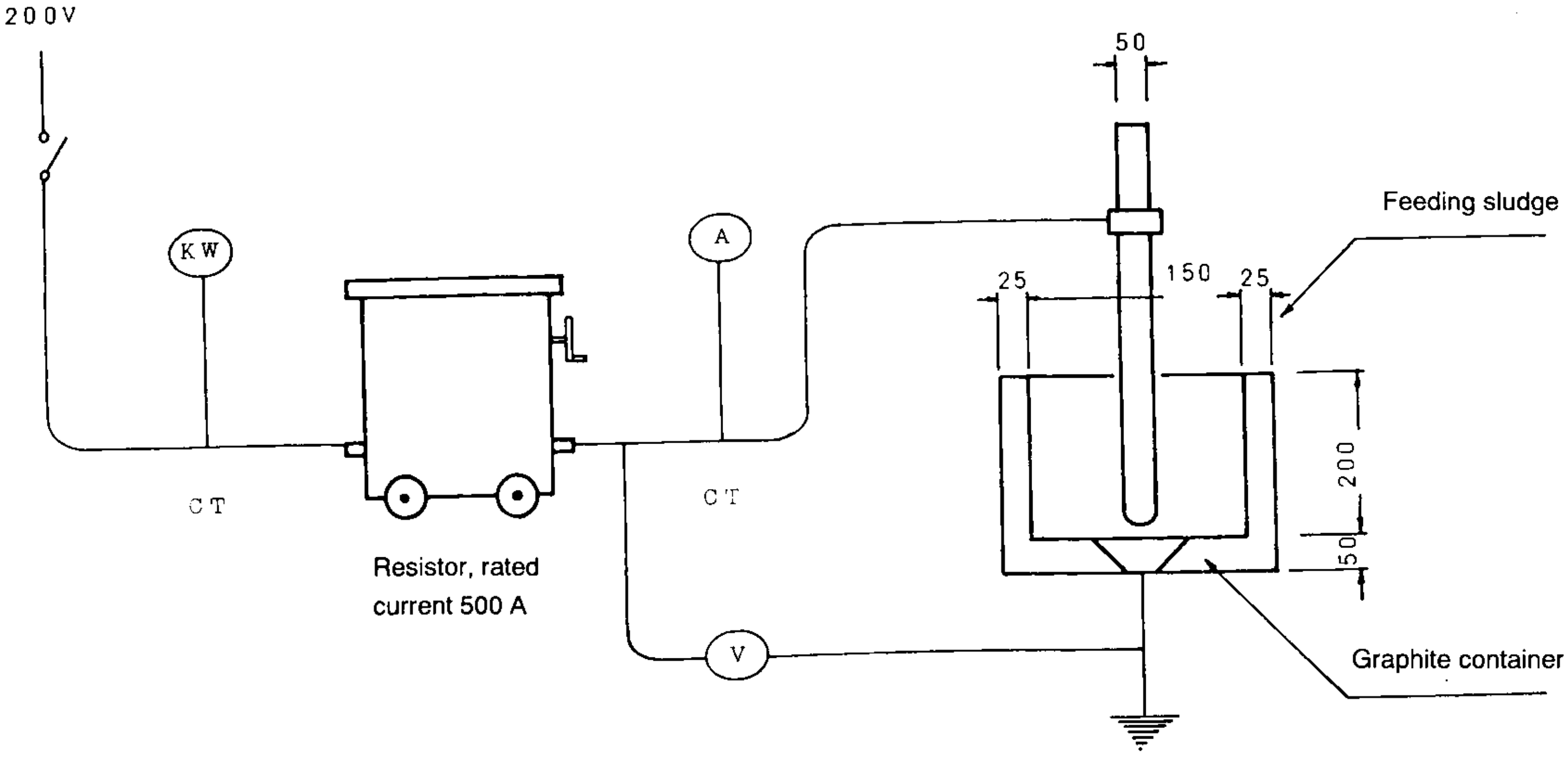


Figure 5-11 Illustration of Small Experimental Device

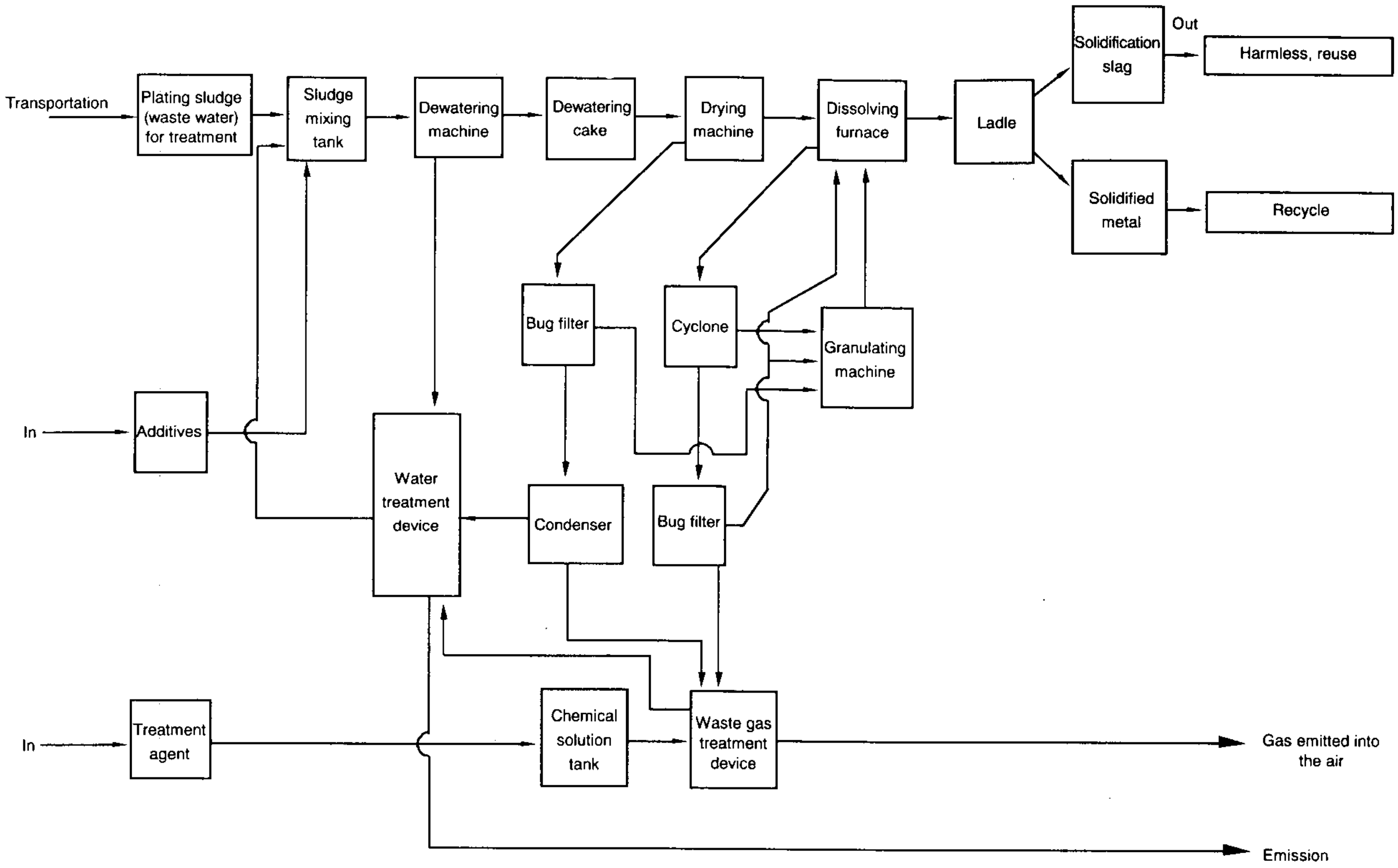
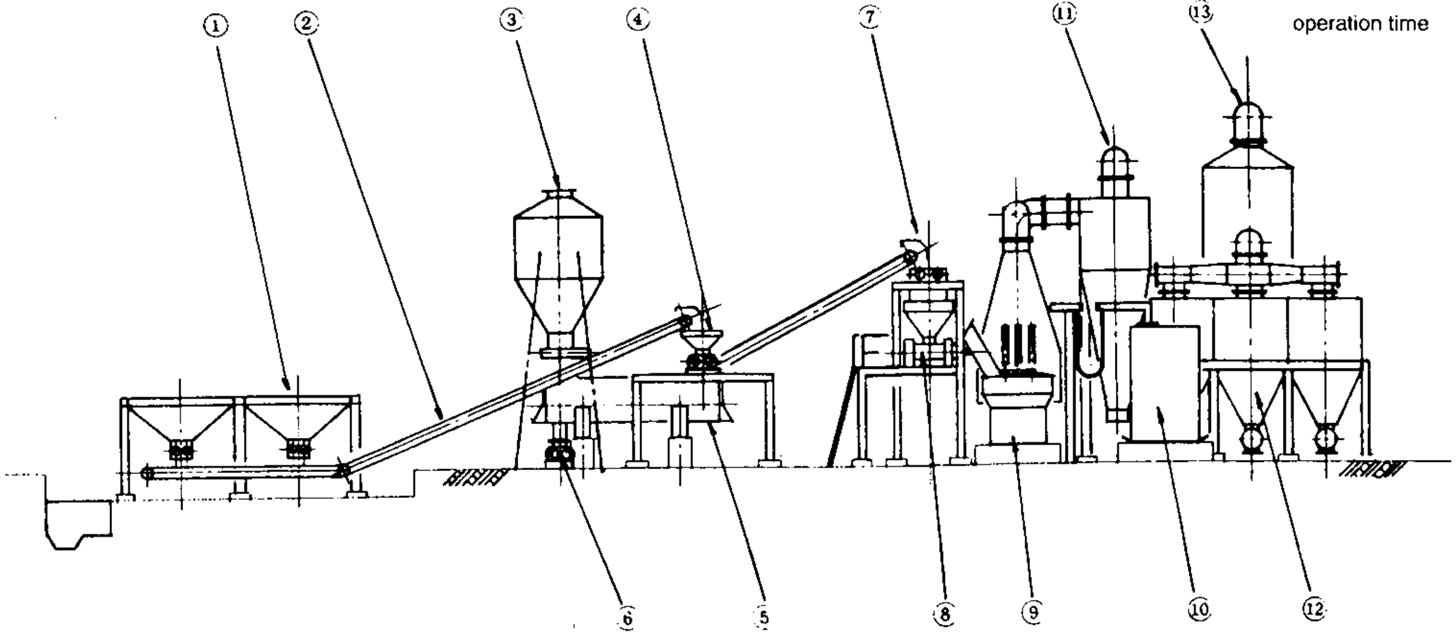


Figure 5-12 Flow Chart

Specifications

1.	Treatment capacity	8 tons/12 hrs
2.	Water content	85%
3.	Dried amount	2.0 tons/12 hrs, water content 40%
4.	Operation time	12 hrs
5.	Furnace operation time	7 hrs
6.	Additives quantity	40% (of dried amount)
7.	Drying machine operation time	12 hrs



No.	Name
1.	Sludge reservoir
2.	Sludge out conveyor
3.	Additives hopper
4.	Sludge supplier
5.	Sludge drying machine
6.	Sludge receiver
7.	Freight conveyor
8.	Fixed quantity supply machine
9.	Electric furnace
10.	Transformer
11.	Cyclone
12.	Bug filter
13.	Waste gas treatment device

Figure 5-13 Sludge Dissolution Facility, Comprehensive Illustration

Table 5-7 Dissolution Test Data of Small Pilot Furnace

Name of Waste	Water Content Ratio (wet %)	Amount (kg)	Anhydride Amount (kg)	Electricity Amount (kWH/kg)	Solidified Amount			Amount Decreased by Heat (%)	Specific Gravity (g/u)	Gas Content (PPM)	Note
					Slag (kg)	Unsolidified Substances (kg)	Metals (kg)				
Burned ash from public sewage	Water content 15.0	5.0	5.0 X 0.85 = 4.25	1.1	3.3			22.0			
Plating sludge	Water content 53.0 Additives (water content) 3.0	2.0 0.2	2.0 X 0.47 = 0.94 0.4 X 0.97 = 0.194	1.89	0.95		0.01	15.3	43.5	CO = 90 SO_2 = 70 CN = 2.7	Oxide plating sludge
Normal garbage	Water content 35.0	5.0	5.0 X 0.65 = 3.25	1.5	1.7	0.1	0.12	41.0		SO_2 = 5.0 Cl_2 = 30	Contains many inflammable substances

Table 5-8 Immersion Test Data of Solidified Substances

Waste	Content Ratio (based on dried amount)	Immersion Days								Elusion Test (ppm)	
		1 day	2 days	3 days	4 days	5 days	10 days	20 day	30 days		
Plating sludge I Additive A	1.0 0.2	○	○	○	○	○	○	○	○	Cd < 0.01 Cu < 0.1 Cr < 0.05 Ni < 0.1	Environmental Agency (Notification No. 13)
Plating sludge I Additive A Additive B	1.0 0.1 0.1	○	○	○	○	○	○	○	○	Cd < 0.01 Cu < 0.1 Cr < 0.05 Ni < 0.1	Environmental Agency (Notification No. 13)
Plating sludge II Additive A	1.0 0.43	○	○	○	○	○	○	○	○	T - Cr 0.2 Cu 0.08 Zn 0.06	Tested at pH 3

* Plating sludge is waste water containing chrome. In immersion tests, a 20 g sample and 60 cc of distilled water are put into a beaker of 100 cc and changes in the immersion fluid are observed daily.

e) Treatment cost

Treated amount 8 tons/6 hrs (water content 85%)

1) Utility charge	
1. Electric furnace	5,400 kWH x 12 yen =64,800 yen
2. Other equipment	1,026 kWH x 12 yen =12,312 yen
2) Chemical materials charge	
1. NaOH (liquid)	200 kg/day x 60 yen = 12,000 yen
2. Additives	500 kg/day x 70 yen = 35,000 yen
3) Personnel expenses	2 people x 7,000 yen = 14,000 yen
Total	138,112 yen

Treatment cost per ton

$$\frac{138{,}112 \text{ yen}}{8 \text{ ton}} = 17{,}264 \text{ yen}$$

In summary, small amounts of harmful metals in sludge can be extracted through dissolution and separation. Secondly, harmful metals that are impossible to extract need to be stabilized during sludge dissolution, and finally sealed in.

Furthermore, the amount of sludge can be reduced through dissolution, facilitating reclamation.

If new, fail-safe techniques to dissolve, separate, and finally extract harmful metals can be developed, they would be received as the most innovative sludge treatment techniques to date.

To realize such a system, we need to conduct further research focusing not only on separation, but also on additives and furnace temperatures.

If separation and extraction become 100% feasible, the amounts of extracted harmful metals must be sufficiently small to be temporarily stored. Recycling, on the other hand, is some time off.

The remains from the extraction of harmful metals are harmless, and their reuse and disposal are relatively easy. Researching their treatment, including reuse, is on the horizon.

c) Circulating reuse techniques

The returning to mine smelter method is a popular circulating reuse technique.
The method of returning plating sludge to mine refineries uses the vaporization method jointly developed by NISSO Metal Chemical Co., Ltd. and Nippon Soda Co., Ltd. NISSO's Aizu-based refinery, is collecting plating sludge and treating it to render it harmless. This treatment system is only possible with mine refineries that have existing refining facilities. The treatment process is explained in the illustration below. First, the system's treatment process is introduced.

1) Drying process

   After removal from its container, sludge is put into a fixed quantity supply device. The sludge is then sent to the drying machine by the conveyors. The drying machine uses an indirect steam heating system designed for low-temperature drying to prevent hydrocyanic acid gas generation, which occurs at high temperatures. The disc dryer helps steam pass through the revolving shaft and inside the impeller blade.

   The sludge is dried here and sent to a raw materials supply device to become volatile. Waste gas has its dust cleaned by a scrapping absorber, and the cleaning water is sent to the final waste water treatment device for disposal.

2) Reduction vaporization process

   Dried and then powdered sludge is put into a reduction volatility furnace, a cylinder type furnace with inclined rotation. When plating sludge is mixedly treated in an existing furnace for non-ferrous metal refinery, the following problems exist.

   1) Powdered sludge containing various impurities tend to pollute conventional or intermediate products.
   2) Being fine powder, dried powdered sludge can easily scatter, helping this tendency to increase.
   3) Since powdered sludge remains a hydroxide, it is combined with water. In terms of pyrometallurgy, despite its dried condition, powdered sludge still contains water. If sludge is put into the furnace of high temperatures, it triggers a sudden boiling, leading to product pollution and furnace damage, including wall damage.

   However, the treatment facility in question has solved these problems with the development of specific devices that can produce excellent undissolved clinkers. The behavior of each element in the furnace is the same as in the case of treatment of reddish minerals. In short, cyanogen is reduced to carbon dioxide and nitrogen gas at 1200 - 1300℃.

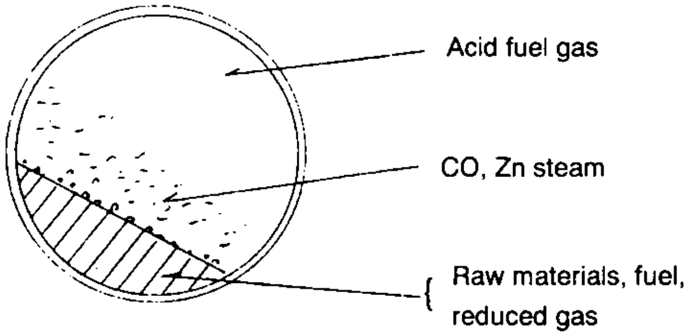


Figure 5-14

The illustration is a simulation of the cross section of a furnace. Elements like zinc, lead, and cadmium whose chemical compounds are easily reduced, and their metals can easily become volatile, at first, become volatile as metal steam, and become oxidized powders by contacting the air over the furnace. Then powders are absorbed by the cyclone and Cottrel precipitator. The absorbed powders are called "coarse zinc oxide," an intermediate product of the Aizu-based smelter.

Waste gas from which these substances have been collected is emitted into the air after powdered dust and sulfur dioxide are excluded by a jet collector and mist separator.

Gas cleaning water is treated at the final waste water treatment facility.

Copper, iron, chrome, nickel, and aluminum are emitted from the furnace as clinker, a highly reducible semi-melted substance that contains approximately 12% fixed carbon. The clinker then goes through the slag-concentration process.

Iron is ultimately reduced into metals. In the chrome reduction and neutralization and sedimentation techniques, both used at normal plating plants, hexavalent chromium remains in the sludge in small amounts.

Hexavalent chromium can be easily reduced into trivalent chrome in forcibly reduced atmosphere at high temperatures. Some part of the total chromium is reduced into metallic chromium due to large amounts of semi-melted metallic iron, and finally dispersed into the iron structure. As a result, metallic chrome is stable enough not to dissolve at normal temperatures, nor to be oxidized back into hexavalent chromium. This process is more stable than the sintered ceramics technique. Copper and nickel, meanwhile, are changed into sulfurs, and aluminum is changed into oxide.

3) Furnace process

As a rule, clinker from the reduction smelting vaporization process are sent to the clinker-concentration process. It is put into a copper blast furnace with supplementary raw materials, such as coke, silica, and limestone, and melted at 1,250℃.

Since the sulfur content in raw materials is approximately the same as the copper content, it is simply melted. The copper is concentrated in the copper regulus to a grade of approximately 20%, and finally separated from slag that contains iron. In this process, the fixed carbon in the raw material clinker acts effectively, contributing to keeping the reducing atmosphere inside the furnace regardless of the smaller amount of added coke. Finally, the clinker is changed into sand-like water-crushed clinker by a granulator. Waste gas has its dust cleaned by a cyclone and bug filter, and then cleaned by a cooler, jet collector, and mist separator to render it harmless. Finally, the waste gas is discharged. The gas cleaning water is sent to the final water treatment facility for treatment.

4) The advantages of the vaporization technique are as follows:

   1) Cadmium and lead can be made into products with zinc, and small amounts of residue with complex but stable structures with other metallic chemical compounds can never become volatile even at pH 5.8 - 6.3. Moreover, hexavalent chromium can be easily reduced and changed into an undissolved substance. Cyanogen also becomes harmless after dissolution.

   2) There is no fear of the possibility of secondary pollution of products, since they are not made from waste gas from which coarse zinc oxide is collected.

   3) The technique does not need specific supplementary raw materials.

   4) Clinker from the reduction volatility furnace is subjected to a furnace-driven treatment, and is finally reused as copper regulus through concentration. Nickel follows suit.

   5) Coarse zinc oxide is sent to an electric zinc manufacturing process through a zinc-free burning process. The burning removes impure elements.

   Consequently, in terms of harm and pollution, any kind of plating sludge must be technically treated, since it contains no mercury and organic phosphorus.

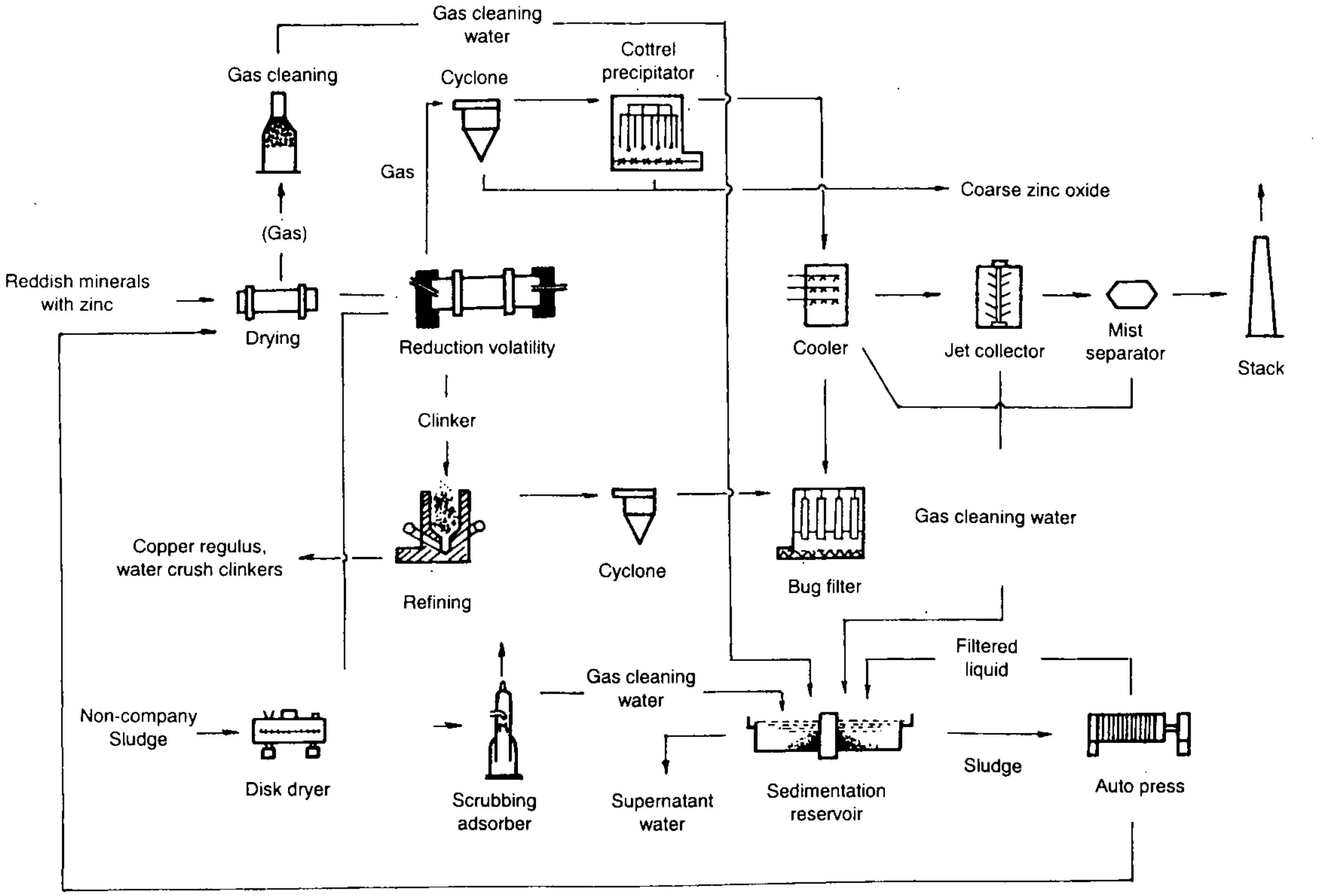


Figure 5-15 Illustration of Reddish Minerals Containing Zinc, and Reduction Volatility Process for Plating Sludge

5.1.2 Problems and Future Direction of Sludge Treatment and Disposal Systems

As discussed thus far, solutions for treatment issues of sludge with heavy metals depend on further development of treatment systems for waste water containing heavy metals. In other words, development that initially takes sludge treatment into account must proceed.

It is reasonable and feasible to try to improve emission structures rather than to focus on industrial waste treatment alone; to address treatment systems, whose entropy has already been magnified, alone, requires enormous energy.

The key point is that sludge can be fully treated if a separate treatment system designed for each harmful metal is established. To this end, not only heavy metals but also cyanogen compounds, BOD and COD elements in pre-treatment agents for brighteners and oil require treatment. Ion exchange resin method is not necessarily only one solution, but provides an effective technique towards finding a solution.

Nature's organic substances have been circulating in the natural environment for a very long time, constantly recycled when inorganic substances are synthesized into organic substances after effective use.

Man-made products have appeared quite recently given the earth's long history. Products remain incomplete and resistant to recycling after use, disposal, and recovery.

Used substances, originally underground, must be treated by humans because we extract them from the earth. Our society implements production, circulation, and consumption, but it has not yet established resource recycling. Establishing resource recycling systems is crucial to our future needs; failure to launch resource recycling projects will destroy the environment and accelerate our extinction.

Of immediate concern is the need to crack down on irresponsible emission and illegal dumping. For the sake of a clean environment, tacit approval of impractical government policies on sludge treatment must never be given.

Sludge with heavy metals has been difficult to treat; however for it doubles as a precious resource of reusable high metal content. We must not scatter sludge into environment as a valueless substance, or dump it into the oceans because it is difficult to separate. Rather, we must build huge, water-proof concrete tanks to store dewatered sludge. Should the earth one day contain only low grade ore, sludge-stored concrete tanks will provide an affluent source of minerals.

The solvent extraction technique to separate uranium, developed under the Manhattan Project of atomic industry fame, enables the separation of zirconium and hafnium, as well as separation of other, highly cohesive rare substances.

Countries worldwide have studied the heavy metals separation technique, using the solvent extraction technique. Some methods have already been put into practical use. In Japan, it is hoped that further research will progress and practical applications can be achieved.

We must eliminate mixed waste water treatment systems. We need to examine existing treatment systems for those coming out mixed. Hopefully, in the near future, some effective and innovative techniques such as the solvent extraction technique can be applied to sludge treatment.

Sludge treatment systems must be developed for resource recovery, and water treatment technology that hinders resource recovery must be reformed.

Chapter 6 Fundamental Concepts of Sludge Treatment and Disposal Systems

Our purpose here is to issue a research report to examine joint treatment systems for sludge in the metal surface treatment industry (primarily metal plating). Through this report, which covers various experiments, we have learned that we cannot establish effective countermeasures for sludge treatment without thinking about comprehensive measures to prevent environmental pollution. In short, sludge must be given top priority in all environmental conservation concerns.

In concrete terms, we must devise countermeasures by setting up a long-term treatment project. To this end, we need to clarify conditions that may apply to these measures.

6.1 Analysis of Current Sludge Treatment and Disposal Systems

Before explaining the fundamental concepts of sludge treatment and disposal systems, we need to summarize current treatment systems.

In the water quality maintenance technique, a "water treatment system" aimed at treating polluted water is popular.

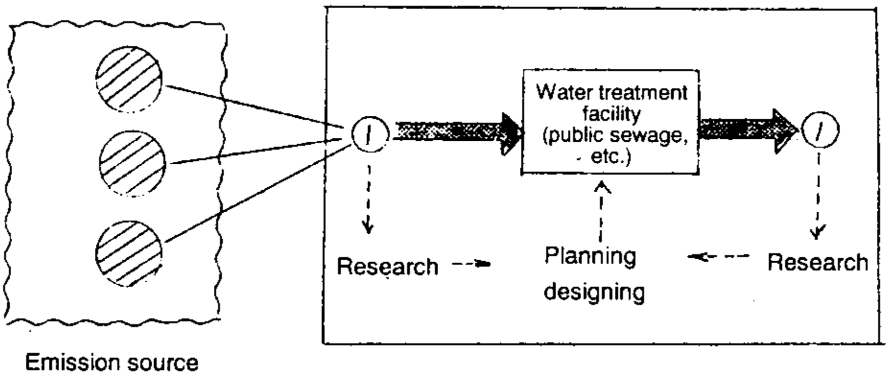


Figure 6-1 Current Water Treatment System

The "large (joint) intensive treatment" designed to treat waste water comprehensively by mixing in water is the most popular water treatment system used to treat waste.

This technique, however, works only where polluted water is self-cleaning and the amount of emission is very small. It cannot be applied to polluted substances, including harmful heavy metals. Nevertheless, it is still used by industries that care little for nature's limited cleaning ability due to the fact that polluted substances in plating industry contain harmful heavy metals. Industry appears to use large, intensive treatment systems with a view only towards efficient manufacturing, economy, and investment growth. Such an irresponsible and self-centered approach poses a serious problem for society; the functional upgrading of water treatment systems works only to "exclude" larger amounts of polluted substances. This is because the technique provides a poor link between the prevention of environmental pollution and environmental conservation; it is ultimately inconsistent in the treatment process.

As a result, sludge treated by such treatment systems remains complex in its physical characteristics, making such a treatment method almost impossible.

To this end, the concrete solidification, plastic solidification, and artificial aggregate gravelization techniques have been developed. These techniques, however, require space for treatment. Moreover, since Japan relies heavily on overseas production for most natural resources, the notion of discarding waste as quite valueless and spending enormous energy and capital investment on treatment needs to be reformed. In addition, harmful substances solidified through treatment and buried in the reclaimed land will offer the possibility of appearing from the land in the future. This leads to secondary environmental pollution despite a quality that meets legal standards.

Consequently, new sludge treatment systems that take current water treatment problems into account must be developed.

We must attack the sludge issue with recovery and recycling in mind. To this end, we need to develop new systems that are capable of producing reducible sludge and of collecting it for recycling. The function of conventional water treatment systems is limited to discharging mixed sludge with harmful heavy metals.

6.2 Control of Basic Factors That Cause Sludge

It is clear that focusing on the sludge treatment issue alone would make little sense in a project for comprehensive sludge treatment systems. We must consider far-reaching social factors, such as the size of emission sources, location, and people's way of thinking. The focus is never limited to the issue of the treatment facility alone.

According to emission research, most small companies do not use waste water treatment systems, meaning they do not even produce sludge. Their treatment is terribly underdeveloped and irresponsible. As a result, more sludge is expected to be emitted from companies who care only about circumventing water quality regulations.

In summary, the following three "mechanisms" are linked to sludge generation.

1. "Direct generation" from waste water treatment systems;
2. "Indirect generation" that occurs when emission sources change;
3. "Peripheral generation," such as technological standards and a transformation of social consciousness.

The following are major factors that dominate direct generation.

1. Qualitative and quantitative differences in harmful sludge due to differences in treatment facilities and methods
2. Qualitative and quantitative differences in harmful sludge due to changes in production output and product types

The major factors in indirect generation are:

1. Qualitative and quantitative differences in harmful sludge due to enhancement of social awareness of environmental pollution
2. Qualitative and quantitative differences in harmful sludge due to industrial reorganization under urban projects
3. Qualitative and quantitative differences in harmful sludge due to changes in water use systems

The major factors in peripheral generation are:

1. Qualitative and quantitative increases in harmful sludge due to society's increased awareness of environmental pollution
2. Qualitative and quantitative differences in harmful sludge due to enhancement of treatment technique levels, as well as greater control
3. Qualitative and quantitative differences in harmful sludge due to enforcement of regulations (from concentrations to total amounts)
4. Qualitative and quantitative differences in harmful sludge due to development of joint industrial complexes.

Although we have been unable to analyze the several factors discussed above, it is obvious from this research that a proper sludge treatment system can be achieved by totally grasping these three factors.

On this basis, then, the essential first step is to determine accurately what factors are indispensable to sludge treatment.

We have, of course, taken all necessary actions including obtaining as many data and much information as possible.

Further research and examination are also indispensable to upgrading sludge treatment techniques.

Thus, this research report covering the fundamental concepts of sludge treatment and disposal systems falls short in the following areas:

1. Technical possibility of controlling major factors in sludge creation.
2. Economical possibility of controlling major factors in sludge development
3. Possibility of emission mechanism improvements
4. Possibility of introduction of joint emission and treatment operations
5. Possibility of sludge recycling in terms of distribution, economy and technology

6.3 Fundamental Concepts of Sludge Treatment Systems

We need to establish the following consistent treatment project while examining the insufficient research areas noted above.

1. Short-term countermeasures for sludge treatment
2. Medium-term countermeasures for sludge separation and recycling
3. Long-term countermeasures to introduce the closed system for waste water treatment

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Conclusion

Through this and previous research, we have acknowledged that the treatment of sludge containing harmful metals has not improved, and remains a major issue to those charged with handling treatment.

Local governments still have a difficult time coping with normal garbage treatment, let alone industrial waste. Some local governments, however, such as Nagano Prefecture, have established a public corporation to address sludge treatment. Other local governments also plan to follow Nagano's lead.

Despite different situations at each location, the ultimate goal is environmental conservation. On this point, the Nagano Prefectural government must be applauded for its achievements, regardless of its sludge treatment systems.

The most important practical solution is to decrease sludge emission through improvements in manufacturing processes and closed waste water treatment systems. This is, unfortunately, difficult to achieve, for it is financially difficult for small plating companies to renovate their current waste water treatment equipment with further investment.

As a result, some companies secretly commit illegal "treatment" acts in "midnight," discharging waste water without implementing the necessary treatment process.

Should this continue, it is only a matter of time before we experience environmental pollution at its worst. Nevertheless, companies as well as local governments still support the establishment of efficient treatment systems. Still, underdeveloped treatment technology, the enormous cost of conventional treatment systems, a shortage of appropriate waste disposal sites, and problems regarding the waste producer's responsibilities under the Waste Disposal and Public Cleaning Law — these restrictions actually prevent local government intervention in sludge treatment.

Heavily polluted areas desperately need immediate counter-measures, and some are planning to adopt large treatment systems with the commitment of local government behind them. Significant though this may be, there are technical drawbacks and financial problems. What is ultimately needed, therefore, is drastic improvement capable of encompassing the overall issues.

Again, sludge treatment requires hefty technologies and enormous costs. Consequently, new treatment systems that cover recovery, reuse and recycling of resources in a comprehensive way need to be established. This can only be accomplished with extensive cooperation among industrial companies, pharmaceutical companies, treatment service companies and manufacturers of anti environmental pollution equipment.