3.5 Conceptional Design of the Optimum Systems

Conceptional design regarding the previously selected 3 systems (CASE-1, -2, -3) is made, and the specifications and layout of equipment are decided on.

3.5.1 Preconditions

Preconditions for conceptional design as basically the same as that of II. Plating Industrial Estate. The Conditions are shown below.

A. Purchasing expenses for the construction site are excluded.

B. Excluded are water & wastewater plumbing from the dyeing industrial estate to the central treatment plant, reserve stocks, works of piling, ground reform and remaining soil disposal in contraction expenses, plumbing from the central treatment plant to the treatment water discharging terminal, outside exclusive road development, gardening, fence works, first stage power supply, outside lighting works. Heating and indoor lighting works are included to have the facilities generalized in Korea.

C. Sludge is dehydrated to form dehydrated cakes of 85% water content, that is delivered out and disposed of as industrial waste.

D. Wastewater treatment is made by continuous & automatic operation.

E. Facilities operate 24 hrs/day.

F. Reclamation of activated carbon is consigned to an outside company.

G. Power used is 220 V. 50 Hz.

H. Construction period is 2 years.

3.5.2 System meeting the existing effluent standards (CASE-1)

(1) Conceptional design

Fig. 3.5.1 shows a diagram of CASE-1. Treatment from biological treatment to coagulation sedimentation is conducted through 4 systems. The conceptional design results is as follows.

A. Sedimentation basin

A-1 Grit chamber

Particles of over 0.2 mm diameter are submerged.

a) Design condition

Flowing water quantity	:	100,000 m^3/day
Flow speed	:	0.25 m/s
Retention time	:	1 - 2 min.

b) Specifications

Capacity	:	56 m^3
Shape	:	2.5 mW x 11.2 mL x 2.0 mD (effective)
Material	:	Reinforced concrete
Quantity	:	2 sets

c) Supplementary equipment

* Sludge collector		
Type	:	Basket conveyer type
* Rough screen		
Type	:	Fixed & hand scratching type
Pitch	:	100 mm
* Fine screen		
Type	:	Successive rake type
* Pitch	:	20 mm
* Gate		
Type	:	Electricity powered type, 1,000 mm x 1,000 mm

A-2 Pump pit

a) Design condition

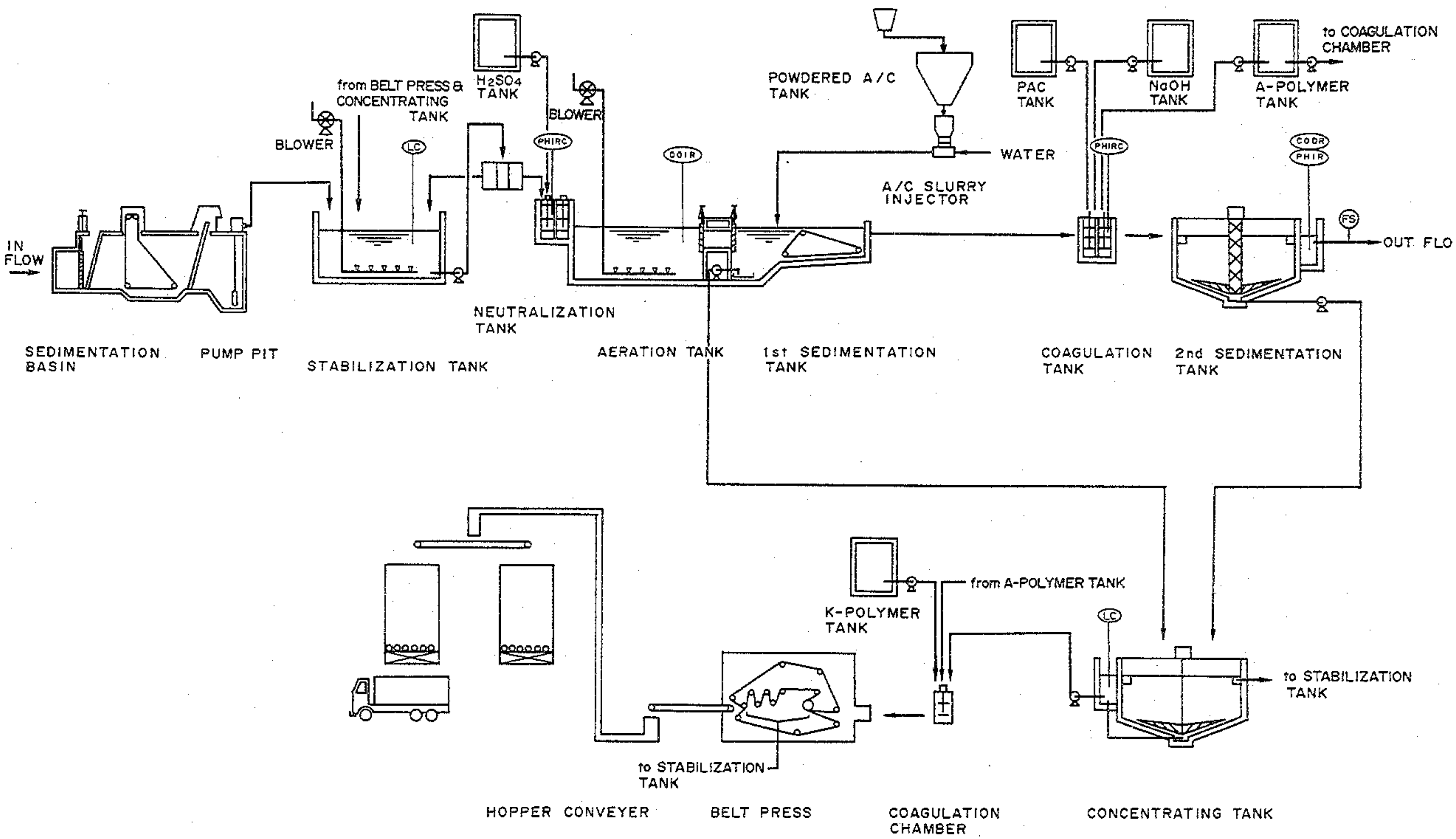


Fig. 3.5.1 Flowchart of Treatment in CASE-1

Flowing water quantity : 100,000 m^3day
Retention time : 1 - 2 min.

b) Specifications

Capacity : 150 m^3
Shape : 10.0 mW x 5.0 mL x 3.0 mD
Material : RC
Quantity : 1 set

c) Supplementary equipment

* Pump

Type : Vertical type mixed flow pump
Capacity : 17.5 m^3/min. x 10 mH x 400ø
Electric motor : 55 kW x 440 V
Quantity : 4 + 2 sets

B. stabilization tank

a) Design condition

Flowing water quantity : 100,000 m^3/day
Average 4,170 m^3/h
(max. 6,500 m^3/h, min. 2,100 m^3/h)

Retention time : 4.5 h
Retention time (RT) is decided on, referring to current wastewater flow condition.

b) Design calculation

Calculation

Capacity : 100,000 m^3/day x 1/24 x 4.5 h = 18.750 m^3

c) Specifications

Capacity : 18,750 m^3
Shape : 50 mW x 75 mL x 5 mD(effective)
Material : RC
Quantity : 1 set

d) Supplementary equipment

* Blower

Aeration rate : 0.5 m^3/m^3.h
Capacity calculation

$$18,750\ m^3 \times 0.5\ m^3/m^3.h \times 1/60 = 156\ m^3/min.$$

Capacity : 156 Nm^3/min. x 0.5 kgf/cm^2
Electric motor : 200 kW x 440 V
Quantity : 1 set

* Pump

Capacity calculation

$$4,170\ m^3/h \times 1/60 \times 1.2 = 83.4 m^3/min.$$

Capacity : 10.5 m^3.min. x 15 mH
Electric motor : 440 V x 37 kW
Quantity : 8 + 4 sets

C. Measuring & neutralization tank

C-1 Measuring instrument

a) Specifications

Shape : Partial flume
Material : Stainless steel
Quantity : 2 sets

C-2 Neutralization tank

a) Design condition

Flowing water quantity : 100,000 m^3/day
Retention time : 10 min.

b) Design calculation

Calculation
Capacity : 100,000 m^3/day x 1/1440 x 10 min. = 694 m^3

c) Specifications

Shape : 5 mW x 5 mL x 5 mD x 3 tanks
Material : RC
Quantity : 2 sets

d) Supplementary equipment

* Agitator

Type : Vertical propeller blade
Rotation : 300 rpm
Electric motor : 15 kW x 440 V
Quantity : 6 sets

D. Aeration tank

a) Design condition

Flowing water quantity	:	25,000 m^3/day x 4 lines
BOD load	:	25,000 m^3/day x 300 g-BOD/m^3
		1000 = 7,500 kg-BOD/day
BOD volumetric load	:	1.1 kg-BOD/m^3day
F/M ratio	:	0.2 kg-BOD/kg-MLSS·day

b) Design calculation

Calculation capacity	:	7,500 kg-BOD/day
		x 1/1.1 kg-BOD/m^3/day
		= 6,820 qam^3
MLSS concentration	:	1.1 kg-BOD/m^3/day
		x 1/0.2 kg-BOD/kg-MLSS/day
		x 1000 = 5,500 mg/l

c) Specifications

Capacity	:	7,000 m^3
Shape	:	5 mW x 35 mL x 5 mH x 8 lines
Material	:	RC
Quantity	:	4 sets

d) Supplementary equipment

* Blower

O/C load 1.5

Capacity calculation

7,500 kg-BOD/day x 1.5 x 1/0.277
x 1/0.2 x 1/1440 = 141 Nm^3/min.

Type	:	Turbo blower
Capacity	:	36 Nm^3/min. x 0.5 kgs/cm^2
Electric motor	:	45 kW x 440 V
Quantity	:	(4 x 1) x 4 sets

E. 1st sedimentation tank

a) Design condition

Flowing water quantity	:	25,000 m^3/day x 4 lines
Surface load	:	20 m^3/m^2/day

b) Design calculation

Required area	:	25,000 m^3/day x 1/20 m^3/m^2/day
		= 1,250 m^2

c) Specifications

Shape	:	5 mW x 32 mL x 3 mH x 8 lines

Material : RC

Quantity : 4 sets

d) Supplementary equipment

* Sludge collector (main)

Type : Chain flight type 5mW x 32 mL

Quantity : 8 x 4 sets

* Sludge collector (cross)

Type : Chain flight type 1.5 mW x 20 mL

Quantity : 2 x 4 sets

* Sludge pump

Type : Non-clog type

Capacity : 8.8 m^3/min. x 15 kgs/cm^2

Electric motor : 22 kW x 440 V

Quantity : (2 + 1) x 4 sets

F. Contact aeration tank

a) Design condition

Flowing water quantity : 25,000 m^3/day x 4 sets

Retention time : 4.8 h

b) Design calculation

Calculation capacity : 25,000 m^3/day x 1/24 x 4.8 h = 5,000 m^3

c) Specifications

Surface area : 1,280 m^2

Shape : 5 mW x 25 mL x 5 mH x 8 lines

Material : Tank RC
Contact media
Honoycomb type 500 m^3 x 8 lines
PVC product
Contact media table
Stainless steel product

Quantity : 4 sets

d) Supplementary equipment

* Blower

Aeration rate 1 $m^3/m^3/h$

5,000 m^3 x 1 $m^3/m^3/h$ x 1/60 = 83 Nm^3/min.

Type : Turbo blower

Capacity	:	42 Nm^3/min. x 0.5 kgf/cm^2
Electric motor	:	45 kW x 440 V
Quantity	:	(2 + 1) x 4 sets

G. Reaction and coagulation tank

a) Design condition

Flowing water quantity	:	25,000 m^3/day x 4 lines
Retention time	:	14 min. (reaction tank 7 min., coagulation tank 7 min.)

b) Design calculation

Calculation capacity	:	25,000 m^3/day x 1/1440 x 14 min. = 243 m^3

c) Specifications

Capacity	:	250 m^3 (reaction tank 125 m^3, coagulation tank 125 m^3)
Shape	:	5 mW x 10 mL x 2.5 mD x 2 tanks
Material	:	RC
Quantity	:	4 sets

d) Supplementary equipment

* Agitator (reaction tank)

Type	:	Vertical propeller blade
Rotation	:	300 rpm
Electric motor	:	30 kW x 440 V
Quantity	:	4 x 2 sets

* Agitator (coagulation tank)

Type	:	Vertical paddle blade
Rotation	:	60 rpm
Electric motor	:	22 kW x 440 V
Quantity	:	4 x 2 sets

H. 2nd sedimentation tank

a) Design condition

Flowing water quantity	:	25,000 m^3/day x 4 lines
Surface load	:	40 m^3/m^2/day

b) Design calculation

Required area	:	25,000 m^3/day x 1/40 m^3/m^2/day = 625 m^2

c) Specifications

Shape	:	29 mø x 3 mH
Material	:	RC
Quantity	:	4 sets

d) Supplementary equipment

* Sludge collector

Type	:	Rake type sludge collector
Quantity	:	4 sets

* Sludge pump

Type	:	Horizontal slurry pump
Capacity	:	1.2 m^3/min. x 1.5 kgf/cm^2
Electric motor	:	7.5 kw x 440 V
Quantity	:	4 + 1 set

I. Sludge thickener

Estimation of producing sludge quantity

SS (120-30) g/m^3 x 1/1,000 x 100,000 m^3/day
= 9,000 kg/day

BOD (300-30) g/m^3 x 1/1,000 x 30% x 100,000 m^3/day
= 8,100 kg/day

Coagulation 100,000 m^3/day x 500 ppm x 1/1,000 x 15%
= 7,500 kg/day

Total 24,600 kg/day

Sludge measurement is 2,460 m^3/day at the sludge density of 10 kg/m^3.

a) Design condition

Treatment quantity	:	2,460 m^3/day
Surface load	:	10 m^3/m^2/day
RT	:	16 h
Sludge concentration	:	3% concentration from 1%

b) Design calculation

Required area	:	2,460 m^3/day x 1/10 m^3m^2/day = 246 m^2
Design calculation	:	2,460 m^3/day x 1/3 x 1/24 x 16 h = 547 m^3

c) Specifications

* Sludge collector

Shape	:	15 mø x 3 mH
Material	:	RC
Quantity	:	2 sets

d) Supplementary equipment

* Sludge collector

Type	:	Rake type sludge collector
Quantity	:	2 sets

* Sludge pump

Type	:	Horizontal slurry pump
Capacity	:	0.38 m^3/min. x 15 kgf/cm^2
Electric motor	:	7,5 kW x 440 V
Quantity	:	2 sets

J. Sludge dewatering tank

Dewatering of sludge is processed in 3 lines. Operation time is 8 h/day.

J-1 Coagulation tank

a) Design condition

Treatment quantity	:	820 m^3/day (3% sludge concentration)
Retention time	:	3 min.

b) Design calculation

Calculation capacity	:	820 m^3/day x 1/8 h x 1/60 x 3 min. = 5.1 m^3

c) Specifications

Capacity	:	1.73 m^3
Shape	:	1.5 mø x 1.0 mH
Material	:	RC
Quantity	:	3 sets

J-2 Dehydrator

a) Design condition

Treatment capacity	:	24,600 kg/day

(3% sludge concentration)

Sludge water content : 85%

b) Design calculation

Filtration speed : 24,600 kg/day x 1/8 h/day = 3075 kg/h

Dewatered sludge : 24,600 kg/day x 1/0.15 x 1/1,000 = 164 t

c) Specifications

Type : Beltpress type

Material : SS

Quantity : 3 sets

K. Chemicals pouring equipment

K-1 Sulfuric acid tank

a) Design condition

Pouring quantity : pH 11.5 wastewater is neutralized to ph 7.0, and 0.15 kg/m^3 concentration sulfuric acid) is available.

Retention time : 1 week

b) Design calculation : 100,000 m^3/day x 0.15 kg/m^3 / 0.75 / 1.7 x 1/1000 x 2 = 23.6 m^3/day

Capacity : 23.6 m^3/day x 6 days = 142 m^3

c) Specification

Capacity : 75 m^3

Shape : 5 mW x 3 mL x 5 mH

Material : RC acid resistant finish

Quantity : 2 sets

d) Supplementary equipment

* Sulfuric acid pouring pump

Type : Oil pressure diaphragm type

Capacity : 8.2l/min. x 5.0 kgf/cm^2

Electric motor : 1.5 kW x 440 V

Material : Teflon

Quantity : 2 + 1 sets

K-2 PAC tank

a) Design condition

Pouring quantity	:	500 ppm
Retention time	:	1 week

b) Design calculation

Consumption quantity	:	100,000 m^3/day x 500 ppm x 1/1000 x 1/1.1 x 1/1000 = 44.2 m^3/day
Capacity	:	44.2 m^3/day x 6 days = 265 m^3

c) Specifications

Capacity	:	275 m^3
Shape	:	5 mW x 11 mL x 5 mH
Material	:	RC acid resistant finish
Quantity	:	2 sets

d) Supplementary equipment

* PAC pouring pump

Type	:	Oil pressure diaphragm type
Capacity	:	7.7l/min. x 5.0 kgf/cm^2
Electric motor	:	1.5 kW x 440 V
Material	:	Teflon
Quantity	:	4 + 1 sets

K-3 Caustic soda tank

a) Design condition

Pouring quantity	:	55 ppm (25% concentration)
Retention time	:	1 week

b) Design calculation

Consumption quantity	:	100,000 m^3/day x 55 ppm x 1/1000 x 1/0.25 x 1/1.2 x 1/1000 x 2 = 36.6 m^3/day
Capacity	:	36.6 m^3/day x 6 days = 220 m^3

c) Specifications

Capacity	:	275 m^3
Shape	:	5 mW x 3 mL x 5 mH
Material	:	RC alkali resistant finish
Quantity	:	2 sets

d) Supplementary equipment

* Caustic soda pouring pump

Type	:	Oil pressure diaphragm type
Capacity	:	6.41/min. x 5.0 kgf/cm^2
Electric motor	:	1.5 kW x 440 V
Material	:	Teflon
Quantity	:	4 + 1 sets

K-4 A-polymer coagulant tank

a) Design condition : Water treatment use 2 ppm
(0.1% concentration)
Dewatering use
0.5% dried solid content
(0.1% concentration)

b) Design calculation

Consumption : Water treatment use
100,000 m^3/day x 2 ppm
x 1/1000 = 200 kg/day
Dewatering use
16,500 kg/day x 0.5%
= 82.5 kg/day
282.5 kg/day x 1/0.001
x 1/1000 = 282.5 m^3

c) Specifications

Capacity	:	250 m^3
Shape	:	5 mw x 10 mL x 5 mH
Material	:	RC chemical resistant finish
Quantity	:	2 sets

d) Supplementary equipment

* A-polymer coagulant tank agitator

Type	:	Vertical propeller blade
Rotation	:	300 rpm
Electric mot or	:	30 kW x 440 V
Material	:	Stainless steel
Quantity	:	4 sets

* A-polymer coagulant pump
(water treatment use)

Type	:	Oil pressure diaphragm type

Capacity	:	351/min. x 6.0 kgf/cm^2
Electric motor	:	2.2 kw x 440 V
Quantity	:	4 + 1 sets
(dewatering use)		
Type	:	Oil pressure diaphragm type
Capacity	:	861/min. x 6.0 kgf/cm^2
Electric motor	:	2.2 kW x 440 V
Material	:	Teflon
Quantity	:	2 + 1 sets

K-5 K-polymer coagulant tank

a) Design condition

Pouring quantity	:	Dewatering use 0.5% dried solid content (0.2% concentration)

b) Design calculation

Consumption	:	Dewatering use 16,500 kg/day x 0.5% = 82.5 kg/day 82.5 kg/day x 1/0.002 x 1/1000 = 41.3 m^3/day

c) Specifications

Capacity	:	26 m^3
Shape	:	2.3MW x 2.3ML x 5MH
Material	:	RC chemical resistant finish
Quantity	:	2 sets

d) Supplementary equipment

* K-polymer coagulant tank agitator

Type	:	Vertical propeller blade
Rotation	:	300 rpm
Electric motor	:	17.5 kW x 440 V
Material	:	Stainless steel
Quantity	:	2 sets

* K-polymer coagulant pump

Type	:	Oil pressure diaphragm type
Capacity	:	431/min. x 6.0 kgf/cm^2
Electric motor	:	2.2 kW x 440 V
Material	:	Teflon

Quantity : 2 + 1 sets

Table 3.5.1 shows specifications of equipment of CASE-1.

Table 3.5.1 Specification of Equipmet in CASE-1

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
1	SEDIMENTATION BASIN	2	RC	$2.5m^{W} x 12m^{L} x 2.2m^{H}$	
	SLUDGE COLLECTER	2	SS	Busket Conveyor type	
	ROUGH SCREEN	2	SS	Pich 100mm	
	FINE SCREEN	2	SS	Pith 10mm	
2	PUMP PIT	1	RC	$10m^{W} x 5m^{L} x 3m^{H}$	pHIR, LICA
	PUMP	4 + 2	FC	17.5m3/mx10mHx55kW	
3	STABILIZATION	1	RC	$50m^{W} x 75m^{L} x 5m^{H}$	LICA
	BLOWER	1	FC	$156Nm^3/m x 0.5kgf/cm^2 x 200kW$	
	PUMP	8 + 4	FC	$10.5m^3/m x 15mH x 37kW$	
4	MEASURING INSTRUMENT	2	SUS	Partial Flume	FIRQ
5	NEUTRALIZATION TANK	2	RC	$5m^{W} x 5m^{L} x 5m^{H}$ x3tanks	pHIRC
	AGITATOR	6	SUS	500rpm x15kW	
6	AERATION TANK	4	RC	$5m^{W} x 34m^{L} x 5m^{H}$ x8lines	DOIR
	BLOWER	16 + 4	FC	$36Nm^3/m x 0.5kgf/cm^2 x 45kW$	
	MEASURING INSTRUMENT	8	SUS		FIRQ
	OUT FLOW GATE	16	FC	1000mm x 1000mm	
7	1st SEDIMENTATION TANK	4	RC	$5m^{W} x 32m^{L} x 3m^{H}$ x8lines	
	SLUDGE COLLECTOR (M)	32	SS, Rasin	Chain Flight type $5m^{W} x 32m^{L}$	
	SLUDGE COLLECTOR (C)	8	SS, Rasin	Chain Flight type $1.5m^{W} x 20m^{L}$	
	SLUDGE POMP	8 + 4	FC	$8.8m^3/m x 15mH x 22kW$	
8	CONTACT AERATION TANK	4	RC	$5m^{W} x 25m^{L} x 5m^{H}$ x8lines	DOIR
	CONTACT MATERIAL	4	PVC	$500m^3$ x8lines	
	BLOWER	8 + 2	FC	$42Nm^3/m x 0.5kgf/cm^2 x 45kW$	
9	COAGULATION TANK	4	RC	$5m^{W} x 10m^{W} x 2.5m^{H}$ x2tanks	pHIRC
	AGITATER (R)	8	SUS	300rpm x 30kW	
	AGITATOR (C)	8	SUS	60rpm x 22kW	

Table 3.5.1 Specification of Equipmet in CASE-1 (continue)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
10	2nd SEDIMENTATION TANK	4	RC	29mφx3m^H	CODR, pHIR
	SCRAPER	4	SS	Rake type 29m	
	SLURRY PUMP	4 + 1	FC	1.2m^3/mx15mHx7.5kW	
11	CONCENTRATING TANK	2	RC	15mφx3m^H	LICA
	SCRAPER	2	SS	Rake type 15m	
	SLURRY PUMP	2	FC	0.38m^3/mx15mHx7.5kW	
12	COAGULATION CHAMBER	3	RC	1.5mφx1m^H	
13	BELT PRESS	3	SS	3m^W 3.7kW	
	VELT CONVEYOR	2	SS, NBR	600m^{W}x14m^{L}x1.5kW	
	SCREW CONVEYOR	1	SS	5.5kW	
	CAKE HOPPER	2	SS	2.7m^{W}x5m^{L}x5m^H	
14	H_2SO_4 TANK	2	RC	5m^{W}x3m^{L}x5m^H	LIA
	PUMP	2 + 1	Teflon	8.2ℓ/mx5kgf/cm^{2}x1.5kW	
15	PAC TANK	2	RC	5m^{W}x5.5m^{L}x5m^H	LIA
	PUMP	4 + 1	Teflon	7.7ℓ/mx5kgf/cm^{2}x1.5kW	
16	NaOH TANK	2	RC	5m^{W}x3m^{L}x5m^H	LIA
	PUMP	4 + 1	Teflon	6.4ℓ/mx5kgf/cm^{2}x1.5kW	
17	A-COAGULANT TANK	2	RC	5m^{W}x10m^{L}x5m^H	LIA
	AGITATER	4	SUS	300rpm x 30kW	
	PUMP (W)	4 + 1	Teflon	35ℓ/mx6kgf/cm^{2}x2.2kW	
	PUMP (S)	2 + 1	Teflon	86ℓ/mx5kgf/cm^{2}x2.2kW	
18	K-COAGULANT TANK	2	RC	5m^{W}x10m^{L}x5m^H	LIA
	AGITATER	2	SUS	300rpm x 17.5kW	
	PUMP	2 + 1	Teflon	43ℓ/mx6kgf/cm^{2}x1.5kW	

(2) Layout

Fig. 3.5.2 shows the layout of CASE-1 treatment facilities. The site area is 50,700 m^2 (195 mW x 260 mL).

3.5.3 Advanced treatment system for removal of COD (CASE-2)

(1) Conceptional design

Fig. 3.5.3 shows the system of CASE-2. CASE-2 treats 80,000 m^3/day partially out of the treated water in CASE-1.

Conceptional design for equipment is performed for the distribution pit after CASE-1 treatment to the mixing tank.

A. Distribution equipment

A-1 Distribution pit

20,000 m^3/day and 80,000 m^3/day are distributed.
The former is sent to the mixing tank, and the latter is also sent to the mixing tank after sand filtration and activated carbon adsorption.

a) Design condition

Flowing water quantity	:	100,000 m^3/day

b) Specifications

Capacity	:	6 m^3
Shape	:	3.0 mW x 1.0 mL x 2.0 mD (effective)
Material	:	RC
Quantity	:	1 set

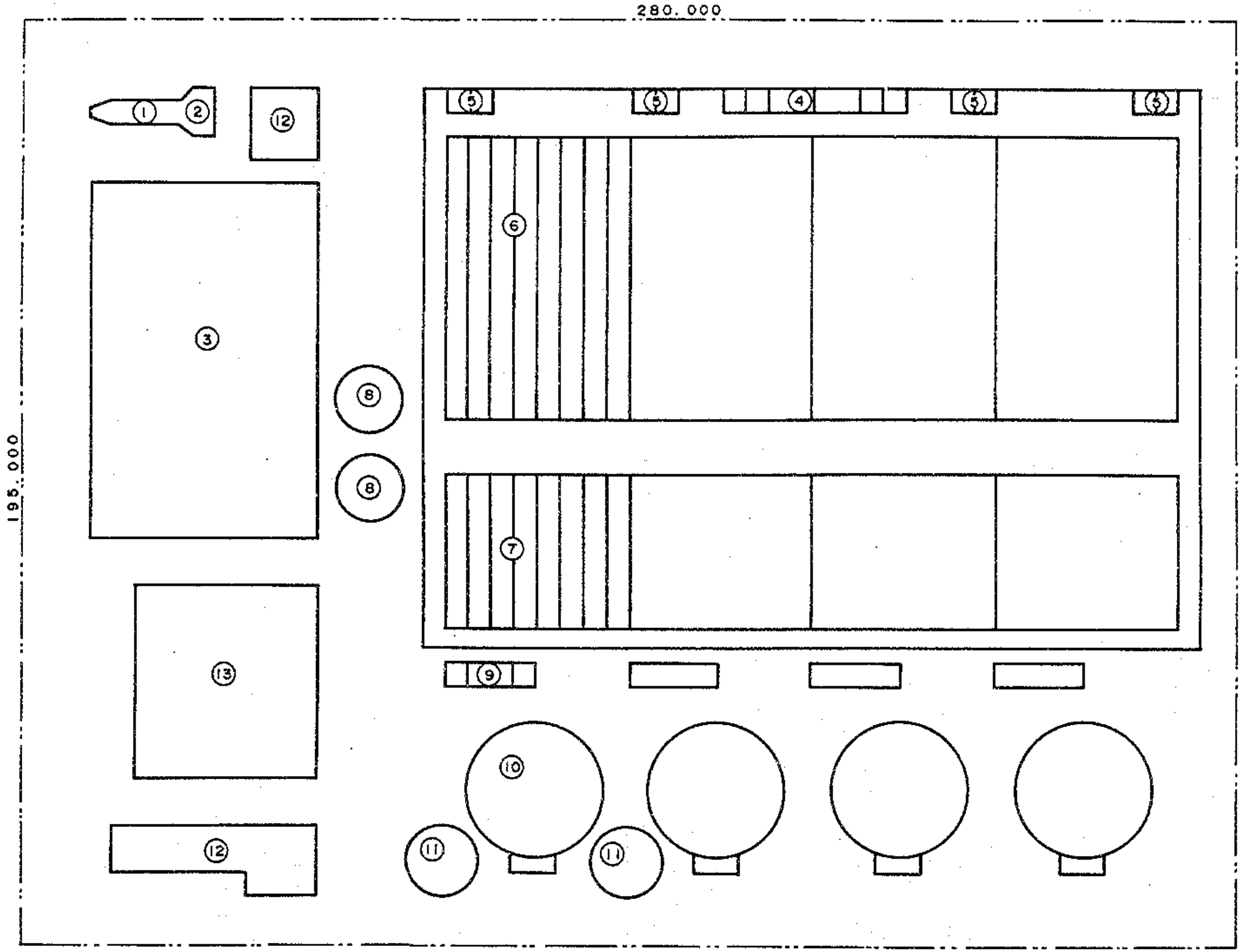
A-2 Coagulation sedimentation tank

a) Design condition

Flowing water quantity	:	80,000 m^3/day
Retention time	:	10 min.

b) Design calculation

Calculation capacity	:	80,000 m^3/day x 1/1440 x 10



No.	DESIGNATION
13	HOUSE 1F BLOWER 2F DEHYDRATOR 3F CONTROL ROOM
12	CHEMICAL CHAMBER YARD
11	CONCENTRATED TANK
10	2nd SEDIMANTATION TANK
9	COAGULATION TANK
8	POWDERED A/C TANK
7	1st SEDIMANTATION TANK
6	AERATION TANK
5	NEUTRALIZATION TANK
4	DISTRIBUTION TANK
3	STABILIZATION TANK
2	PUMP PIT
1	SEDIMENTATION BASIN

Fig. 3.5.2 Layout in CASE-1

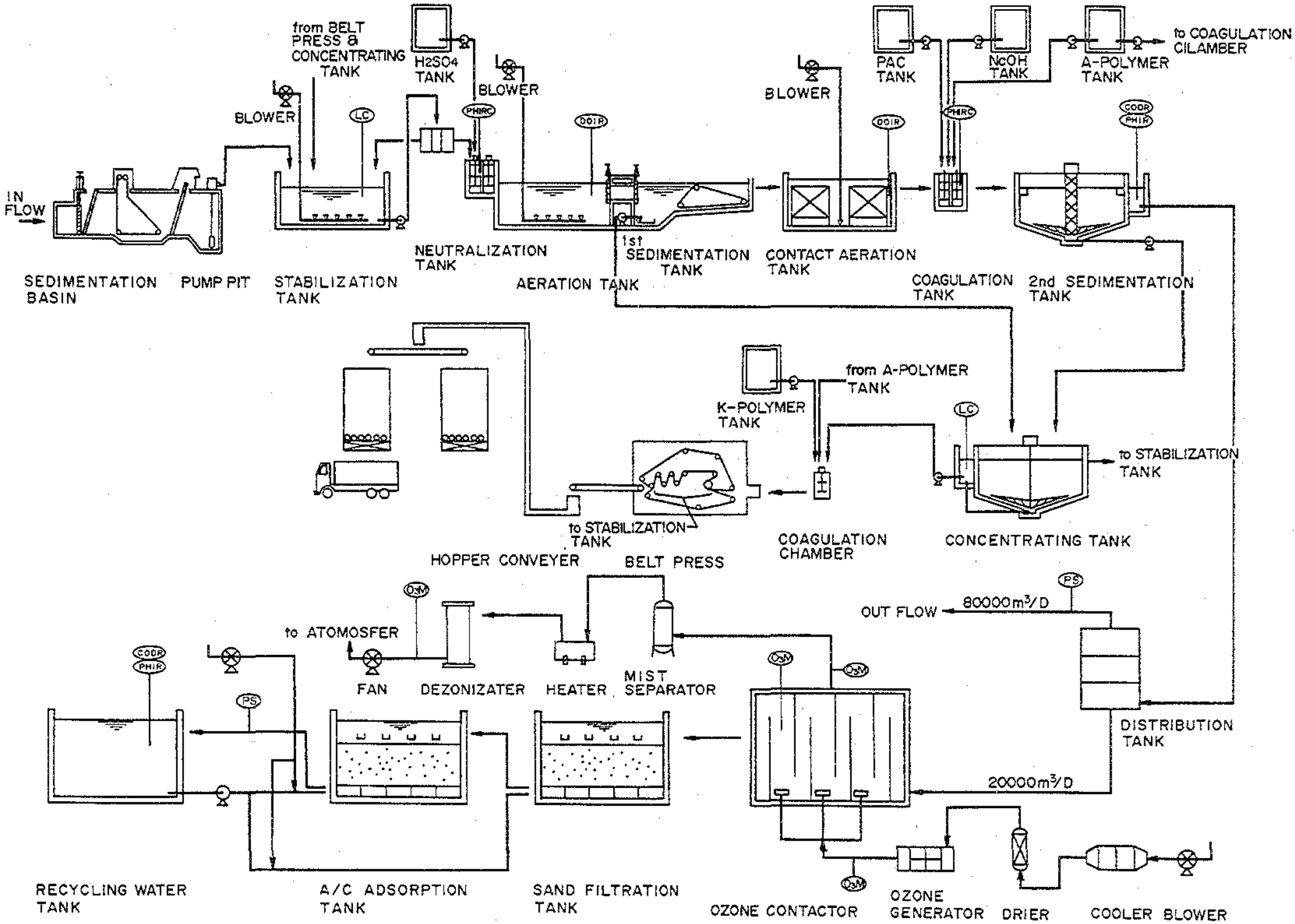


Fig. 3.5.3 Flowchart of Treatment in CASE-2

c) Specification

Capacity	:	600 m^3
Shape	:	10.0 mW x 12.0 mL x 5.0 mD
Material	:	RC
Quantity	:	1 set

d) Supplementary equipment

* Pump

Type	:	Horizontal whirlpool pump
Capacity	:	14 m^3/min. x 15 mH
Electric motor	:	45 kW x 440 V
Quantity	:	4 + 1 set

B. Sand filtration tank

a) Design condition

Flowing water quantity	:	80,000 m^3/day
LV	:	7.0 m/h
SV	:	2.0 h^{-1}

b) Design calculation

Required area	:	80,000 m^3/day x 1/24 x 1/7 m/h = 476 m^2
Capacity	:	80,000 m^3/day x 1/24 x 1/2 h^{-1} = 1667 m^3

c) Specifications

Shape	:	10.0 mW x 12.0 mL x 6.0 mD (filling height 3.5 m)
Material	:	RC
Quantity	:	4 sets

C. Activated carbon adsorption tank

C-1 Activated carbon adsorption tank

a) Design condition

Flowing water quantity	:	80,000 m^3/day
LV	:	7.0 m/h
SV	:	2.0 h^{-1}

b) Design calculation

Required area	:	80,000 m^3/day x 1/24 x 1/7 m/h = 476 m^2

Capacity	:	80,000 m^3/day x 1/24 x 1/2 h ≈ 1667 m^3

c) Shape

Type	:	10.0 mW x 12.0 mL x 6.0 mD (filling height 3.5 m)
Material	:	RC
Quantity	:	4 sets

C-2 Backwash tank

a) Design condition

Each tank is backwashed one by one.

Backwash time	:	5.0 min.
Backwash flow	:	86 m^3/min.

b) Design calculation

Backwash water quantity:

86 m^3/min. x 5 min.
≈ 430 m^3/time

c) Specifications

Shape	:	10.0 mW x 10.0 mL x 5.0 mD
Material	:	RC
Quantity	:	1 set

d) Supplementary equipments

* Backwash pump

Type	:	Horizontal whirlpool pump
Capacity	:	43 m^3/min. x 30 mH
Electric motor	:	160 kW x 440 V
Quantity	:	2 sets

* Backwash blower

Type	:	Turbo blower
Capacity	:	120 Nm^3/min. x 0.5 kgf/cm^2
Electric motor	:	220 kW x 440 V
Quantity	:	1 set

D. Mixing tank

a) Design condition

Flowing water quantity	:	100,000 m^3/day
Retention time	:	7 min.

b) Design calculation

Calculation capacity : 100,000 m^3/day x 1/1440 x 7 min. = 486 m^3

c) Specifications

Shape : 10.0 mW x 10.0 mL x 5.0 mD

Material : RC

Quantity : 1 set

Table 3.5.2 shows a list of CASE-2 main equipment.

(2) Layout

Fig. 3.5.4 shows CASE-2 layout. The site area is 57,200 m^2 (220 mW x 260 mL).

3.5.4 Combination of reclamation system and wastewater treatment system existing effluent standards (CASE 3)

(1) Conceptional design

CASE-3 treatment flow is illustrated in Fig. 3.5.5 CASE-3 treats 20,000 m^3/day in CASE-1 treated water. Conceptional design is done for equipment from the distribution pit to the reclamation tank.

A. Distribution equipment

80,000 m^3/day and 20,000 m^3/day are distributed. The former is discharged into the sewage treatment plant, while the latter is reclaimed by ozone oxidation, sand filtration and activated carbon adsorption.

a) Design condition

Flowing water quantity : 100,000 m^3/day

b) Specifications

Capacity : 66 m^3

Shape : 3.0 mW x 1.0 mL x 2.0 mD (effective)

Material : RC

Quantity : 1 set

c) Specifications

Table 3.5.2 Specification of Equipmet in CASE-2

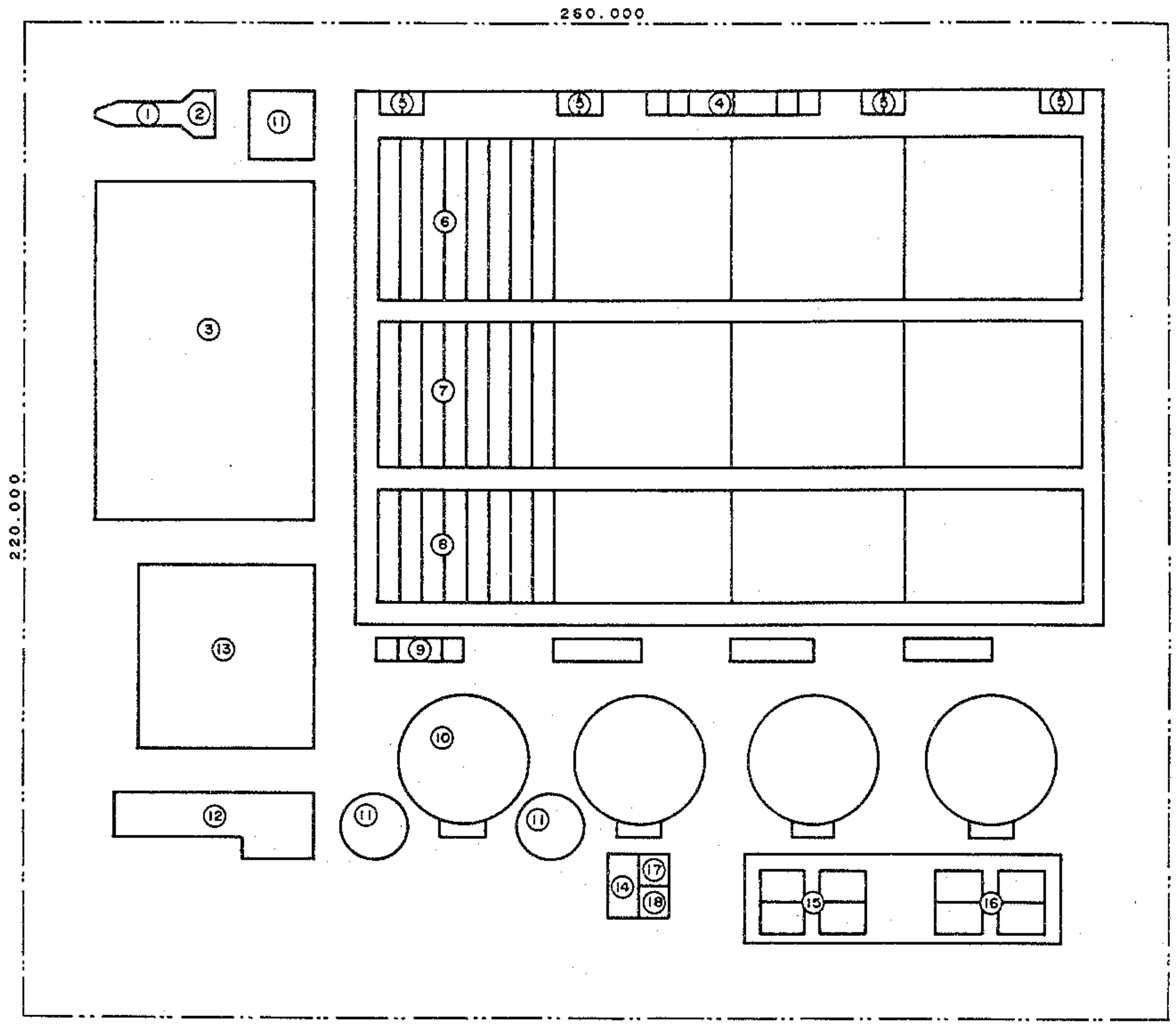
No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
1	SEDIMENTATION BASIN	2	RC	$2.5m^W x 12m^L x 2.2m^H$	
	SLUDGE COLLECTER	2	SS	Busket Conveyor type	
	ROUGH SCREEN	2	SS	Pich 100mm	
	FINE SCREEN	2	SS	Pith 10mm	
2	PUMP PIT	1	RC	$10m^W x 5m^L x 3m^H$	pHIR, LICA
	PUMP	4 + 2	FC	17.5m3/mx10mHx55kW	
3	STABILIZATION	1	RC	$50m^W x 75m^L x 5m^H$	LICA
	BLOWER	1	FC	$156Nm^3/m x 0.5kgf/cm^2 x 200kW$	
	PUMP	8 + 4	FC	$10.5m^3/m x 15mH x 37kW$	
4	MEASURING INSTRUMENT	2	SUS	Partial Flume	FIRQ
5	NEUTRALIZATION TANK	2	RC	$5m^W x 5m^L x 5m^H$ x3tanks	pHIRC
	AGITATOR	6	SUS	500rpm x15kW	
6	AERATION TANK	4	RC	$5m^W x 34m^L x 5m^H$ x8lines	DOIR
	BLOWER	16 + 4	FC	$36Nm^3/m x 0.5kgf/cm^2 x 45kW$	
	MEASURING INSTRUMENT	8	SUS		FIRQ
	OUT FLOW GATE	16	FC	1000mm x 1000mm	
7	1st SEDIMENTATION TANK	4	RC	$5m^W x 32m^L x 3m^H$ x8lines	
	SLUDGE COLLECTOR (M)	32	SS, Rasin	Chain Flight type $5m^W x 32m^L$	
	SLUDGE COLLECTOR (C)	8	SS, Rasin	Chain Flight type $1.5m^W x 20m^L$	
	SLUDGE POMP	8 + 4	FC	$8.8m^3/m x 15mH x 22kW$	
8	CONTACT AERATION TANK	4	RC	$5m^W x 25m^L x 5m^H$ x8lines	DOIR
	CONTACT MATERIAL	4	PVC	$500m^3$ x8lines	
	BLOWER	8 + 2	FC	$42Nm^3/m x 0.5kgf/cm^2 x 45kW$	
9	COAGULATION TANK	4	RC	$5m^W x 10m^W x 2.5m^H$ x2tanks	pHIRC
	AGITATER (R)	8	SUS	300rpm x 30kW	
	AGITATOR (C)	8	SUS	60rpm x 22kW	

Table 3.5.2 Specification of Equipmet in CASE-2 (continue)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
10	2nd SEDIMENTATION TANK	4	RC	$29m\phi x3m^H$	CODR, pHIR
	SCRAPER	4	SS	Rake type 29m	
	SLURRY PUMP	4 + 1	FC	$1.2m^3/mx15mHx7.5kW$	
11	DISTRIBUTION TANK	1	RC	$3m^Wx1m^Lx2m^H$	FQR
12	C/S TREATMENT TANK	1	RC	$10m^Wx12m^Lx5m^H$	LIC
	PUMP	4 + 1	FC	$14m^3/mx15mHx45kW$	
13	SAND FILTRATION TANK	4	RC	$10m^Wx12m^Lx6m^H$	
14	A/C ADSORPTION TANK	4	RC	$10m^Wx12m^Lx6m^H$	
15	BACKWASH TANK	1	RC	$10m^Wx10m^Lx5m^H$	
	PUMP	2	FC	$43m^3/mx30mHx160kW$	
	BLOWER	1	FC	$120Nm^3/mx0.5kgf/cm^2x200kW$	
16	MIXING TANK	1	RC	$10m^Wx10m^Lx5m^H$	
17	CONCENTRATING TANK	2	RC	$15m\phi x3m^H$	LICA
	SCRAPER	2	SS	Rake type 15m	
	SLURRY PUMP	2	FC	$0.38m^3/mx15mHx7.5kW$	
18	COAGULATION CHAMBER	3	RC	$1.5m\phi x1m^H$	
19	BELT PRESS	3	SS	$3m^W$ 3.7kW	
	VELT CONVEYOR	2	SS, NBR	$600m^Wx14m^Lx1.5kW$	
	SCREW CONVEYOR	1	SS	5.5kW	
	CAKE HOPPER	2	SS	$2.7m^Wx5m^Lx5m^H$	
20	H_2SO_4 TANK	2	RC	$5m^Wx3m^Lx5m^H$	LIA
	PUMP	2 + 1	Teflon	$8.2\ell/mx5kgf/cm^2x1.5kW$	
21	PAC TANK	2	RC	$5m^Wx5.5m^Lx5m^H$	LIA
	PUMP	4 + 1	Teflon	$7.7\ell/mx5kgf/cm^2x1.5kW$	
22	NaOH TANK	2	RC	$5m^Wx3m^Lx5m^H$	LIA
	PUMP	4 + 1	Teflon	$6.4\ell/mx5kgf/cm^2x1.5kW$	

Table 3.5.2 Specification of Equipmet in CASE-2 (continue)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
23	A-COAGULANT TANK	2	RC	$5m^W x 10m^L x 5m^H$	LIA
	AGITATER	4	SUS	300rpm x 30kW	
	PUMP (W)	4 + 1	Teflon	35 ℓ/mx6kgf/cm²x2.2kW	
	PUMP (S)	2 + 1	Teflon	86 ℓ/mx5kgf/cm²x2.2kW	
24	K-COAGULANT TANK	2	RC	$5m^W x 10m^L x 5m^H$	LIA
	AGITATER	2	SUS	300rpm x 17.5kW	
	PUMP	2 + 1	Teflon	43 ℓ/mx6kgf/cm²x1.5kW	



No.	DESIGNATION
18	MIXING TANK
17	BACKWASH TANK
16	A/C ADOSORPTION TANK
15	SAND FILTIRATION TANK
14	C/S TREATMENT TANK
13	HOUSE 1F BLOWER 2F DEHYDRATOR 3F CONTROL ROOM
12	CHEMICAL CHAMBER YARD
11	CONCENTRATED TANK
10	2nd SEDIMANTATION TANK
9	COAGULATION TANK
8	CONTACT AERATION TANK
7	1st SEDIMANTATION TANK
6	AERATION TANK
5	NEUTRALIZATION TANK
4	DISTRIBUTION TANK
3	STABILIZATION TANK
2	PUMP PIT
1	SEDIMENTATION BASIN

Fig. 3.5.4 Layout in CASE-2

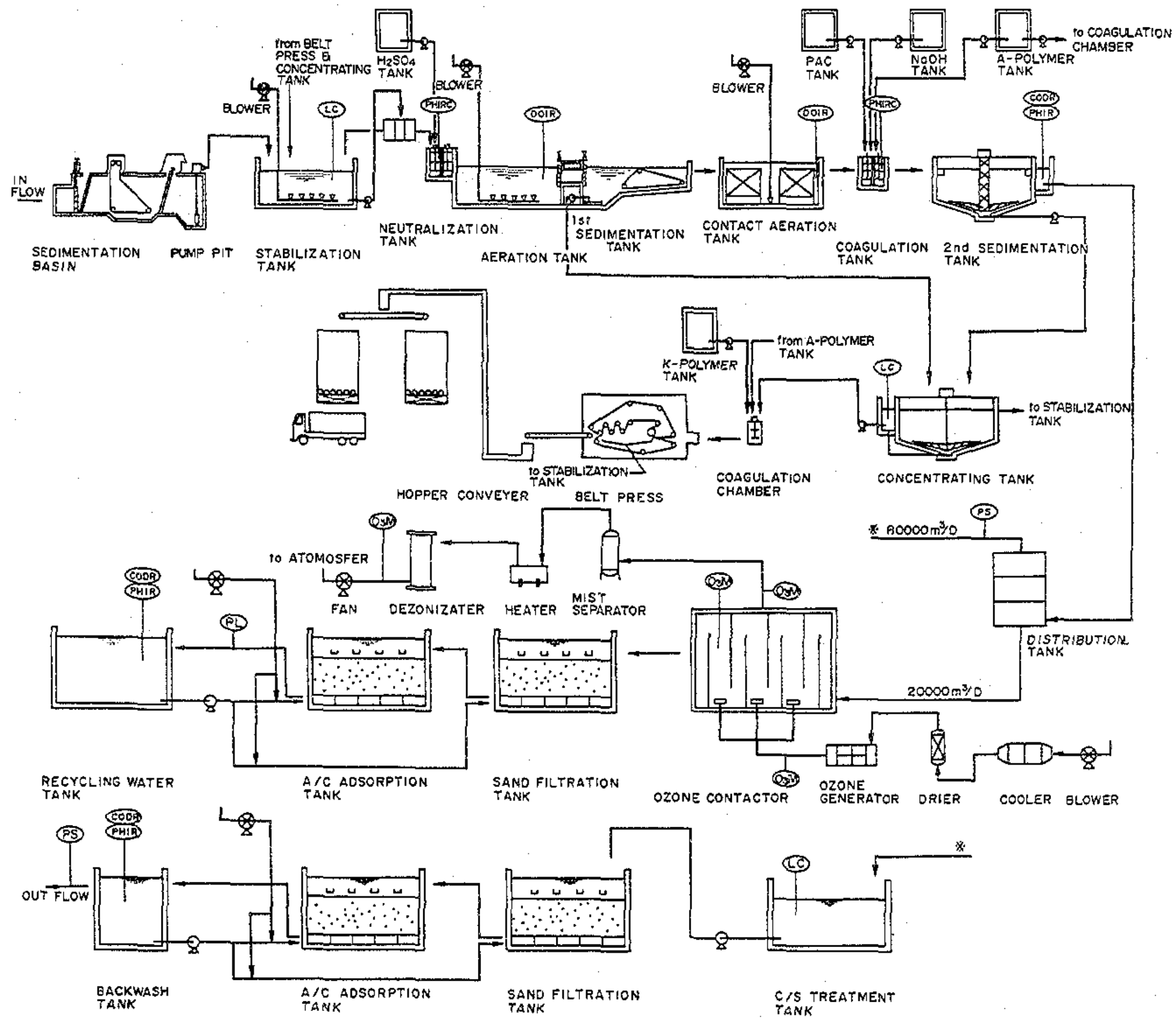


Fig. 3. 5. 5 Flowchart of Treatment in CASE-3

Capacity	:	225 m^3
Shape	:	5.0 mW x 9.0 mL x 5.0 mD
Material	:	RC
Quantity	:	1 set

d) Supplementary equipment

* Mist separator

Type	:	Eliminator type
Quantity	:	10 sets

* Heater

Type	:	Steam type
Quantity	:	10 sets

* Ozone adsorption tower

Type	:	Activated carbon adsorption type
Capacity	:	4 mø x 15 mH
Quantity	:	10 sets

* Blower

Capacity	:	41 Nm^3/min. x 0.5 kgf/cm^2
Electric motor	:	45 kW x 440 V
Quantity	:	5 sets

B-2 Ozone generator

a) Design condition

Required ozone quantity	:	4 times as much as COD quantity
Required air quantity	:	1.32 m^3-air/min/kg-O_3/h

b) Design calculation

Generated ozone	:	80 g-COD/m^3 x 1/1000 x 20,000 m^3/day x 1/24 x 4 = 267 kg-O_3/h
Air	:	267 kg-O_3/h x 1.32 m^3-air/min./kg-O_3/h = 203 m^3/min.

c) Specifications

Type	:	Silent electric discharging type
Capacity	:	10 kg-O_3/h
Quantity	:	27 + 5 sets

d) Supplementary equipment

* Blower

Type	:	Turbo blower
Capacity	:	41 Nm^3/min. x 1.0 kgf/cm^2

Electric motor : 150 kW x 440 V
Quantity : 5 sets

* Air cooler
  Type : Brine type chilling unit
  Quantity : 5 sets
* Dehumidifier
  Type : Heating reclamation type activated alumina adsorption
  Quantity : 10 sets

C. Sand filtration

a) Design condition
Flowing water quantity : 20,000 m^3/day
LV : 7.0 m/h
SV : 2.0 h^{-1}

b) Design calculation
Required area : 20,000 m^3/day x 1/24 x 1/7 m/h = 119 m^2
Capacity : 20,000 m^3/day x 1/24 x 1/2h^{-1} = 417 m^3

c) Specifications
Type : 10.0 mW x 12.0 mL x 6.0 mD (filling height 3.5 m)
Material : RC
Quantity : 1 set

D. Activated carbon adsorption tank

D-1 Activated carbon adsorption tank

a) Design condition
Flowing water quantity : 20,000 m^3/day
LV : 7.0 m/h
SV : 2.0 h^{-1}

d) Design calculation
Required area : 20,000 m^3/day x 1/24 x 1/7 m/h = 119 m^2

Capacity : $20,000\ m^3/day \times 1/24 \times 1/2\ h^{-1}$
$= 417\ m^3$

c) Specifications

Shape : 10.0 mW x 12.0 mL x 6 mD (filling height 3.5 m)

Material : RC

Quantity : 1 set

E. Reclamation water tank

a) Design condition

Retention time : 5 h

b) Design calculation

Calculation capacity : $20,000\ m^3/day \times 1/24 \times 5\ h$
$= 2167\ m^3$

c) Specifications

Capacity : $4200\ m^3$

Shape : 30.0 mW x 28.0 mL x 5.0 mD

Material : 1 set

d) Supplementary equipment

* Backwash pump

Type : Horizontal whirlpool pump

Capacity : $43\ m^3/min. \times 30\ mH$

Electric motor : 160 kW x 440 V

Quantity : 2 sets

* Backwash blower

Type : Turbo blower

Capacity : $220\ Nm^3/min. \times 0.5\ kgf/cm^2$

Electric motor : 220 kW x 440 V

Quantity : 1 set

Table 3.5.3 shows a list of main equipment of CASE-3 facilities.

(2) Layout

Diagram 3.5.6 illustrates the layout of CASE-3 facilities. The site area is $57,200\ m^2$ (220 mW x 260 mL).

Table 3.5.3 Specification of Equipmet in CASE-3

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
1	SEDIMENTATION BASIN	2	RC	$2.5m^{W}x12m^{L}x2.2m^{H}$	
	SLUDGE COLLECTER	2	SS	Busket Conveyor type	
	ROUGH SCREEN	2	SS	Pich 100mm	
	FINE SCREEN	2	SS	Pith 10mm	
2	PUMP PIT	1	RC	$10m^{W}x5m^{L}x3m^{H}$	pHIR, LICA
	PUMP	4 + 2	FC	17.5m3/mx10mHx55kW	
3	STABILIZATION	1	RC	$50m^{W}x75m^{L}x5m^{H}$	LICA
	BLOWER	1	FC	$156Nm^{3}/mx0.5kgf/cm^{2}x200kW$	
	PUMP	8 + 4	FC	$10.5m^{3}/mx15mHx37kW$	
4	MEASURING INSTRUMENT	2	SUS	Partial Flume	FIRQ
5	NEUTRALIZATION TANK	2	RC	$5m^{W}x5m^{L}x5m^{H}x3tanks$	pHIRC
	AGITATOR	6	SUS	500rpm x15kW	
6	AERATION TANK	4	RC	$5m^{W}x34m^{L}x5m^{H}x8lines$	DOIR
	BLOWER	16 + 4	FC	$36Nm^{3}/mx0.5kgf/cm^{2}x45kW$	
	MEASURING INSTRUMENT	8	SUS		FIRQ
	OUT FLOW GATE	16	FC	1000mm x 1000mm	
7	1st SEDIMENTATION TANK	4	RC	$5m^{W}x32m^{L}x3m^{H}x8lines$	
	SLUDGE COLLECTOR (M)	32	SS, Rasin	Chain Flight type $5m^{W}x32m^{L}$	
	SLUDGE COLLECTOR (C)	8	SS, Rasin	Chain Flight type $1.5m^{W}x20m^{L}$	
	SLUDGE POMP	8 + 4	FC	$8.8m^{3}/mx15mHx22kW$	
8	CONTACT AERATION TANK	4	RC	$5m^{W}x25m^{L}x5m^{H}x8lines$	DOIR
	CONTACT MATERIAL	4	PVC	$500m^{3}x8lines$	
	BLOWER	8 + 2	FC	$42Nm^{3}/mx0.5kgf/cm^{2}x45kW$	
9	COAGULATION TANK	4	RC	$5m^{W}x10m^{W}x2.5m^{H}x2tanks$	pHIRC
	AGITATER (R)	8	SUS	300rpm x 30kW	
	AGITATOR (C)	8	SUS	60rpm x 22kW	

Table 3.5.3 Specification of Equipmet in CASE-3 (continue)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
10	2nd SEDIMENTATION TANK	4	RC	29mφx3m^H	CODR, pHIR
	SCRAPER	4	SS	Rake type 29m	
	SLURRY PUMP	4 + 1	FC	1.2m^3/mx15mHx7.5kW	
11	DISTRIBUTION TANK	1	RC	3m^{W}x1m^{L}x2m^H	FQR
12	OZONE CONTACTOR	1	RC	5m^{W}x9m^{L}x5m^H	O_3IR
	MIST SEPARATOR	10			
	HEATOR	10			
	OZONE ADSORP. TOWER	10		4mφx3m^H	O_3IR
	BLOWER	5	FC	41Nm^3/mx0.5kgf/cm^{2}x45kW	
13	OZONE GENERATOR	27 + 5		10kg-O_3/h	O_3IR
	BLOWER	5	FC	41Nm^3/mx1.0kgf/cm^{2}x150kW	
	CHILLER	5			
	DRYER	10			
14	SAND FILTRATION TANK	1	RC	10m^{W}x12m^{L}x6m^H	
15	DEOZONIZATER	1	RC	10m^{W}x12m^{L}x6m^H	
16	RECYCLING WATER TANK	1	RC	30m^{W}x28m^{L}x5m^H	
	PUMP	2	FC	43m^3/mx30mHx160kW	
	BLOWER	1	FC	120Nm^3/mx0.5kgf/cm^{2}x200kW	
17	CONCENTRATING TANK	2	RC	15mφx3m^H	LICA
	SCRAPER	2	SS	Rake type 15m	
	SLURRY PUMP	2	FC	0.38m^3/mx15mHx7.5kW	
18	COAGULATION CHAMBER	3	RC	1.5mφx1m^H	
19	BELT PRESS	3	SS	3m^W 3.7kW	
	VELT CONVEYOR	2	SS, NBR	600m^{W}x14m^{L}x1.5kW	
	SCREW CONVEYOR	1	SS	5.5kW	
	CAKE HOPPER	2	SS	2.7m^{W}x5m^{L}x5m^H	
20	H_2SO_4 TANK	2	RC	5m^{W}x3m^{L}x5m^H	LIA

Table 3.5.3 Specification of Equipmet in CASE-3 (continue)

No.	NAME	Q'TY	MATERIAL	SPECIFICATION	REMARK
	PUMP	2 + 1	Teflon	8.2 ℓ/mx5kgf/cm^2x1.5kW	
21	PAC TANK	2	RC	$5m^W$x$5.5m^L$x$5m^H$	LIA
	PUMP	4 + 1	Teflon	7.7 ℓ/mx5kgf/cm^2x1.5kW	
22	NaOH TANK	2	RC	$5m^W$x$3m^L$x$5m^H$	LIA
	PUMP	4 + 1	Teflon	6.4 ℓ/mx5kgf/cm^2x1.5kW	
23	A-COAGULANT TANK	2	RC	$5m^W$x$10m^L$x$5m^H$	LIA
	AGITATER	4	SUS	300rpm x 30kW	
	PUMP (W)	4 + 1	Teflon	35 ℓ/mx6kgf/cm^2x2.2kW	
	PUMP (S)	2 + 1	Teflon	86 ℓ/mx5kgf/cm^2x2.2kW	
24	K-COAGULANT TANK	2	RC	$5m^W$x$10m^L$x$5m^H$	LIA
	AGITATER	2	SUS	300rpm x 17.5kW	
	PUMP	2 + 1	Teflon	43 ℓ/mx6kgf/cm^2x1.5kW	

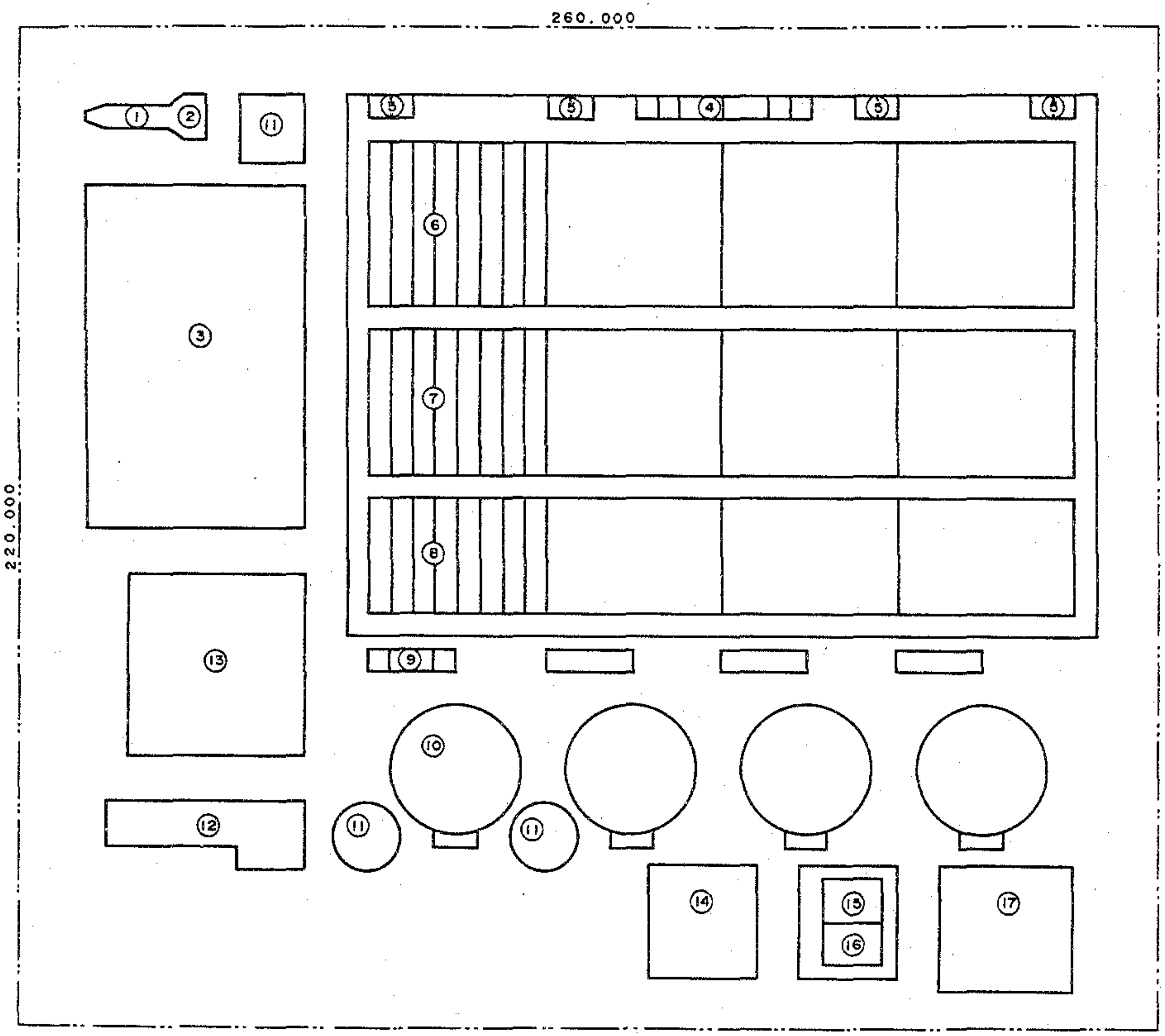


Fig. 3.5.6 Layout in CASE-3

No.	DESIGNATION
17	RECYCLING WATER TANK
16	A/C ADOSORPTION TANK
15	SAND FILTIRATION TANK
14	OZONE TREATMENT HOUSE
13	HOUSE 1F BLOWER 2F DEHYDRATOR 3F CONTROL ROOM
12	CHEMICAL CHAMBER YARD
11	CONCENTRATED TANK
10	2nd SEDIMANTATION TANK
9	COAGULATION TANK
8	CONTACT AERATION TANK
7	1st SEDIMANTATION TANK
6	AERATION TANK
5	NEUTRALIZATION TANK
4	DISTRIBUTION TANK
3	STABILIZATION TANK
2	PUMP PIT
1	SEDIMENTATION BASIN

3.5.5 Combination of reclamation system and advanced treatment system for removal of COD (CASE-4)

The flow sheet and the layout of CASE-4 facilities are shown respectively in Fig. 5.5.7 and 3.5.8. Table 3.5.4 illustrates treated water quality in each process CASE-4.

3.5.6 Elimination system for irresolvable substances (CASE-5)

The Diagram and the layout of CASE-5 facilities are respectively shown in Diagram 3.5.9 and 3.5.10. Table 3.5.5 illustrates treated water quality in each process of CASE-5.

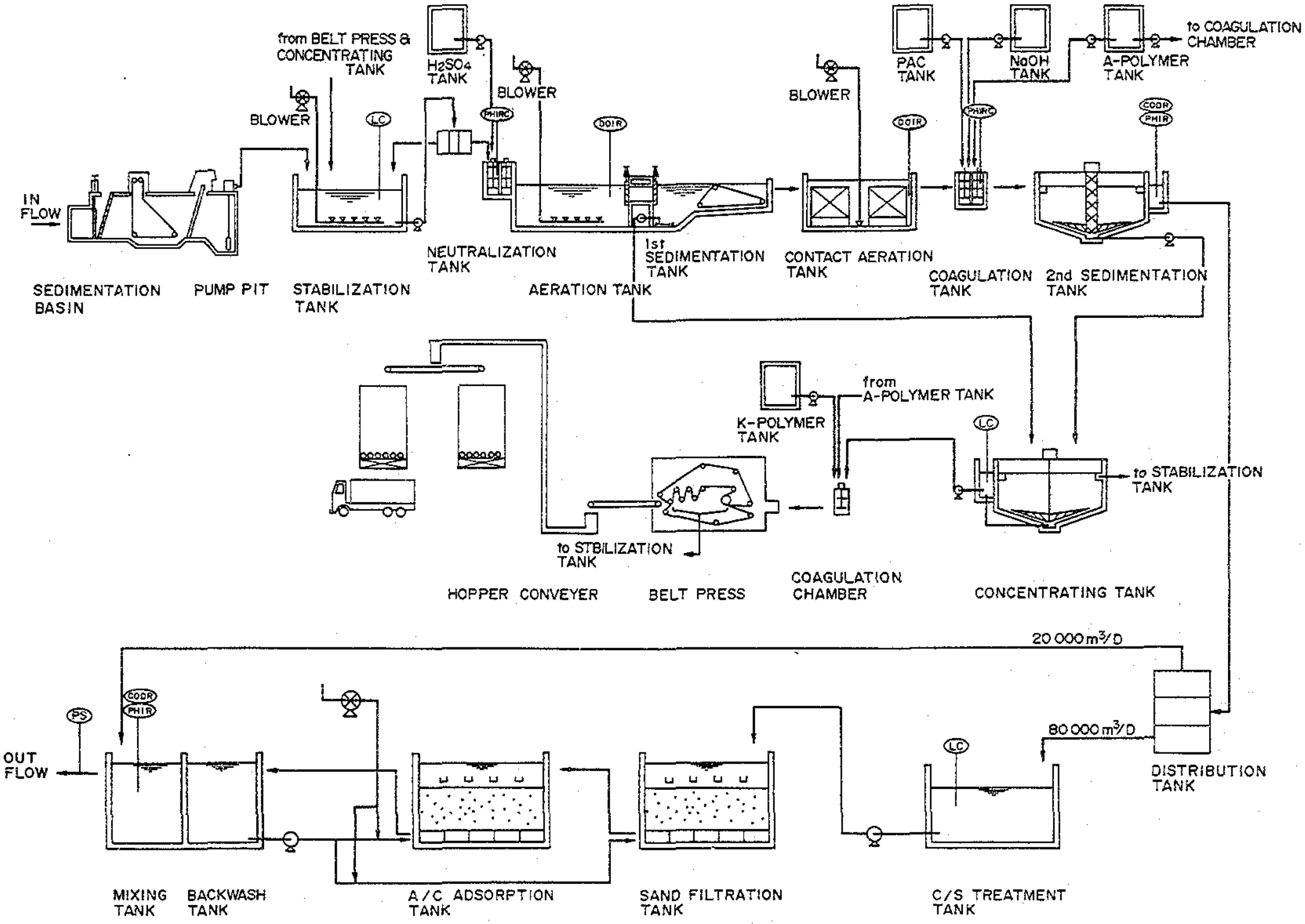


Fig. 3.5.7 Flowchart of Treatment in CASE-4

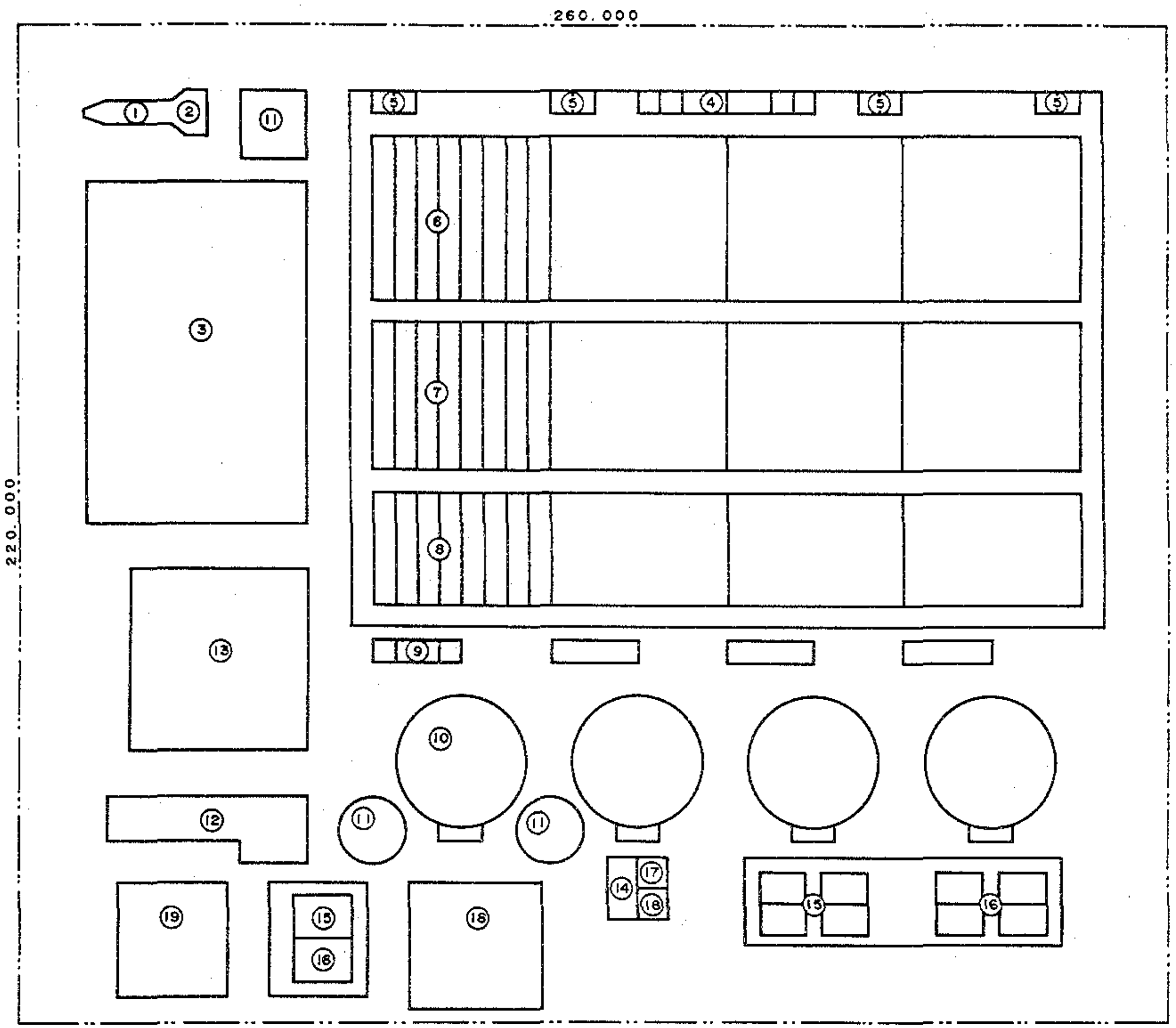


Fig. 3. 5. 8 Layout in CASE-4

19	OZONE TREATMENT HOUSE
18	RECYCLING WATER TANK
17	BACKWASH TANK
16	A/C ADOSORPTION TANK
15	SAND FILTIRATION TANK
14	C/S TREATMENT TANK
13	HOUSE 1F BLOWER 2F DEHYDRATOR 3F CONTROL ROOM
12	CHEMICAL CHAMBER YARD
11	CONCENTRATED TANK
10	2nd SEDIMANTATION TANK
9	COAGULATION TANK
8	CONTACT AERATION TANK
7	1st SEDIMANTATION TANK
6	AERATION TANK
5	NEUTRALIZATION TANK
4	DISTRIBUTION TANK
3	STABILIZATION TANK
2	PUMP PIT
1	SEDIMENTATION BASIN
No.	DESIGNATION

Table 3.5.4 Quality of Effluent after each Treatment in CASE-4 (Design Criteria)

[Treated Water by CASE-1 Process] ⑥ → Sand Filtration ⑧ → Activated Carbon Adsorption ⑨ → [Effluent]

⑪ → Ozonination ⑫ → Sand Filtration ⑬ → Activated Carbon Adsorption ⑭ → [Recycling Water]

Process		⑥	⑧	⑨	⑪	⑫	⑬	⑭
Quantity	[m^3/day]	80,000	20,000	20,000	20,000	20,000	20,000	20,000
pH	[-]	6～8	6～8	6～8	6～8	6～8	6～8	6～8
BOD	[mg/ℓ]	25	25	15	25	-	-	-
COD	[mg/ℓ]	80	80	30	80	60	60	10
SS	[mg/ℓ]	20	2	2	20	20	2	2
n-Hex	[mg/ℓ]	<10	<10	<10	<10	-	-	-

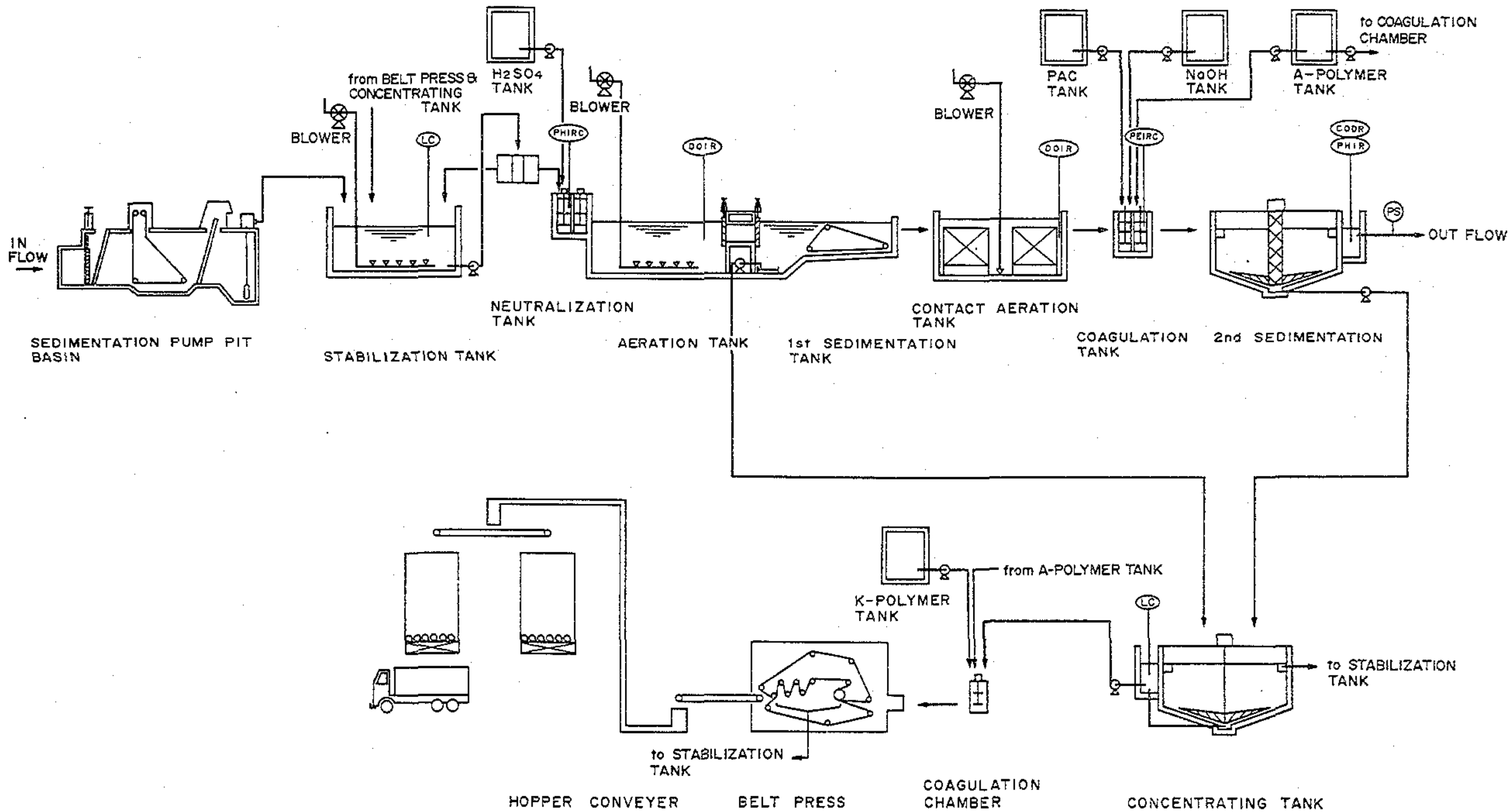
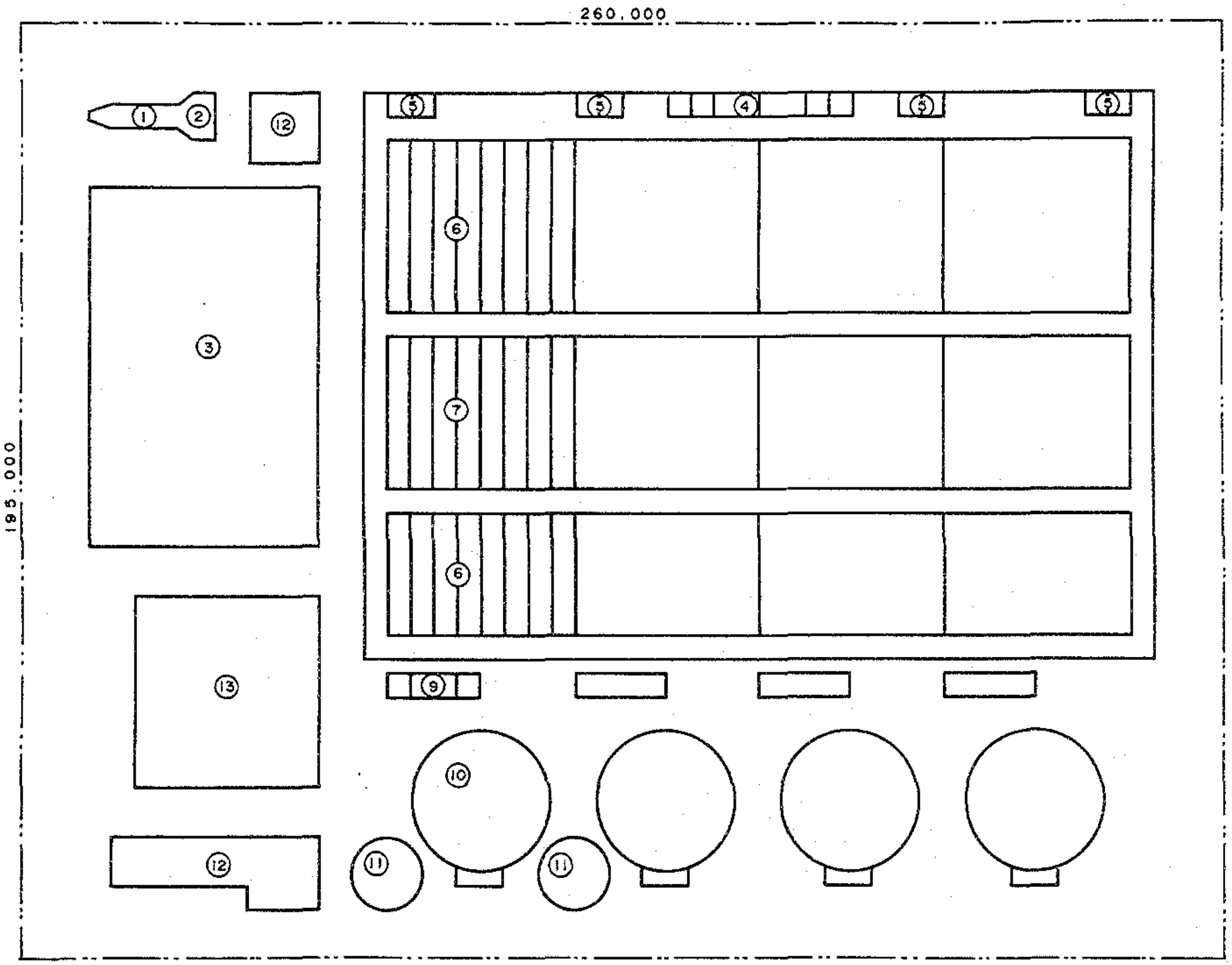


Fig. 3.5.9 Flowchart of Treatment in CASE-5



No.	DESIGNATION
13	HOUSE 1F BLOWER 2F DEHYDRATOR 3F CONTROL ROOM
12	CHEMICAL CHAMBER YARD
11	CONCENTRATED TANK
10	2nd SEDIMANTATION TANK
9	COAGULATION TANK
8	CONTACT AERATION TANK
7	1st SEDIMANTATION TANK
6	AERATION TANK
5	NEUTRALIZATION TANK
4	DISTRIBUTION TANK
3	STABILIZATION TANK
2	PUMP PIT
1	SEDIMENTATION BASIN

Fig.3.5.10 Layout in CASE-5

Table 3.5.5 Quality of Effluent after each Treatment in CASE-5 (Design Criteria)

[Waste Water] → Stabilization →① Neutralization →② Biological Activated Carbon Treatment

→ Sedimentation →⑮ Coagulation → Sedimentation →⑯ [Effluent]

Process		①	②	⑮	⑯
Quantity	[m^3/day]	100,000	100,000	100,000	100,000
pH	[-]	11.5	6～8	6～8	6～8
BOD	[mg/ℓ]	300	300	-	-
COD	[mg/ℓ]	400	400	<10	<10
SS	[mg/ℓ]	120	120	50	5
n-Hex	[mg/ℓ]	20	20	-	-

3.6 Economic Feasibility of the Optimum System

Construction costs, operation costs and other related costs are calculated for the above-mentioned 3 systems (CASE-1, -2, -3) on a trial basis.

3.6.1 Construction costs

Calculated construction costs are as follows.

CASE-1 65.4 bil Won
CASE-2 77.7 bil Won
CASE-3 85.4 bil Won

Based on the Korean prices as of February, 1992. Each breakdown is shown in Table 3.6.1.

3.6.2 Operating Cost

Calculated operating costs are as follows.
CASE-1 9.37 bil Won/year
CASE-2 18.84 bil Won/year
CASE-3 13.54 bil Won/year

Treatment plant working days are assumed to be 300 days/year.

Breakdowns of chemicals, industrial water, electricity and sludge treatment in each case are shown in Tables 3.6.2 - 4. Unit prices were obtained by referring to research data at the central treatment plant. In this case, reclamation of activated carbon is supposedly carried out by an outside company so that only the portion lost in reclamation will be replaced by new carbon. The activated carbon reclamation cost shown in Tables 3.6.3 - 4 is calculated as the sum of the costs of reclamation and supplementary replacement with new carbon. The supplementary replacement quantity is estimated as 5% of the reclamation quantity. The quantity of new carbon supplied is 1,000 kg/day in CASE-2 and 250kg/day in CASE-3. For the calculation of electricity, the operation rate of each equipment is assumed to be 80%.

Table 3.6.1 Items of Construction Cost

(1,000,000Won)

Items	CASE-1	CASE-2	CASE-3
Civil and Architectual Work	45,800	54,500	50,000
Machinerary and Equipments	8,200	9,900	20,700
Electrical Work	1,100	1,300	1,500
Piping Work	1,500	1,600	1,700
Test Run etc.	300	300	400
Sub-Total	56,900	67,600	74,300
Overhead(15%)	8,500	10,100	11,100
Total	65,400	77,700	85,400

Table 3.6.2 Cost of Chemicals, Industrial Water, Electricity and Sludge Disposal (CASE-1)

Items	Consumption	Unit Price	Cost [Won/m³]	Cost [10^6Won/Y]
Chemicals				
H_2SO_4	30,090kg/day	63Won/kg	18.96	5.69
NaOH	10,980kg/day	149Won/kg	16.35	4.91
PAC	49,900kg/day	185Won/kg	92.32	27.70
A-Polymer	283kg/day	1,700Won/kg	48.11	14.43
K-Polymer	83kg/day	3,150Won/kg	26.15	7.85
Sub-Total			201.89	60.57
Industrial Water	500m³/day	110Won/m³	0.55	0.17
Electricity	50,218kW/day	60Won/kW	30.13	9.04
Sludge Disposal	164 t/day	46,800Won/t	76.75	23.20
Total			309.32	92.98

Table 3.6.3 Cost of Chemicals, Industrial Water, Electricity and Sludge Disposal (CASE-2)

Items	Consumption	Unit Price	Cost [Won/m³]	Cost [10⁸Won/Y]
Chemicals				
H_2SO_4	30,090kg/day	63Won/kg	18.96	5.69
NaOH	10,980kg/day	149Won/kg	16.35	4.91
PAC	49,900kg/day	185Won/kg	92.32	27.70
A-Polymer	283kg/day	1,700Won/kg	48.11	14.43
K-Polymer	83kg/day	3,150Won/kg	26.15	7.85
A/C Reclamation	20,000kg/day	1,021Won/kg	204.20	61.26
Sub-Total			406.09	154.68
Industrial Water	500m³/day	110Won/m³	0.55	0.17
Electricity	53,674kW/day	60Won/kW	32.20	9.66
Sludge Disposal	164 t/day	46,800Won/t	76.75	23.03
Total			515.59	187.78

Table 3.6.4 Cost of Chemicals, Industrial Water, Electricity and Sludge Disposal (CASE-3)

Items	Consumption	Unit Price	Cost [Won/m³]	Cost [10⁸Won/Y]
Chemicals				
H_2SO_4	30,090kg/day	63Won/kg	18.96	5.69
NaOH	10,980kg/day	149Won/kg	16.35	4.91
PAC	49,900kg/day	185Won/kg	92.32	27.70
A-Polymer	283kg/day	1,700Won/kg	48.11	14.43
K-Polymer	83kg/day	3,150Won/kg	26.15	7.85
A/C Reclamation	5,000kg/day	1,021Won/kg	51.05	15.32
Sub-Total			252.94	75.88
Industrial Water	500m³/day	110Won/m³	0.55	0.17
Electricity	196,810kW/day	60Won/kW	118.09	35.43
Sludge Disposal	164 t/day	46,800Won/t	76.75	23.20
Total			448.33	134.68

In each case, the cost of chemicals accounts for more than 50% of the running cost.

The breakdown of labor costs is shown in the Table 3.6.5. The calculation of labor cost excludes personnel such as office workers, maintenance personnel, etc., who are not directly involved in the operation of the treatment plant. Also, maximum power systems are employed in the treatment plant and further, labor saving automated systems have been introduced in the detection mechanism, control mechanism and in the command processing function to reduce the number of operating personnel. For every case, one manager, one engineer and two workers constitute the operator team of the treatment plant and they work on 2 shifts x 3 units x 1 person. This formula is applied for all three cases.

The breakdown of running costs is shown in Table 3.6.6. To comply with the existing wastewater standards, the operating cost per treated amount is 312 Won/m^3 for the CASE-1. For the CASE-2, to remove higher percentage of COD, the cost rises to 628 Won/m^3 by the addition of 316 Won/m^3. Operating cost per reclaimed amount is 1007 Won/m^3.

Table 3.6.5 Items of Personnel Expenses

Qualify	Unit Price [Won/Y·person]	Workers [persons]	Personnel Expenses [Won/Y]	Remark
Maneger	23,000,000	1	23,000,000	
Technician	16,000,000	1	16,000,000	
Operater	11,000,000	3	33,000,000	1 per. x 3 units x 2 sifts
Total			71,000,000	

Table 3.6.6 Items of Running Cost

Items	CASE-1		CASE-2		CASE-3	
	[Won/m³]	[10⁸Won/Y]	[Won/m³]	[10⁸Won/Y]	[Won/m³]	[10⁸Won/Y]
Chemicals	201.89	60.57	406.09	154.68	252.94	75.88
Industrial Water	0.55	0.17	0.55	0.17	0.55	0.17
Electricity	30.13	9.04	32.20	9.66	118.09	35.43
Sludge Disposal	76.75	23.20	76.75	23.20	76.75	23.20
Sub-Total	309.32	92.80	515.59	187.71	448.33	134.68
Personnel Expenses	2.37	0.71	2.37	0.71	2.37	0.71
Total	311.69	93.68	517.96	188.42	450.70*)	135.39

*) reclamation cost :

$(450.70 \text{Won/m}^3 - 311.69 \text{Won/m}^3) \times 1/0.2 + 311.69 \text{Won/m}^3 = 1006.74 \text{Won/m3}$

3.7 Matters to be Considered for the Determination of the Optimum System

(1) Treatment of heavy metals

At the selection of the optimum system, it is assumed that wastewater contains no heavy metals such as chrome. It is because that the number of factories discharging such heavy metals is too small for intensive treatment to be economically performed. The treatment system does not include heavy metal treatment process in consideration of the above assumption.

(2) Water reclamation

As shown in the previous section, construction costs and running costs for both advanced treatment and reclamation are relatively expensive when compared with treatment to conform with existing standard. In Japan, there is a case in which an advanced treatment of Case-2 level has been implemented under very tight water quality control, however, in view of the cost, there is no case where reclamation has been implemented.

In CASE-3, reclaimed water is used only for pre-treatment before dyeing process (desizing, scouring and bleaching) whose effect on the product is minimum. Water quality, therefore, is not necessarily as good as industrial water. It is technically possible to treat water to the level of pure water; however, it is not practical in view of extremely high costs for reclamation. Even for the selected optimum system, reclamation costs are 1007 Won/m^3 including costs for wastewater treatment, and it is more than double the total of the present City water cost and waste-water treatment costs (422 Won/m^3).

It is too costly for the single industrial estate to plan and implement the water reclamation project and the due administrative guidance and appropriate subsidy will be required.

(3) Land Area

With regard to the selection of the optimum system, it is assumed that the land and its shape can be freely chosen, but, in reality, there will be cases where a certain limitation will be placed on the land area. To cope with such a situation, some technical notes to reduce land area are provided in the following. As shown in the layout of each case, most of the land area is occupied by the biological treatment tank and the sedimentation tank is unavoidable. To reduce the size of the biological treatment tank, various methods are available, including the following two approaches.

1) To concentrate active sludge to a higher degree.
2) To alter the shape of the tank to a deep aeration type or deep shaft type.

Method involved in approach of 1) above include an entrapped immobilization of active sludge (microorganism), binding immobilization, self-immobilization, etc. An immobilization method using membrane is also being studied in Japan. These immobilization methods enable not only the size of the biological treatment tank to be reduced but also the sedimentation tank to be eliminated. Furthermore, these methods enable the quantity of excess sludge to be reduced. To make highly concentrated active sludge method operational, it is necessary to use it together with highly efficient method of oxygen solution, such as aeration with pure oxygen, etc. The deep shaft type tank of 2) above can also be used for highly concentrated active sludge method as it has a higher oxygen transfer rate. However, its construction cost is rather expensive.

(4) Sludge Treatment

In this instance, it is considered that an excess sludge be consigned to an outside company for disposal at a dumping site after being dehydrated. In Japan, although the practice of excess sludge disposal by industrial waste treatment contractors is widespread, due to the shortage of dumping sites and the increased costs of disposal, some firms which produce large quantities of excess sludge consign the sludge to the contractor after first reducing the quantity by burning it at their own plants. Actual cases of sludge treatment in Japan are also explained in section 3.6 of Chapter V.

4 Financial and Economic Analysis

4.1 Total Capital Requirements and Operating Costs

4.1.1 Major Assumptions for Estimation

(1) Date for base cost estimation

This financial analysis is made on a fixed-price basis at the end of 1992. Thus, all of investment costs are also estimated at the price level of that time.

(2) Utilization of local currency

Total capital requirements and operating costs are assumed to be secured from local financing sources. Therefore, in this study, the foreign portion is not due in consideration for cost estimation. Won is used as the standard currency. Japanese yen is converted into won by the following fixed exchange rate, if needed.

One won = 0.157 Japanese yen

4.1.2 Items of Capital Investment

The estimated capital requirement covers following items.

(1) Plant construction cost
(2) Preoperational expenses
(3) Interest during construction

Land acquisition cost is optionally included for the financial analysis in the sub-section below although this cost is excluded from the costs estimation according to the Inception Report.

4.1.3 Plant Construction Cost

Plant construction costs are shown in Table 4.1.1 for only three cases, which are defined in Chapter 3. (The system for waste water treatment with the treatment level of existing standards is defined as Case 1. The system for waste water treatment with the treatment level of high reduction of COD is as Case 2. The system for waste water treatment and recycling with the treatment level of existing standards is as Case 3.) The details of costs estimation are also shown in Chapter 3.

Table 4.1.1 Construction Cost

Unit: million won

	Case 1	Case 2	Case 3
Civil and architectural work	52,642	62,643	57,470
Machinery and equipments	9,425	11,379	23,792
Electrical work	1,264	1,494	1,724
Piping work	1,724	1,839	1,954
Total	65,055	77,355	84,940

4.1.4 Preoperational Expenses

As preoperational expenses, cost in test runs is estimated. This cost covers initial charge of utilities and relevant consumables such as chemicals and spare parts for replacements, which are required during the test operation. The estimated costs are 345 million won for Case 1 and 2, and 460 million won for Case 3.

4.1.5 Interest during Construction

Interest during construction is calculated on the debt portion of disbursed capital expenditures (long term loan) for the period from such disbursement time through the end of completion date of the plant. The capital expenditures in the debt portion are assumed to be disbursed at two times equally in each year. The first half is disbursed at the beginning of the year and the second half is disbursed at the middle of the year. As a result, the total amount of interest during construction is 3,727 million won for Case 1, 4,431 million for Case 2, and 4,867 million for Case 3. The interest rate is 7 percent in year.

4.1.6 Total Capital Requirements

Total capital requirements are shown in Table 4.1.2. Optionally, the land acquisition cost is included in the table. This cost is assumed to be 17,160 million won for Case 1 at 42,900 m^2 and 19,360 million won for Case 2 and Case 3 at 48,400 m^2. These amounts are based on the actual purchase price of the dyeing industrial estate in Ansan City. Unit price is set at 400,000 won per m^2.

Table 4.1.2 Total Capital Requirements

Unit: million won

	Case 1	Case 2	Case 3
Construction cost	65,055	77,355	84,940
Preoperational expenses	345	345	460
Interest during construction	3,727	4,431	4,867
Total (1)	69,127	82,131	90,267
Land acquisition cost	17,160	19,360	19,360
Total (1)+Land acquisition cost	86,287	101,491	109,627

4.1.7 Operating Costs and Expenses

(1) Variable operating cost

This cost covers chemicals, water, utility (electricity) and disposal cost of sludge are included. The cost is summarized in Table 4.1.3. Details are discussed in Section 6 of Chapter 3.

(2) Fixed operating cost

Fixed operating cost consists of labor cost and maintenance cost. Labor cost is assumed to be 70 million won per year for each case. Details are shown in Chapter 3.

On the other hand, annual maintenance cost is estimated as 1.0 percent of the construction costs through out the project life period. The cost is summarized in Table 4.1.3.

Table 4.1.3 Operating Costs

Unit: million won

	Case 1	Case 2	Case 3
Variable operating cost			
Chemicals	6,057	15,468	7,588
Water	17	17	17
Utility (electricity)	904	966	3,543
Disposal cost of sludge	2,320	2,320	2,320
Sub-total	9,298	18,771	13,468
Fixed operating cost			
Labor cost	70	70	70
Maintenance costs	654	777	854
Sub-total	724	847	924
Total	10,022	19,618	14,392

4.2 Financial Analysis

4.2.1 Basic Assumptions and Premises

For the purpose of the financial calculations, the following basic premises are applied.

(1) Project life and plant operation

(a) Project life ; construction period : 2 year
; operating period : 15 years
(b) Implementation body : Non-profit industrial cooperative
(c) Waste water treatment capacity : 30 million m^3 per year
(d) Volume of recycling water: 6 million m^3 per year(Case 3)
(e) Annual operating days : 300 days
(f) Annual operating hours : 7,200 hours (24 hours per day)

(2) Escalation of costs and prices

All costs and prices used in the financial analysis are assumed to be fixed in the end of 1992, and no escalation factors are applied.

(3) Corporate income tax

Corporate income tax will be imposed at a rate of 10 % of taxable income. This preferential rate is provided to an operator of environment protection facilities under the regulation.

(4) Depreciation and amortization

Depreciable assets are assumed to be depreciate as follows.

(a) Mode : Declining balance method
(b) Period : 15 years
(c) Salvage value : 10 percent

Also, interest during construction are amortized for five years in the declining balance method.

4.2.2 Financial Plan

(1) Debt-Equity ratio

Total capital requirements and operating costs are assumed to be financed locally. An equity portion is assumed to be 30 percent for the total capital requirements. On the other hand, a portion by a long term loan is assumed to be 70 percent of them.

Unit: million won

	ratio	Case 1	Case 2	Case 3
Equity	30%	20,738	24,639	27,080
Debt (long term loan)	70%	48,389	57,491	63,186
Total	100%	69,127	82,131	90,267

(2) Financing sources

A long term loan is assumed to be available from the Small and Medium Industry Promotion Fund through the Ministry of Trade and Industry. Although the maximum amount of the loan for the this fund is some 300 - 500 million won, some cases are exceptionally authorized to remove the ceiling of the loan amount by the government. In fact, "B" Cooperative (the operator of the waste water treatment plant at dyeing industrial estate in Ansan City) is allowed to have a loan of 10 billion won from the Fund. Therefore, in this financial analysis, all the amount of the loan portion (70 percent of the total capital requirements) in each case is assumed to be financed by the Fund.

(3) Financing terms for long term loan

Financing terms for long term loan are assumed as follows. These terms are based on the Small and Medium Industry Promotion Fund's loan conditions.

Amount of loan	: as shown in the above table
Interest rate	: 7 percent per year
Grace period	: 3 years
Installment period	: 5 years
Installment term	: equally divided in 5 years

(4) Financing terms for short term loan

Whenever a deficiency in the annual cash flow arises during the operating period, a short term loan from local financing institutions (commercial bank or others) is assumed to be made available at an annual interest rate of 12 percent. The full amount will be repaid in the year subsequent to the year when the loan is made.

4.2.3 Method of Financial Analysis

(1) Fixed profitability

In this financial analysis, emphasis is laid on whether or not the price of the discharged fee of waste water calculated based on the fixed level of Financial Internal Rate of Return on Investment (FIRROI) is viable. This means the price level of the fee is calculated in order to attain the target FIRROI. The applied rate is 10 percent.

The rationale in this method is as follows.

(a) Revenue for the implementation body is only the discharged fee of waste water from individual dyeing factories. That is to say that the profitability of the cooperative depends on the price level of the fee.

(b) The price level of discharged fee of waste water is not totally controlled by the government. Therefore, the price level is not decided as the exogenous factor.

(c) Since this project is a conceptual design, it is worth to show the viable price level of the discharged fee rather than the profitability.

(d) The fixed rate at 10 percent is mainly based on the interest rate of the preferential loan to private industries by public institutions. This rate is applied because the implementation body is assumed to be a non-profit cooperative although the rate is below the market rate in local commercial banks (12 - 13 percent per year).

(2) Internal Rate of Return (IRR) as applied indicators

In this analysis, two types of IRR are applied. One is Financial Internal Rate of Return on Investment (FIRROI) and the other is Financial Internal Rate of Return on Equity (FIRROE).

FIRROI is an indicator of the profitability in the total investment of the project. The total capital requirements except interest during construction, revenue, and operating costs in cash flow statements are components for calculating this indicator. The interest or repayment of debt is not included.

FIRROE, on the other hand, indicates the profitability of invested own funds (equity) in the project. Thus, this rate depends on financing conditions (interest, repayment amount and so on) as well as the total capital requirements, revenue, and operating costs.

4.2.4 Results of Financial Analysis

(1) Projected price of the discharged fee

The levels of the discharged fee in order to attain the target FIRROI (10.0 %) for three cases are shown below. The levels of the fee for the case with land acquisition cost are also presented.

	Case 1	Case 2	Case 3
FIRROI	10.00	10.00	10.00
FIRROE	7.60	7.64	7.62
Price of Fee (won per m^3)	**625**	**1,000**	**860**
FIRROI (cases with Land Acquisition Cost)	10.00	10.00	10.00
Price of Fee (won per m^3)	**690**	**1,073**	**933**

According to the interview to "B" Cooperative, the discharged fee from individual factories is set at 450 won per m^3 in 1992. When compared with this price, the projected fee levels in Case 1, 2 and 3 are higher by 40 percent, 120 percent, and 90 percent, respectively.

(2) Financial projections

Based on the above assumptions and conditions, the following financial projections are prepared for three cases.

(a) Income Statements
(b) Cash Flow Statements
(c) Production Cost Statements

Income statements and Cash Flow Statements are shown in Table 4.2.1 - Table 4.2.3. Production cost statements are shown in Table 4.2.4 - Table 4.2.6.

According to the cash flow statements, the implementation body can retain approximately 8,000 million won per year for Case 1, 9,500 million for Case 2 and 10,500 million for Case 3 respectively from 9th year to 15th year. Therefore, if the levels of the fee (revenue) can be changed in accordance with "one year budget" basis, the unit price levels of the fee (per m^3) can be decreased from 625 to 358 for Case 1, 1,000 to 683 for Case 2, and 860 to 510 for Case 3, respectively, in 9th - 15th years.

In case that a short term loan is not made, the projection model of the cash flow statements indicates the deficiency of cash in the 4th - 6th years in all three cases. Thus, if the levels of fee (revenue) can be changed year by year and can be increased in the certain amount, the cash flow shall be balanced. The additional levels of fee per m^3 are summarized below. According to this analysis, if the fee is increased to be 645 (625 + 20) won per m^3 in 4th year of Case 1, the cash flow will be balanced in the same year, for example.

	4th year	5th year	6th year
(Case 1)			
Additional fee (won per m^3)	20	106	88
(Case 2)			
Additional fee (won per m^3)	23	125	104
(Case 3)			
Additional fee (won per m^3)	26	138	114

Based on the production cost statements, the averages of unit production cost are 511 won per m^3 for Case 1, 864 won per m^3 for Case 2 and 711 won per m^3.

Table 4.2.1 Income Statements and Cash Flow Statements for Dyeing Industries Waste Water Treatment Plant (Case 1)

INCOME STATEMENTS

Unit: million Won

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OPERATING INCOME			18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756	18,756
OPERATING EXPENSES			20,635	18,827	17,401	16,224	15,620	14,316	13,730	13,145	12,754	12,364	11,974	11,778	11,453	11,258	11,128
VARIABLE OPERATING COST			9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298	9,298
FIXED OPERATING COST			724	724	724	724	724	724	724	724	724	724	724	724	724	724	724
DEPRECIATION & AMORTIZATION			10,613	8,805	7,379	6,202	5,598	4,294	3,708	3,123	2,732	2,342	1,952	1,756	1,431	1,236	1,106
DEPRECIABLE FIXED ASSETS			9,238	7,937	6,831	5,855	5,009	4,294	3,708	3,123	2,732	2,342	1,952	1,756	1,431	1,236	1,106
INTEREST DURING CONSTRUCTION			1,375	868	548	347	589	0	0	0	0	0	0	0	0	0	0
OPERATING PROFIT(GROSS PROFIT)			-1,879	-71	1,355	2,532	3,136	4,440	5,026	5,611	6,002	6,392	6,782	6,978	7,303	7,498	7,628
NON-OPERATING EXPENSES			3,387	3,387	3,123	2,445	1,834	1,505	1,157	589	0	0	0	0	0	0	0
INTEREST ON LONG TERM DEBT			3,387	3,387	3,123	2,445	1,768	1,091	413	0	0	0	0	0	0	0	0
INTEREST ON SHORT TERM DEBT			0	0	0	0	66	415	744	589	0	0	0	0	0	0	0
NET PROFIT BEFORE TAX			-5,266	-3,458	-1,768	87	1,302	2,935	3,869	5,022	6,002	6,392	6,782	6,978	7,303	7,498	7,628
CORPORATE TAX			0	0	0	9	130	294	387	502	600	639	678	698	730	750	763
NET PROFIT AFTER TAX (RETAINED EARNINGS)			-5,266	-3,458	-1,768	78	1,172	2,642	3,482	4,520	5,402	5,753	6,104	6,280	6,573	6,748	6,865

CASH FLOW ANALYSIS

Unit: million Won

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SOURCES																	
CASH GENERATED	0	0	5,347	5,347	5,611	6,280	6,770	6,935	7,190	7,643	8,134	8,095	8,056	8,036	8,004	7,984	7,971
PROFIT AFTER TAX	0	0	-5,266	-3,458	-1,768	78	1,172	2,642	3,482	4,520	5,402	5,753	6,104	6,280	6,573	6,748	6,865
DEPRECIATION AND AMORTIZATION	0	0	10,613	8,805	7,379	6,202	5,598	4,294	3,708	3,123	2,732	2,342	1,952	1,756	1,431	1,236	1,106
FINANCIAL RESOURCES	26,973	42,154	0	0	0	547	3,455	6,198	4,909	0	0	0	0	0	0	0	0
EQUITY(SHARE CAPITAL)	8,092	12,646	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LONG TERM DEBT	18,881	29,508	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHORT TERM DEBT	0	0	0	0	0	547	3,455	6,198	4,909	0	0	0	0	0	0	0	0
SOURCES TOTAL	26,973	42,154	5,347	5,347	5,611	6,827	10,225	13,133	12,099	7,643	8,134	8,095	8,056	8,036	8,004	7,984	7,971
USES																	
FIXED CAPITAL EXPENDITURE	26,973	42,154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-DEPRECIABLE ASSETS	0	345	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEPRECIABLE FIXED ASSETS	26,022	39,033	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INTEREST DURING CONSTRUCTION	951	2,776	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEBT SERVICES	0	0	0	3,776	9,678	9,678	10,225	13,133	12,099	4,909	0	0	0	0	0	0	0
REPAYMENT OF LONG TERM DEBT	0	0	0	3,776	9,678	9,678	9,678	9,678	5,902	0	0	0	0	0	0	0	0
REPAYMENT OF SHORT TERM DEBT	0	0	0	0	0	0	547	3,455	6,198	4,909	0	0	0	0	0	0	0
USES TOTAL	26,973	42,154	0	3,776	9,678	9,678	10,225	13,133	12,099	4,909	0	0	0	0	0	0	0
CASH INCREASE (OR DECREASE)	0	0	5,347	1,571	-4,067	-2,851	0	0	-0	2,734	8,134	8,095	8,056	8,036	8,004	7,984	7,971
BEGINNING CASH BALANCE	0	0	0	5,347	6,917	2,851	-0	-0	0	-0	2,734	10,868	18,962	27,018	35,054	43,058	51,042
ENDING CASH BALANCE	0	0	5,347	6,917	2,851	-0	-0	0	-0	2,734	10,868	18,962	27,018	35,054	43,058	51,042	59,014

Table 4.2.2 Income Statements and Cash Flow Statements for Dyeing Industries Waste Water Treatment Plant (Case 2)

INCOME STATEMENTS

Unit: million Won

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OPERATING INCOME			30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
OPERATING EXPENSES			32.237	30.088	28.392	26.992	26.274	24.723	24.027	23.331	22.867	22.403	21.939	21.707	21.320	21.088	20.933
VARIABLE OPERATING COST			18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771
FIXED OPERATING COST			847	847	847	847	847	847	847	847	847	847	847	847	847	847	847
DEPRECIATION & AMORTIZATION			12.619	10.470	8.774	7.374	6.656	5.105	4.409	3.713	3.249	2.785	2.321	2.089	1.702	1.470	1.315
DEPRECIABLE FIXED ASSETS			10.984	9.437	8.122	6.962	5.956	5.105	4.409	3.713	3.249	2.785	2.321	2.089	1.702	1.470	1.315
INTEREST DURING CONSTRUCTION			1.635	1.032	651	412	700	0	0	0	0	0	0	0	0	0	0
OPERATING PROFIT(GROSS PROFIT)			-2.237	-88	1.608	3.008	3.726	5.277	5.973	6.669	7.133	7.597	8.061	8.293	8.680	8.912	9.067
NON-OPERATING EXPENSES			4.024	4.024	3.710	2.905	2.176	1.785	1.370	695	0	0	0	0	0	0	0
INTEREST ON LONG TERM DEBT			4.024	4.024	3.710	2.905	2.100	1.295	491	0	0	0	0	0	0	0	0
INTEREST ON SHORT TERM DEBT			0	0	0	0	76	490	880	695	0	0	0	0	0	0	0
NET PROFIT BEFORE TAX			-6.262	-4.112	-2.102	103	1.549	3.491	4.602	5.974	7.133	7.597	8.061	8.293	8.680	8.912	9.067
CORPORATE TAX			0	0	0	10	155	349	460	597	713	760	806	829	868	891	907
NET PROFIT AFTER TAX (RETAINED EARNINGS)			-6.262	-4.112	-2.102	93	1.394	3.142	4.142	5.377	6.420	6.837	7.255	7.464	7.812	8.021	8.160

CASH FLOW ANALYSIS

Unit: million Won

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SOURCES																	
CASH GENERATED	0	0	6.358	6.358	6.672	7.467	8.051	8.248	8.551	9.090	9.669	9.622	9.576	9.553	9.514	9.491	9.475
PROFIT AFTER TAX	0	0	-6.262	-4.112	-2.102	93	1.394	3.142	4.142	5.377	6.420	6.837	7.255	7.464	7.812	8.021	8.160
DEPRECIATION AND AMORTIZATION	0	0	12.619	10.470	8.774	7.374	6.656	5.105	4.409	3.713	3.249	2.785	2.321	2.089	1.702	1.470	1.315
FINANCIAL RESOURCES	32.073	50.058	0	0	0	633	4.080	7.331	5.788	0	0	0	0	0	0	0	0
EQUITY(SHARE CAPITAL)	9.622	15.017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LONG TERM DEBT	22.451	35.040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHORT TERM DEBT	0	0	0	0	0	633	4.080	7.331	5.788	0	0	0	0	0	0	0	0
SOURCES TOTAL	32.073	50.058	6.358	6.358	6.672	8.100	12.131	15.579	14.339	9.090	9.669	9.622	9.576	9.553	9.514	9.491	9.475
USES																	
FIXED CAPITAL EXPENDITURE	32.073	50.058	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-DEPRECIABLE ASSETS	0	345	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEPRECIABLE FIXED ASSETS	30.942	46.413	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INTEREST DURING CONSTRUCTION	1.131	3.300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEBT SERVICES	0	0	0	4.490	11.498	11.498	12.131	15.579	14.339	5.788	0	0	0	0	0	0	0
REPAYMENT OF LONG TERM DEBT	0	0	0	4.490	11.498	11.498	11.498	11.498	7.008	0	0	0	0	0	0	0	0
REPAYMENT OF SHORT TERM DEBT	0	0	0	0	0	0	633	4.080	7.331	5.788	0	0	0	0	0	0	0
USES TOTAL	32.073	50.058	0	4.490	11.498	11.498	12.131	15.579	14.339	5.788	0	0	0	0	0	0	0
CASH INCREASE (OR DECREASE)	-0	-0	6.358	1.867	-4.826	-3.399	0	-0	0	3.302	9.669	9.622	9.576	9.553	9.514	9.491	9.475
BEGINNING CASH BALANCE	0	0	-0	6.358	8.225	3.399	-0	0	-0	0	3.302	12.971	22.593	32.169	41.722	51.236	60.727
ENDING CASH BALANCE	-0	-0	6.358	8.225	3.399	-0	0	-0	0	3.302	12.971	22.593	32.169	41.722	51.236	60.727	70.202

Table 4.2.3 Income Statements and Cash Flow Statements for Dyeing Industries Waste Water Treatment Plant (Case 3)

INCOME STATEMENTS

Unit: million Won

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OPERATING INCOME			25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800	25,800
OPERATING EXPENSES			28,249	25,889	24,026	22,489	21,701	19,998	19,234	18,469	17,959	17,450	16,940	16,685	16,261	16,006	15,836
VARIABLE OPERATING COST			13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468	13,468
FIXED OPERATING COST			924	924	924	924	924	924	924	924	924	924	924	924	924	924	924
DEPRECIATION & AMORTIZATION			13,857	11,497	9,634	8,097	7,309	5,606	4,842	4,077	3,567	3,058	2,548	2,293	1,869	1,614	1,444
DEPRECIABLE FIXED ASSETS			12,061	10,363	8,919	7,645	6,540	5,606	4,842	4,077	3,567	3,058	2,548	2,293	1,869	1,614	1,444
INTEREST DURING CONSTRUCTION			1,796	1,134	715	453	769	0	0	0	0	0	0	0	0	0	0
OPERATING PROFIT(GROSS PROFIT)			-2,449	-89	1,774	3,311	4,099	5,802	6,566	7,331	7,841	8,350	8,860	9,115	9,539	9,794	9,964
NON-OPERATING EXPENSES			4,423	4,423	4,078	3,193	2,393	1,964	1,508	766	0	0	0	0	0	0	0
INTEREST ON LONG TERM DEBT			4,423	4,423	4,078	3,193	2,309	1,424	539	0	0	0	0	0	0	0	0
INTEREST ON SHORT TERM DEBT			0	0	0	0	84	539	969	766	0	0	0	0	0	0	0
NET PROFIT BEFORE TAX			-6,872	-4,512	-2,304	117	1,706	3,838	5,058	6,565	7,841	8,350	8,860	9,115	9,539	9,794	9,964
CORPORATE TAX			0	0	0	12	171	384	506	656	784	835	886	911	954	979	996
NET PROFIT AFTER TAX (RETAINED EARNINGS)			-6,872	-4,512	-2,304	106	1,535	3,455	4,552	5,908	7,056	7,515	7,974	8,203	8,585	8,815	8,968

CASH FLOW ANALYSIS

Unit: million Won

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SOURCES																	
CASH GENERATED	0	0	6,985	6,985	7,330	8,203	8,844	9,061	9,394	9,985	10,624	10,573	10,522	10,497	10,454	10,429	10,412
PROFIT AFTER TAX	0	0	-6,872	-4,512	-2,304	106	1,535	3,455	4,552	5,908	7,056	7,515	7,974	8,203	8,585	8,815	8,968
DEPRECIATION AND AMORTIZATION	0	0	13,857	11,497	9,634	8,097	7,309	5,606	4,842	4,077	3,567	3,058	2,548	2,293	1,869	1,614	1,444
FINANCIAL RESOURCES	35,218	55,049	0	0	0	702	4,495	8,072	6,385	0	0	0	0	0	0	0	0
EQUITY(SHARE CAPITAL)	10,565	16,515	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LONG TERM DEBT	24,652	38,534	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHORT TERM DEBT	0	0	0	0	0	702	4,495	8,072	6,385	0	0	0	0	0	0	0	0
SOURCES TOTAL	35,218	55,049	6,985	6,985	7,330	8,905	13,340	17,133	15,779	9,985	10,624	10,573	10,522	10,497	10,454	10,429	10,412
USES																	
FIXED CAPITAL EXPENDITURE	35,218	55,049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-DEPRECIABLE ASSETS	0	460	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEPRECIABLE FIXED ASSETS	33,976	50,964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INTEREST DURING CONSTRUCTION	1,242	3,625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEBT SERVICES	0	0	0	4,930	12,637	12,637	13,340	17,133	15,779	6,385	0	0	0	0	0	0	0
REPAYMENT OF LONG TERM DEBT	0	0	0	4,930	12,637	12,637	12,637	12,637	7,707	0	0	0	0	0	0	0	0
REPAYMENT OF SHORT TERM DEBT	0	0	0	0	0	0	702	4,495	8,072	6,385	0	0	0	0	0	0	0
USES TOTAL	35,218	55,049	0	4,930	12,637	12,637	13,340	17,133	15,779	6,385	0	0	0	0	0	0	0
CASH INCREASE (OR DECREASE)	0	0	6,985	2,054	-5,307	-3,732	0	-0	-0	3,601	10,624	10,573	10,522	10,497	10,454	10,429	10,412
BEGINNING CASH BALANCE	0	0	0	6,985	9,039	3,732	-0	0	-0	-0	3,601	14,225	24,798	35,320	45,816	56,270	66,699
ENDING CASH BALANCE	0	0	6,985	9,039	3,732	-0	0	-0	-0	3,601	14,225	24,798	35,320	45,816	56,270	66,699	77,110

Table 4.2.4 Production Cost Statements for Dyeing Industries Waste Water Treatment Plant (Case 1)

Unit: million Won (unless otherwise designated)

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) PRODUCTION (1000 m3/year)			30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
(2) VARIABLE OPERATING COST			9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298	9.298
(3) FIXED OPERATING COST			724	724	724	724	724	724	724	724	724	724	724	724	724	724	724
(4) CASH COST TOTAL:(2)+(3)			10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022	10.022
(5) UNIT CASH COST: (4)/(1);won per m3			334	334	334	334	334	334	334	334	334	334	334	334	334	334	334
(6) DEPRECIATION & AMORTIZATION			10.613	8.805	7.379	6.202	5.598	4.294	3.708	3.123	2.732	2.342	1.952	1.756	1.431	1.236	1.106
(7) OPERATING EXPENSES:(2)+(3)+(6)			20.635	18.827	17.401	16.224	15.620	14.316	13.730	13.145	12.754	12.364	11.974	11.778	11.453	11.258	11.128
(8) INTEREST ON LONG TERM DEBT			3.387	3.387	3.123	2.445	1.768	1.091	413	0	0	0	0	0	0	0	0
(9) INTEREST ON SHORT TERM DEBT			0	0	0	0	66	415	744	589	0	0	0	0	0	0	0
(10)TOTAL PRODUCTION COST			24.022	22.214	20.524	18.669	17.454	15.821	14.887	13.734	12.754	12.364	11.974	11.778	11.453	11.258	11.128
(11)UNIT PRODUCTION COST:(10)/(1):won per m3			801	740	684	622	582	527	496	458	425	412	399	393	382	375	371

* Average of Unit Production Cost for 15 years
511 won per m3

(Percentage of components)

Unit: percent

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) VARIABLE OPERATING COST		-	38.71	41.86	45.30	49.80	53.27	58.77	62.46	67.70	72.90	75.20	77.65	78.94	81.18	82.59	83.56
(2) FIXED OPERATING COST		-	3.01	3.26	3.53	3.88	4.15	4.58	4.86	5.27	5.68	5.86	6.05	6.15	6.32	6.43	6.51
(3) DEPRECIATION & AMORTIZATION		-	44.18	39.64	35.95	33.22	32.07	27.14	24.91	22.74	21.42	18.94	16.30	14.91	12.50	10.98	9.94
(4) INTEREST ON LONG TERM DEBT		-	14.10	15.25	15.22	13.10	10.13	6.89	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(5) INTEREST ON SHORT TERM DEBT		-	0.00	0.00	0.00	0.00	0.38	2.62	5.00	4.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(6) TOTAL PRODUCTION COST		-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.2.5 Production Cost Statements for Dyeing Industries Waste Water Treatment Plant (Case 2)

Unit: million Won (unless otherwise designated)

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) PRODUCTION (1000 m3/year)			30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
(2) VARIABLE OPERATING COST			18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771	18.771
(3) FIXED OPERATING COST			847	847	847	847	847	847	847	847	847	847	847	847	847	847	847
(4) CASH COST TOTAL:(2)+(3)			19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618	19.618
(5) UNIT CASH COST: (4)/(1):won per m3			654	654	654	654	654	654	654	654	654	654	654	654	654	654	654
(6) DEPRECIATION & AMORTIZATION			12.619	10.470	8.774	7.374	6.656	5.105	4.409	3.713	3.249	2.785	2.321	2.089	1.702	1.470	1.315
(7) OPERATING EXPENSES:(2)+(3)+(6)			32.237	30.088	28.392	26.992	26.274	24.723	24.027	23.331	22.867	22.403	21.939	21.707	21.320	21.088	20.933
(8) INTEREST ON LONG TERM DEBT			4.024	4.024	3.710	2.905	2.100	1.295	491	0	0	0	0	0	0	0	0
(9) INTEREST ON SHORT TERM DEBT			0	0	0	0	76	490	880	695	0	0	0	0	0	0	0
(10)TOTAL PRODUCTION COST			36.262	34.112	32.102	29.897	28.451	26.509	25.398	24.026	22.867	22.403	21.939	21.707	21.320	21.088	20.933
(11)UNIT PRODUCTION COST:(10)/(1):won per m3			1.209	1.137	1.070	997	948	884	847	801	762	747	731	724	711	703	698

* Average of Unit Production Cost for 15 years
864 won per m3

(Percentage of components)

Unit: percent

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) VARIABLE OPERATING COST		-	51.77	55.03	58.47	62.79	65.98	70.81	73.91	78.13	82.09	83.79	85.56	86.48	88.04	89.01	89.67
(2) FIXED OPERATING COST		-	2.34	2.48	2.64	2.83	2.98	3.20	3.33	3.53	3.70	3.78	3.86	3.90	3.97	4.02	4.05
(3) DEPRECIATION & AMORTIZATION		-	34.80	30.69	27.33	24.66	23.40	19.26	17.36	15.45	14.21	12.43	10.58	9.62	7.98	6.97	6.28
(4) INTEREST ON LONG TERM DEBT		-	11.10	11.80	11.56	9.72	7.38	4.89	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(5) INTEREST ON SHORT TERM DEBT		-	0.00	0.00	0.00	0.00	0.27	1.85	3.46	2.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(6) TOTAL PRODUCTION COST		-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.2.6 Production Cost Statements for Dyeing Industries Waste Water Treatment Plant (Case 3)

Unit: million Won (unless otherwise designated)

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) PRODUCTION (1000 m3/year)			30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
(2) VARIABLE OPERATING COST			13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468
(3) FIXED OPERATING COST			924	924	924	924	924	924	924	924	924	924	924	924	924	924	924
(4) CASH COST TOTAL:(2)+(3)			14392	14392	14392	14392	14392	14392	14392	14392	14392	14392	14392	14392	14392	14392	14392
(5) UNIT CASH COST: (4)/(1):won per m3			480	480	480	480	480	480	480	480	480	480	480	480	480	480	480
(6) DEPRECIATION & AMORTIZATION			13857	11497	9634	8097	7309	5606	4842	4077	3567	3058	2548	2293	1869	1614	1444
(7) OPERATING EXPENSES:(2)+(3)+(6)			28249	25889	24026	22489	21701	19998	19234	18469	17959	17450	16940	16685	16261	16006	15836
(8) INTEREST ON LONG TERM DEBT			4423	4423	4078	3193	2309	1424	539	0	0	0	0	0	0	0	0
(9) INTEREST ON SHORT TERM DEBT			0	0	0	0	84	539	969	766	0	0	0	0	0	0	0
(10)TOTAL PRODUCTION COST			32672	30312	28104	25683	24094	21962	20742	19235	17959	17450	16940	16685	16261	16006	15836
(11)UNIT PRODUCTION COST:(10)/(1):won per m3			1089	1010	937	856	803	732	691	641	599	582	565	556	542	534	528

* Average of Unit Production Cost for 15 years
711 won per m3

(Percentage of components)

Unit: percent

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) VARIABLE OPERATING COST		-	41.22	44.43	47.92	52.44	55.90	61.33	64.93	70.02	74.99	77.18	79.50	80.72	82.83	84.14	85.05
(2) FIXED OPERATING COST		-	2.83	3.05	3.29	3.60	3.83	4.21	4.45	4.80	5.14	5.30	5.45	5.54	5.68	5.77	5.83
(3) DEPRECIATION & AMORTIZATION		-	42.41	37.93	34.28	31.53	30.34	25.53	23.34	21.20	19.86	17.52	15.04	13.74	11.49	10.08	9.12
(4) INTEREST ON LONG TERM DEBT		-	13.54	14.59	14.51	12.43	9.58	6.48	2.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(5) INTEREST ON SHORT TERM DEBT		-	0.00	0.00	0.00	0.00	0.35	2.46	4.67	3.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(6) TOTAL PRODUCTION COST		-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

4.2.5 Ratio Analysis

The results of conventional ratio analysis are shown in Table 4.2.7 - Table 4.2.9. The definitions of financial performance indicators are summarized below.

(a) Profit on Sales Revenue :

Net profit (after tax) / Operating income (Revenue)

(b) Profit on Equity :

Net profit (after tax) / Equity

(c) Debt Service Coverage Ratio :

(Net profit+Depreciation+Interest)/(Repayment+Interest)

(d) Break Even Revenue (B.E.R, Profit) :

B.E.R = (FOC + DP + Interest)/ (1 - (VC / Revenue))
B.E.P = B.E.R / Revenue

(e) Break Even Revenue (B.E.R, Cash) :

B.E.R = (FOC + Repayment + Interest)/ (1 - (VC / Revenue))
B.E.P = B.E.R / Revenue

where,

B.R.P = Break Even Point Ratio
FOC = Fixed Operating Cost
VC = Variable Operating Cost
DP = Depreciation and Amortization

Table 4.2.7 Ratio Analysis for Dyeing Industries Waste Water Treatment Plant (Case 1)

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Profit on Sales Revenue (%)	-	-	-28.08	-18.44	-9.42	0.42	6.25	14.08	18.57	24.10	28.80	30.67	32.54	33.48	35.04	35.98	36.60	16.04
Profit on Equity (%)	-	-	-7.62	-5.00	-2.56	0.11	1.70	3.82	5.04	6.54	7.81	8.32	8.83	9.08	9.51	9.76	9.93	4.35
Debt Service Coverage Ratio	-	-	2.58	1.22	0.68	0.72	0.71	0.58	0.63	1.50	-	-	-	-	-	-	-	-
Break Even Revenue (Profit)	-	-	29.200	25.614	22.261	18.584	16.174	12.935	11.083	8.796	6.854	6.080	5.306	4.919	4.274	3.887	3.629	11.973
B.E.P. Ratio (%)	-	-	155.68	136.57	118.69	99.08	86.23	68.97	59.09	46.90	36.54	32.42	28.29	26.23	22.79	20.72	19.35	63.84
Break Even Revenue (Cash)	-	-	8.153	15.641	26.821	25.477	25.349	30.464	27.724	12.339	1.436	1.436	1.436	1.436	1.436	1.436	1.436	12.135
B.E.P. Ratio (%)	-	-	43.47	83.39	143.00	135.83	135.15	162.42	147.81	65.79	7.65	7.65	7.65	7.65	7.65	7.65	7.65	64.70

Note: Unit of Break Even Revenue is million won.

Table 4.2.8 Ratio Analysis for Dyeing Industries Waste Water Treatment Plant (Case 2)

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Averag
Profit on Sales Revenue (%)	-	-	-20.87	-13.71	-7.01	0.31	4.65	10.47	13.81	17.92	21.40	22.79	24.18	24.88	26.04	26.74	27.20	11.92
Profit on Equity (%)	-	-	-7.62	-5.01	-2.56	0.11	1.70	3.83	5.04	6.55	7.82	8.33	8.83	9.09	9.51	9.77	9.94	4.35
Debt Service Coverage Ratio	-	-	2.58	1.22	0.68	0.72	0.71	0.58	0.63	1.51	-	-	-	-	-	-	-	-
Break Even Revenue (Profit)	-	-	46.729	40.986	35.615	29.725	25.861	20.672	17.704	14.038	10.943	9.703	8.463	7.843	6.810	6.190	5.776	19.137
B.E.P. Ratio (%)	-	-	155.76	136.62	118.72	99.08	86.20	68.91	59.01	46.79	36.48	32.34	28.21	26.14	22.70	20.63	19.25	63.79
Break Even Revenue (Cash)	-	-	13.015	25.011	42.894	40.744	40.488	48.653	44.233	19.581	2.263	2.263	2.263	2.263	2.263	2.263	2.263	19.364
B.E.P. Ratio (%)	-	-	43.38	83.37	142.98	135.81	134.96	162.18	147.44	65.27	7.54	7.54	7.54	7.54	7.54	7.54	7.54	64.55

Note: Unit of Break Even Revenue is million won.

Table 4.2.9 Ratio Analysis for Dyeing Industries Waste Water Treatment Plant (Case 3)

YEAR	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Profit on Sales Revenue (%)	-	-	-26.64	-17.49	-8.93	0.41	5.95	13.39	17.65	22.90	27.35	29.13	30.91	31.80	33.28	34.17	34.76	15.24
Profit on Equity (%)	-	-	-7.61	-5.00	-2.55	0.12	1.70	3.83	5.04	6.55	7.82	8.33	8.83	9.09	9.51	9.77	9.93	4.36
Debt Service Coverage Ratio	-	-	2.58	1.22	0.68	0.72	0.71	0.58	0.63	1.50	-	-	-	-	-	-	-	-
Break Even Revenue (Profit)	-	-	40.178	35.239	30.620	25.554	22.232	17.770	15.217	12.066	9.397	8.330	7.264	6.731	5.843	5.310	4.954	16.447
B.E.P. Ratio (%)	-	-	155.73	136.59	118.68	99.05	86.17	68.87	58.98	46.77	36.42	32.29	28.16	26.09	22.65	20.58	19.20	63.75
Break Even Revenue (Cash)	-	-	11.187	21.502	36.903	35.053	34.848	41.884	38.099	16.894	1.933	1.933	1.933	1.933	1.933	1.933	1.933	16.660
B.E.P. Ratio (%)	-	-	43.36	83.34	143.04	135.86	135.07	162.34	147.67	65.48	7.49	7.49	7.49	7.49	7.49	7.49	7.49	64.57

Note: Unit of Break Even Revenue is million won.

4.2.6 Sensitivity Analysis

Sensitivity analysis is conducted in two ways. The first one is to see the variation of the discharged fee (revenue) through fluctuating the construction cost and the operating cost on condition that FIRROI keeps at 10 percent. These results are shown in Table 4.2.10 and Fig.4.2.1. According to the results, the operating cost is more sensitive than the construction cost in all three cases.

Table 4.2.10 Sensitivity Analysis (1) (FIRROI = 10 %)

Unit: won per m^3

	Construction Cost	Operating Cost
(Case 1)		
-20	563	559
-10	594	592
0 (Base)	625	625
+10	657	659
+20	688	692
(Case 2)		
-20	926	869
-10	963	935
0 (Base)	1,000	1,000
+10	1,037	1,065
+20	1,074	1,131
(Case 3)		
-20	778	764
-10	819	812
0 (Base)	860	860
+10	901	908
+20	942	956

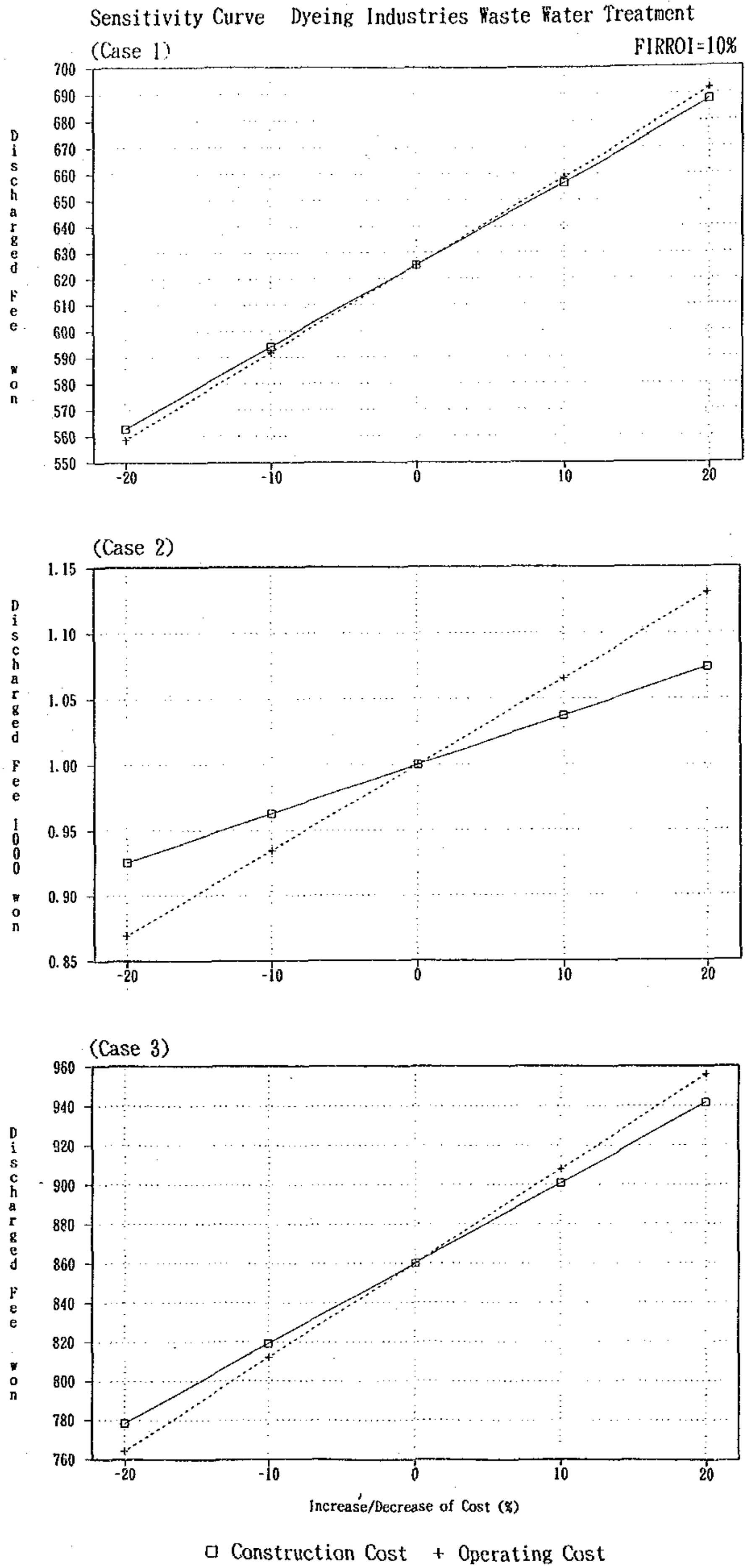


Fig.4.2.1 Sensitivity Analysis (1)

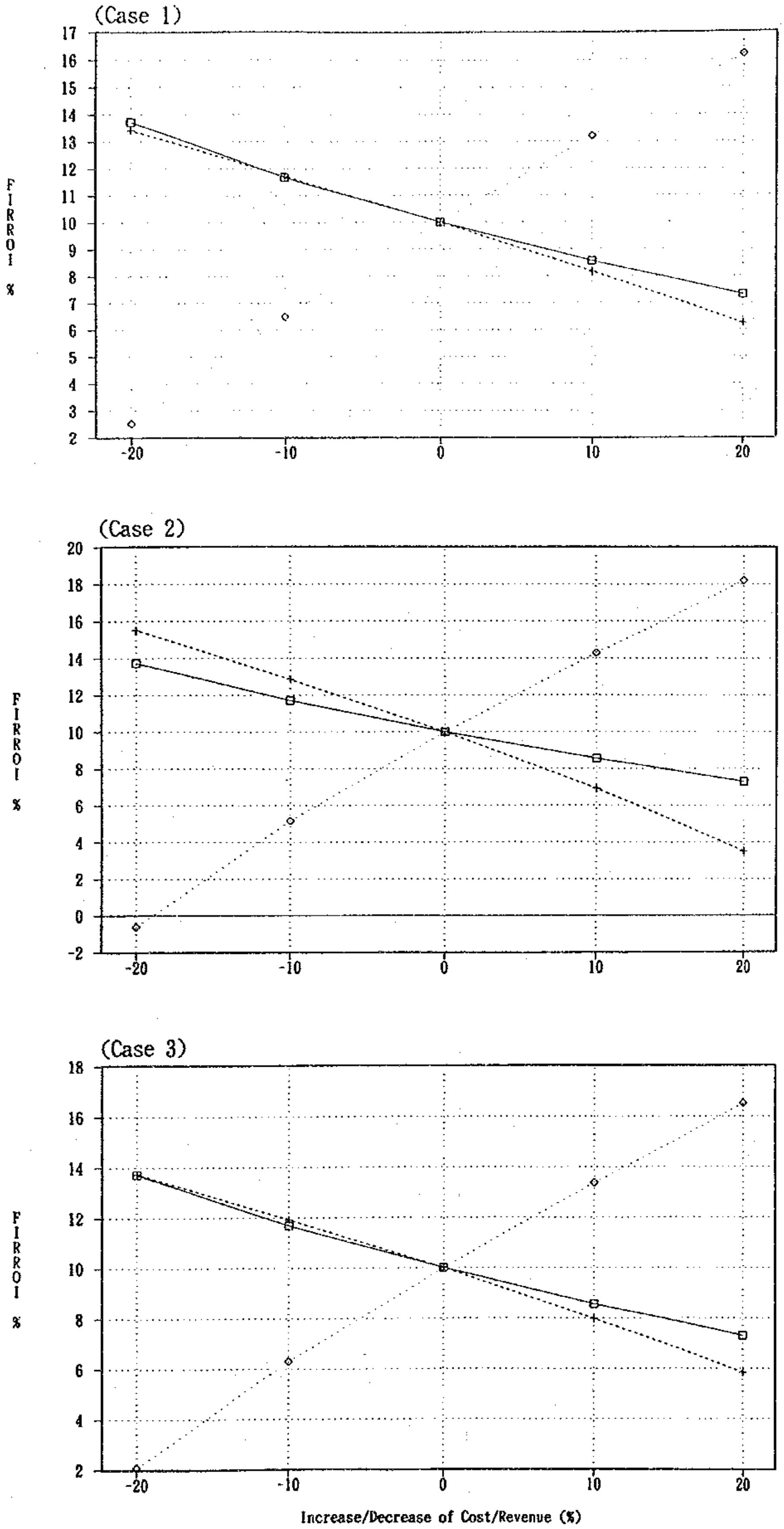
Another way to analyze sensitivity is to see the variation of FIRROI through fluctuating construction cost, operating cost and revenue. The results are shown in Table 4.2.11 and Fig. 4.2.2. The most sensitive factor to influence FIRROI is the variation of the revenue (operating income). A ten percent drop in revenue will cause 3.52%, 4.82%, and 3.71% decrease of FIRROI for Case 1, Case 2 and Case 3, respectively. The increase of the operating cost also influences FIRROI in Case 2 in particular.

Table 4.2.11 Sensitivity Analysis (2)

Unit: percent(FIRROI)

	Construction Cost	Operating Cost	Revenue
(Case 1)			
-20	13.72	13.42	2.52
-10	11.69	11.74	6.48
0 (Base)	10.00	10.00	10.00
+10	8.55	8.16	13.21
+20	7.30	6.23	16.21
(Case 2)			
-20	13.72	15.51	-0.61
-10	11.70	12.85	5.18
0 (Base)	10.00	10.00	10.00
+10	8.56	6.93	14.28
+20	7.31	3.53	18.20
(Case 3)			
-20	13.72	13.75	2.07
-10	11.69	11.92	6.29
0 (Base)	10.00	10.00	10.00
+10	8.56	7.98	13.38
+20	7.31	5.83	16.52

Sensitivity Curve Dyeing Industries Waste Water Treatment



□ Construction Cost + Operating Cost ◇ Revenue

Fig.4.2.2 Sensitivity Analysis (2)

4.3 Economic Analysis

Whereas financial analysis focuses primarily on market prices and cash flows, economic analysis should include the benefits and the costs of the effects that the project have on the environment.

However, the direct loss or damage to the environment in the Study Areas and the vicinity is not seen in this project because this is a conceptional design. As a result, the benefits based on market values can not been identified quantitatively except recycling water produced in Case 3. In this economic analysis, therefore, the introduction of generally applicable methods, the benefits of recycling water in Case 3 and the qualitative socio-economic impacts are discussed. The Economic Internal Rate of Return (EIRR) is not calculated.

4.3.1 Generally Applicable Techniques for the Analysis[1]

Three sets of valuation techniques using market prices, which are those of straightforward benefit-cost analysis, are used in common in the economic analysis on the environmental project. The first one deals with changes in production and the value of output. The second one is the loss of earnings approach. And, the third one is the opportunity cost approach.

The techniques using changes in productivity are direct extensions of traditional benefit-cost analyses. Physical changes in production are valued using market prices for inputs and outputs. (example: Untreated effluent, with a high BOD content, polluted waters and then affected the productivity of a downstream fishery.)

The "loss of earning" technique is to estimate the lost earnings and medical costs that result from the environmental damage caused by a project. (example: an urban water supply project which reduces the incidence of diarrhea)

The opportunity cost approach is based on the concept that the cost of using resources for unpriced or unmarketed purposes can

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1.The contents of this sub-section is mainly relied on "Economic Analysis of the Environmental Impacts of Development Projects" by the Asian Development Bank in 1986.

be estimated by using the forgone income from other uses of the resources as a proxy. This approach is a way of the measuring the "cost of preservation". (example: preserving land for a national park rather than harvesting its tree for timber)

4.3.2 Benefits of recycling water

In Case 3, 30,000 m^3 of recycling water is annually produced. This recycling water is the benefit under the change-in-production approach, which is discussed before. The benefits from the recycling water are calculated based on the alternative resource saved by avoiding the needs to provide clean water (presumably least costly). This means that the production costs on the equal amount of water supply is the benefit for recycling water. Since the unit cost of water supply is 268 won per m^3 according to the data for water production in Inchon area, the total savings (benefits) amount to 8.05 million won per year although this is very small compared with the total cost for the treatment plant. Since recycling water is not produced from Case 1 and Case 2, the savings for these two cases can not be calculated. .

4.3.3 Socio-economic Impact Consideration

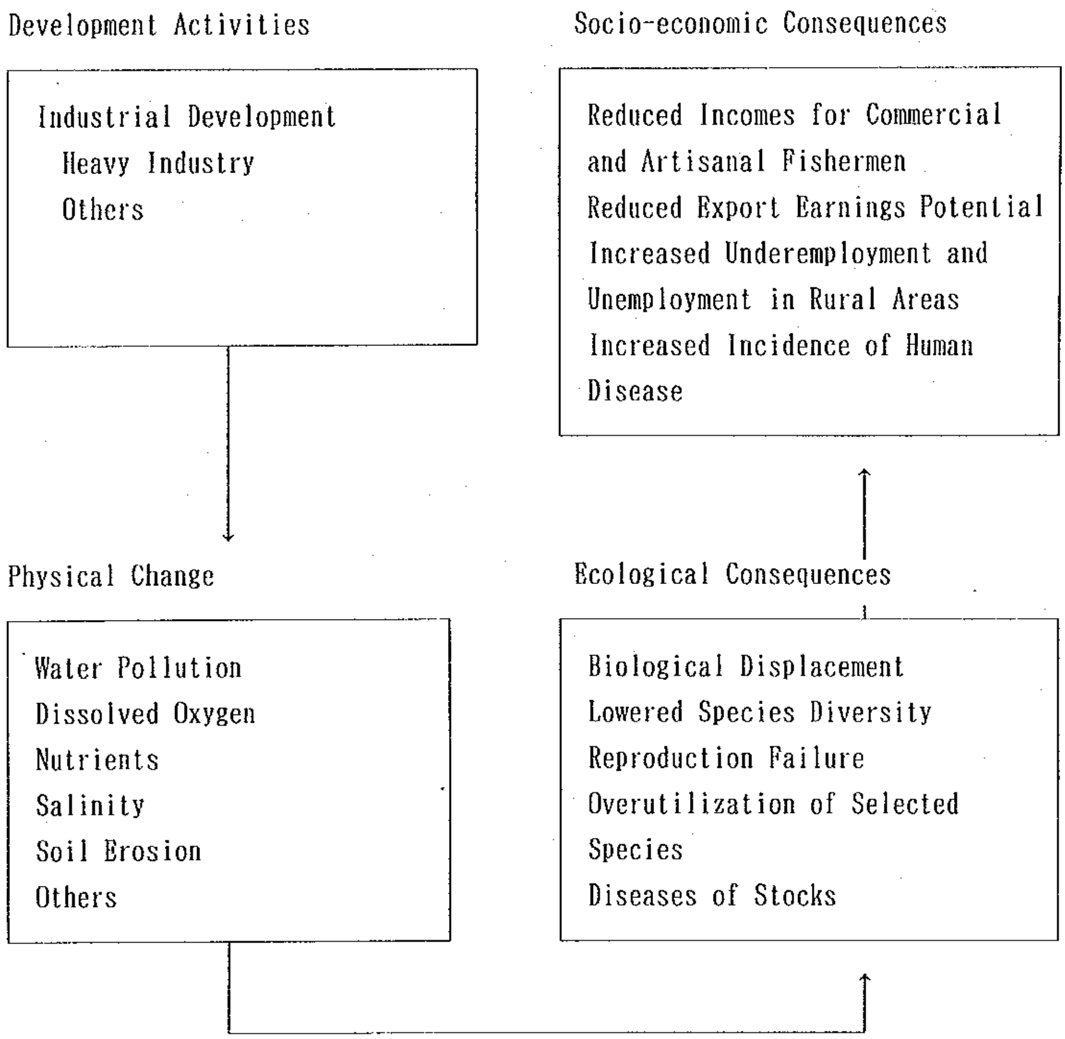
Industrial development (such as plating industrial estate) in general tends to cause the damage to the environment through the linkages. The development causes physical changes in water, air, soil and so on in terms of temperature, dissolved oxygen, nutrients, salinity, siltation, solid wastes and so on. These changes result in ecological changes such as biological displacement, change in species composition, lowered species diversity, reproduction failure, and so on. Then, these have the socio-economic consequences such as reduced incomes for fishermen and farmers through the reduction of the productivity, increased underemployment and unemployment, and increased incidence of human disease. These linkages are shown in Fig. 4.3.1.

Specifically CN, Cu, Cr^{+6} and other heavy metals in the waste water from plating industries may cause the following environmental effects.

(a) Fish and other animals in the water near the plating industrial estate may be contaminated by poisonous heavy metals and incidence of human disease may be increased through a food cycle.

(b) The water supplies used both by people and by animals may be contaminated and the cost may be incurred in replacing the water from other sources.
(c) Additional water-treatment measures (including sewerage) may be needed by downstream users.

Therefore, the proposed project on the waste water treatment plant for plating industries is highly valuable in terms of protection of the environment, although a "with-and-without-project framework" is not simply applied to this project since the Korean Government has stringent standards for effluents.



Note: This diagram is mainly transformed from Table 1 in "Economic Analysis of the Environmental Impacts of Development Projects" published by ADB in 1986.

Fig. 4.3.1 Linkage between Development Activities and their Consequences

IV. Overall Evaluation

IV Overall Evaluation

1. Plating Industrial Estate

1.1 Evaluation and Problems Concerning the Optimum Systems

1.1.1 Technical Evaluation and Problems Concerning the System

The proposed optimum system is intended to perform complete treatment of wastewater produced in the industrial estate of electroplating factories. The system has the following characteristics.

(1) The system can well cope with variable quantities and qualities of the expected wastewater.

The stabilization tank has an adequate capacity for any amounts of water coming from the estate. Furthermore, all components of the treatment process are made with certain capacity margins. Thus, the system as a whole is flexible enough to cope with variable quantities and qualities of wastewater.

(2) The operation of the system is fully automated.

While the existing system is operated manually for the most part and hence requires many operators, the operation of the proposed optimum system is fully automated so that the number of operators can be reduced greatly.

(3) The system is equipped with an adequate number of monitoring instruments.

Monitoring instruments installed at each stage of the optimum system allow the operator to check water quality and operational state of the stage concerned. The existing system has few monitoring instruments installed and hence the operation depends on visual inspection by individual operators. As mentioned before, this has given rise to various problems. The optimum system will virtually eliminate such problems.

(4) The layout of the system is very compact.

The layout of equipment and machinery of the proposed system is designed for easy operation and minimum space requirement . As a result, the space necessary for the optimum system (approx. 700 m^2) is only marginally larger than that of the existing system, while the operation is much improved compared with the existing system.

Perfect though the system planning may be, it cannot realize its functions unless the assumptions for the planning are met. In planning the system, the following assumptions are made:

(1) The factories in the industrial estate use electroplating.

Our survey shows that one factory in the estate uses an anodized aluminum plating method and another uses a chemical plating method. Wastewater from those two factories, however, accounts for only marginal percentage of the whole wastewater, so it does not affect the treatment of wastewater.

Even at the same stage, the agents used for chemical plating are different from those used in electroplating, and they produce very different type of waste water. That is why only those factories which have similar manufacturing processes should be selected in forming an industrial estate.

(2) Each factory will take appropriate measures to reduce the amount wastewater.

For wastewater treatment to be effective, it is important that each factory takes measures to reduce the discharge of wastewater so that only highly concentrated wastewater flows into the central treatment plant. Such measures must be planned before factories start operating and discharging wastewater.

(3) Various types of wastewater coming from factories are separated from each other according to their contents and con-

centration.

As stated before, wastewater discharged by plating factories is classified into (1) cyanic, (2) chrome, and (3) acid/alkaline water. Any wastewater treatment plant is built on the assumption that incoming wastewater is separated based in accordance with classification. Unless wastewater being thus separated,in this way, the treatment would become impossible. Moreover, if cyanic water and acid/alkaline water are mixed, extremely poisonous cyanide gas may be produced. The separation, therefore, must be rigorously applied.

With the above assumption being met, the proposed system offers the best solution to the central treatment of wastewater in the industrial estate.

1.1.2. Economic Evaluation and Problems of Concerning the Systems

As stated in "(4.2) Financial Analysis in (II) Plating Industrial Estate" of this report, the proposed optimum system makes good economic sense. The reasons for this judgment are as follows:

(1) The rate for the treatment is high enough.

Disposal of wastewater produced by plating factories is difficult, and it is very dangerous if discharged into a river or sea without any treatment. For this reason, a relatively high rate may be charged for its treatment. The rate set by the law (i.e.legal rates for subcontracting the disposal) is considerably higher than the rate (according to CASE-3 of 4.2.4 of II, 4,763 Won/m^3) calculated for the proposed system.

(2) Running costs are reasonably low (i.e. consumption of electric power and chemicals is low).

Because of the high capacity required, the construction cost of the pro-posed system will be higher than the existing system. In return, thanks to the installation of many instruments, operation and management is made much easier. As a result the proposed system eliminates unnecessary consumption of power and chemicals, thus keeping running cost to the minimum.

(3) The operation is fully automated.

Because of fully automated operation, labor cost necessary for running the system may greatly be reduced. The proposed system can be run by two operators, whereas the existing system requires six.

However, the economic advantages listed above can be realized only if the following conditions are met.

(1) Equipment and machinery are properly managed and maintained.

To realize the economic advantages of the system, it must be maintained and operated in good condition. It is, therefore, important to assign adequate money and workforce to the daily management and maintenance of the equipment and machinery.

(2) The rate for treatment is set reasonably high.

The cost for wastewater treatment may differ greatly depending on water's qualities (contents, concentration, etc.). So, it is important to charge appropriate rates for each type of water.

(3) Wastewater is appropriately accepted.

In accepting the inflow of wastewater, its quality and quantity must be measured to determine the rate. If water is beyond the treatment capacity of the system, refusal of inflow may be necessary in order to keep the system running economically.

(4) Measures are taken to prevent troubles in treatment

Even if Step (3) above is taken, some factories may, inad vertently or intentionally, still discharge prohibited waste water, which may put the system in disorder. Apart from technical measures to be taken in such cases, some provision should be made to punish the factory concerned, such as refusal of further inflow of wastewater, high amount of a fine, and the like.

The technical evaluation is closely related to the economic one. In general, a technically excellent system will also have an excellent economic evaluation. The proposed system is the very example of this.

1.2. Suggestions Regarding the Introduction of the Optimum Systems

Since considerations in introducing the optimum system are already explained (see II and 1.1 of this chapter), we will make some more suggestions briefly.

(1) Adequate preparatory studies should be conducted sufficiently.

Before constructing the central treatment plant, its basic design conditions must be established properly by carefully studying expected amounts and qualities of wastewater.

Nonetheless, in the case of an industrial complex that is yet to be constructed, there are no data available to study. In such a case, as shown in this report, estimate must be made as accurately as possible by analyzing data gathered from existing factories of similar type.

(2) Each factory should be well informed about wastewater treatment.

Whether the central treatment plant works properly depends on every factory discharging its wastewater as planned. In other words, each factory must take wastewater treatment into account in its production activities. To serve this purpose, the central treatment plant should make the utmost effort to improve each factory's knowledge and technique concerning wastewater treatment.

(3) Appropriate rate should be charged for wastewater treat-treatment.

As stated in 1.1.2 of this chapter, once a rate is set, it becomes difficult to change. That is why appropriate rate should be determined in consultation with the factories prior to starting the treatment system.

(4) The inflow of wastewater should be monitored constantly.

Even a well-planned wastewater treatment system (with appropriate rates) may not bring the expected effects if the amounts and qualities of incoming wastewater are not monitored. So, the inflow of wastewater must be continuously monitored with instruments, and the monitored data must be promptly reflected in the running of the system.

(5) The importance of the technicians and operators of the wastewater treatment plant should be fully understood and proper training should be provided.

There is a tendency to attach less importance to the technicians and operators working for waste water treatment than those working in a manufacturing process. However, in the manufacturing process, production is carried out using materials with more or less the same quality. In contrast, in wastewater treatment, a high quality products (treated water which meets certain standards) must be realized using materials (raw waste water) of various qualities. In consequence, the technical standard for wastewater treatment must be high enough to cope with the wide variation of quantities and qualities of discharged water. For this reason, competent technicians and operators must be assigned to the treatment plant, and sufficient training must be given.

(6) Management/maintenance should be meticulously carried out.

As mentioned in 1.1.2 of this chapter, improper management/maintenance may hinder even the optimum system from functioning as planned.

In order to realize the economic advantages of the system, expense should not be spared as far as management/maintenance is concerned. If possible, as practiced in a manufacturing process, periodical maintenance (once or twice a year) should be carried out.

(7) Cooperative relations should be established between the wastewater treatment plant and the factories.

As mentioned before, wastewater treatment is closely related to a manufacturing process. To keep the treatment system running in good condition, cooperative relations between the treatment plant and each factory is indispensable. One way to achieve this may be to establish a committee consisting of the staff of the treatment plant and the personnel from each factory, thus providing an opportunity to discuss matters of mutual interest and exchange information.

(8) The treatment plant should participate in some way in the manufacturing process of each factory.

The treatment plant should not limit its responsibility to the treatment of wastewater, but should actively participate in the manufacturing process from the standpoint of wastewater treatment. Thus, the treatment plant should not hesitate to give advice, if any, for improving the manufacturing process of each factory.

1.3. Other Problems and Suggestions

The following are problems and suggestions concerning matters other than wastewater treatment.

(1) Managing structure of the industrial estate

At present, the relationship between the central wastewater treatment plant and each factory is that of a landlord and its tenant, which makes it difficult to establish cooperative relations between the two. As is the case in the dyeing industrial estate, it may help if the wastewater treatment plant is managed by a cooperative association consisting of all the factories.

(2) Enlargement of joint work by the industrial estate

At present, wastewater and exhaust gas disposal (using scrubbers for gas disposal) are the only joint project of the estate. By extending joint projects to the supply of utilities (industrial water, cooling water, steam, etc.) and the disposal of industrial wastes, the management of the estate will become more stable and the gain of each factory will increase.

(3) Technical training for the factories

The factories in the estate are small in scale. Therefore, although keen to introduce the latest technologies to improve manufacturing methods, they have little means. It may help a lot if a technical center is established in the estate to give appropriate guidance and training to each factory.

In the existing industrial estate, it may be difficult to implement the suggestions listed above. In case an estate is newly established, however, those suggestions should be taken into consideration.

2. Dyeing Industrial Estate

2.1. Evaluation and Problems Concerning the Optimum Systems

The evaluation and problems concerning the dyeing industrial estate are basically the same as those concerning the plating industrial estate shown in 1. of this chapter. In the following, only those points that are unique to the former are described in detail, other points which are the same as in the plating estate being only listed.

2.1.1. Technical Evaluation and Problems Concerning the System

The proposed optimum system is intended to perform complete treatment of wastewater produced in dyeing factories (where dyeing of synthetic fibers such as polyester is also carried out). The system has the following characteristics.

(1) The system can well cope with the variable quantities and

qualities of the expected wastewater.

(2) The operation of the system is fully automated.

While the existing system has not been automated completely and hence requires many operators, the operation of the proposed optimum system is fully automated so that the number of operators can be greatly reduced.

(3) The system is equipped with an adequate number of monitoring instruments.

Monitoring instruments installed at each stage of the optimum system allow the operator to check water quality and operational state of the stage concerned. With the existing system, too, quite a few monitoring instruments are already installed and are operated from a control room. The proposed system, however, gives greater consideration to the instrumentation.

(4) The layout of the system is designed to allow sufficient space for each component.

At present, owing to the narrowness of the building site, and as a result of the extension work, equipment and machinery of the existing system are placed too close to each other. In contrast, the layout of the proposed optimum system is spacious enough to allow easy operation. The building site for the proposed system is consequently larger than the existing one. The present site is too small to accommodate a system which is expected to treat 100,000 m^3 of waste water a day.

(5) The system makes the final sewage treatment plant redundant.

Currently, water discharged from the central treatment plant is sent to the final sewage plant run by the municipal government of Ansan. As mentioned in 1.2 of I, however, this sewage plant is not working properly. The proposed system is designed to make treated water purer, so that the final sewage plant will become redundant. In particular, the high-degree treatment system for COD elements (CASE-2) will make the final sewage plant totally unnecessary for treating industrial wastes.

Perfect though the system planning may be , it cannot make full use of its functions unless the assumptions for the planning are met. In planning the system, the following assumptions are made:

(1) The estate consists of factories which are mostly engaged in the dyeing of cotton and only partly in the dyeing of synthetic fibers such as polyester.

Our survey has shown that the estate has one factory which carries out leather tanning alongside dyeing. Although the amount of wastewater from this factory is very small, a tiny amount of chrome metal contained in it has an obiouse adverse effect on the operation of the central treatment plant. The existence of a factory of a different nature clearly affects the whole system.

Among the dyeing factories themselves, those which conduct the dyeing of wool or polyester produce a different type of wastewater from the those which are engaged in the dyeing of cotton. Wastewater coming from the wool dyeing factories contains substances (oil, fat, protein, etc.) removed from wool, while waste water of polyester dyeing contains elements (such as ethylene glycol and terephthal acid) that are resolved from polyester when the marcerization method is applied. The treatment of the former is not very difficult, but the latter cannot be removed by the biological treatment alone. See the example shown in 3.4.3 (11) of chapter 5

In creating an industrial estate, therefore, it is important to select only those factories which have more or less the same manufacturing processes.

(2) Each factory will take appropriate measures to reduce the amount of wastewater.

(3) Substances which are hard to process in the central treatment plant are removed from wastewater in advance at the factory level.

As explained in (1) above, all substances (for example, chrome metal) which are hard to process in the central treatment plant must be removed in advance by the factory concerned.

(4) Amounts and qualities of waste water do not fluctuate greatly.

As mentioned before, the proposed system is designed to cope with a wide range of amounts and qualities of wastewater. Nonetheless, since the amount to be processed is enormous, the stabilization tank allows at most a four hour stay of wastewater. Thus, if a huge amount of wastewater flows into the tank at once, it becomes impossible for the tank to accept all of it.

So long as the conditions listed above are met, the proposed system offers the best solution to the central treatment of wastewater in the dyeing industrial complex.

2.1.2. Economic Evaluation and Problems Concerning the System

As stated in 4.2. Financial Analysis in "III, Dyeing Industrial Estate" of this report, the proposed optimum system is evaluated as being fairly economic, although the rate for treatment will be higher than the current one (about 1.4 times in CASE-1). The reasons for this evaluation are as follows:

(1) The proposed optimum system is improved system compared with the current system. So,the higher rate for treatment is natural.

(2) The present plant was completed 5 years ago, and it has already been depreciated to some extent.

On other hand, this study is made on the assumption that the treatment plant is newly constructed.

(3) In this study, in CASE-1 ,the treatment rate will be drop to about 358Won/m^3 after 9 years. This value is about 80% of the current rate.

The reason for the proposed optimum system obtaining a fairy economic evaluation are as follows.

(1) The treatment capacity is very large.

The proposed system has a treatment capacity of 100,000 m^3 a day, which ranks among the top class as a treatment system for industrial wastewater. Scale merit relative to the construction costs is considerable. That is one of the reasons why the proposed system makes good economic sense.

(2) Running costs ares reasonably low (i.e. consumption of electric power and chemicals is low).

(3) The operation is fully automated.

Because of the fully automated operation, the number of operators necessary for running the system can be greatly reduced. The proposed system can be run by three operators, whereas the existing system requires around six.

However, the economic advantages listed above can be realized only if the following conditions are met.

(1) Equipment and machinery should be properly managed and maintained.

(2) The rate for treatment should be set appropriately.

(3) Wastewater should be appropriately accepted.

(4) Measures should be taken to prevent troubles in treatment.

The technical evaluation is closely related to the economic one. In general, a technically excellent system will also have an excellent economic evaluation. The proposed system is the very example of this.

2.2. Suggestions Regarding the Introduction of the Optimum Systems

Since considerations in introducing the optimum system are already explained (see II and 2.1 of this chapter), here we will limit the explanation to those matters which are unique to the dyeing industrial estate (those which are already explained in the section of the plating industrial estate will only be listed).

(1) Adquate preparatory studies should be conducted sufficiently.

(2) Each factory should be well informed about wastewater treatment.

(3) Appropriate rates should be charged for wastewater treatment.

At present, the rates are set in accordance with quantity (450 Won/m^3), an extra rate being charged only when the pH exceeds 11. And yet, besides pH, the COD value and color have significant effects on the actual cost of treatment. These two factors should also be reflected in the rates.

The degrees of color are hard to measure, but are roughly proportional to COD values. Therefore, the COD value may be regarded as a practical criterion of water quality for determining the treatment rate. The pH value and COD value can be measured and recorded continuously by installing appropriate measuring devices at each factory. These values, if they are sent to the central treatment plant through a remote device, are useful not only for determining the rates, but also for monitoring the incoming waste water.

(4) The inflow of wastewater should be monitored constantly.

With the existing system, the qualities of wastewater discharged to the central treatment plant are measured reasonably well. Monitoring of the qualities of incoming wastewater is an indispensable factor for the efficiency of the central treatment plant. As mentioned in (3) above, the installation of a continuos measuring device at each factory will serve this purpose.

(5) The importance of the technicians and operators of the wastewater treatment system should be fully understood and proper training should be provided.

(6) Management/maintenance should be meticulously carried out.

(7) Cooperative relations should be established between the waste treatment plant and the factories.

(8) The treatment plant should participate in some way in the manufacturing process of each factory.

2.3. Other Problems and Suggestions

The following are problems and suggestions concerning matters other than wastewater treatment.

(1) Managing structure of the industrial estate

In the dyeing industrial estate, at present, wastewater treatment is conducted by the cooperative, but industrial water and steam are supplied by the city of Ansan and the Industrial Estate Corporation respectively. In constructing a new industrial estate, if there are no organizations to supply utilities such as industrial water and steam, the cooperative of factories may take charge. The cooperative may take charge of the disposal of industrial wastes, too.

(2) Improvement of positioning of Central Wastewater Treatment Plant

As is stated in section 2.1 of III above, the present central wastewater treatment plant is positioned as a pre-treatment plant for the sewage treatment plant. However the actual water quality is better than that of water discharged from the sewage treatment plant. When it is considered that these two plants comprise one system, it is hardly an efficient system. To rectify this situation, the following approaches shall be considered.

A. As shown in section 3.2.2 of III above, by using advanced treatment of COD, make the wastewater treatment plant capable of discharging treated water into public water.

B. Try to balance the loads of both plants by relaxing water quality standards of the water discharged from the central wastewater treatment plant. The hazard for elimination standard of sewage in Japan is a useful standard for water quality. (Refer to Table 3.6 of I. Introduction)

These approaches have the following advantages and disadvantages.

A. Advantage: It enables to plan a wastewater treatment plant regardless of the existing sewage treatment plant. There is no sewage charge

Disadvantage: Treatment cost is expensive (refer to CASE-2 of Optimum System). Capacity of the existing sewage treatment plant is wasted.

B. Advantage: Central wastewater treatment plant operation becomes easier and cost of the existing sewage treatment plant capacity can be used effectively.
Disadvantage: Present effluent standard can not be satisfied. A modification of the legal regulations is required.

Although as explained in B. this approach can not be implemented under current laws, it is worth considering as a future assignment as it has technical and economic advantages.

(3) Promotion for the reclamation of wastewater

CASE-3 of the optimum system suggests the reclamation of wastewater. In that case, the cost for regenerated water amounts to 860 Won/m^3 (see 4.2 of III), which is significantly higher than city water or industrial water. However, the effects of water reclamation cannot be measured with an economic rule alone. It may bring about the following benefits.

A. Reclamation of wastewater makes it possible to create an industrial estate where the water supply is inadequate.

B. Reclamation reduces the discharge of wastewater, with a consequent reduction in the amount of pollutant discharge (reduction rate is 20% in CASE-3 of III).

C. Where ground water is used, the reclamation of wastewater prevents land subsidence caused by excessive pumping .

Since the reclamation of wastewater brings about such benefits, its introduction should be taken into account when an industrial estate is newly created.

3. Summary of Evaluations

The following is a summary of the evaluations mentioned above.

(1) Technical evaluation

For both the plating and dyeing industrial estates, the optimum system offers a perfect solution to the problems of the existing systems. As stated many times, however, in order to make full use of the advantages of the optimum system, certain assumptions that are made for the planning of the systems must be met.

(2) Economic evaluation

A. In the case of the plating industrial estate, the optimum system make good economic sense, partly because the rates can be reasonably high. Here too, however, the assumptions must be met.

B. In the case of the dyeing industrial estate, the optimum system requires higher rates for treatment than those currently charged. Nonetheless, taking into account of the improvement of treatment and the inflation-adjusted construction costs, the optimum system still makes economic sense.

(3) Proposals

The proposals consist of (1) selection of the optimum system, (2) management of the industrial estate, and (3) enlargement of the activities of the industrial estate. Some of these proposals can be applied to the existing industrial estates immediately, but most are to be realized in the future. In case an industrial estate is newly created, the proposals may be applied more thoroughly.

V. Guidelines for Wastewater Treatment and Reclamation

V. Guidelines for Wastewater Treatment and Reclamation

I. Outline

The purpose of preparing these guidelines and their structure are as follows:

(1) Outline

As has already been shown in II. and III., models were set for plating and dyeing industrial estates in this Study, and optimum systems were selected for each of them. However, products and manufacturing processes involved in both industries are so diverse that the descriptions in II. and III. alone are not sufficient for the purpose of planning new wastewater treatment and reclamation plants.

As a result, it was decided to prepare more general guidelines for use in the planning of new wastewater treatment and reclamation plants for plating and dyeing industrial estates.

Special consideration is made here to suit the current situations of the two industries in Korea, while fully utilizing the investigation results in II. and III.

(2) Structure

Guidelines are divided into two major parts, covering plating and dyeing industries, respectively, with matters relating to production processes, wastewater treatment and reclamation described, and new treatment techniques.

One of the special features of these guidelines is emphasis on production processes and wastewater reclamation, subjects rarely explained in detail in traditional similar guidelines.

While these guidelines are closely related to the selection of optimum systems, they are also readily available as separate reference material.

2. Guidelines for the Plating Industry

2.1 Outline

Plating coats the surface of any object to be plated with metal films for the purpose of decoration, corrosion resistance, heat resistance or wear resistance. It is used for the products and parts widely ranging from automobiles, electric cars, TV sets, radio sets, cameras and electronic apparatus to personal decorations and accessories.

Roughly speaking, the plating industry is classified as electroplating industry, melt plating industry, plated steel pipe manufacturing industry and other metal manufacturing industries. Of them, the electroplating industry is required to take special care for water and wastewater treatment. In some cases, electroplating is done as a part of any other process in a factory in which metal products are manufactured, and in the others, it is done by an exclusive enterprise which is engaged mainly in processing only. The exclusive enterprises works on a processing fee basis and does not manufacture independent products. Therefore, exclusive enterprises are located for the convenience of entrusting metal products manufacturing or automobile manufacturing factories for which they do processing. These exclusive enterprises are very small in scale, but their number is very large as compared with the number of large-scale factories for which they do processing. (Reference 1)

For exclusive enterprises, the construction cost and running cost for having their own wastewater treatment facilities are an economically heavy burden. Further, shortage of engineers in charge of operation and maintenance of these facilities, and of shortage or difficult acquirement of construction sites, etc. impose economically and technically serious problems on them. In addition, wastewaters and exhaust gases discharged from plating factories contain much substances which are harmful to the human health. If the treatment of them has a problem, there may be serious influences on the surroundings of the factory. Therefore, scrupulous care is needed to prevent pollution. (Reference

2)

From the viewpoint as mentioned above, it will be economically and technically advantageous to collect wastewaters and exhaust gases from the workshops in the plating industrial estate and treat them in a central treatment plant, as compared with separate treatment by each exclusive enterprise. Moreover, if exclusive enterprises are gathered in the plating industrial estate, the risk of pollution generation may be reduced from a plane to a point. This is the reason why the spread of the plating industrial estate has been strongly desired.

However, the workshops in the plating industrial estate carry out different kinds of plating from each other, and therefore, wastewaters discharged from them are also various. Therefore, it has also been pointed out that new problems unique to the wastewater treatment of the plating industrial estate should be liable to occur.

With the foregoing in mind, this chapter for guidelines describes the basis of plating wastewater treatment, such as main production processes and wastewaters generated and their quantity, the measures to be taken in production processes for reducing pollutant loading, etc., fundamental wastewater treatment technologies, reclamation technologies, and sludge treatment technologies, and an introduction of new technologies using membrane separation, together with other points to be cared about.

In Japan, many pollution problems with plating wastewaters occurred in the past, but it is very rare at present that any wastewater unable to meet the control limits should be finally discharged. This is mainly due to technological developments made by research and development activities on pollution control technologies at government and local government testing institutes and laboratories, and also by environmental equipment enterprises' activities. On the other hand, devoted guidance and training activities of technical staff of local government research organizations and non-profit foundations directed for plating enterprises for a long time have also been effective. Since the wastewater treatment for plating factories is deeply related with the plating technology, the employees of plating enterprises have consulted with the staff about the wastewater treatment problems and plating technologies to solve these problems and to improve the technologies. It is desired that such testing and research organs should also be installed din Korea.

2.2 Main Production Processes and Wastewater Quality

2.2.1 Basic Processes of Plating

Plating processes are different with the kind of plain metal, condition of plain metal, kind of plating, kind of plating liquor, method of plating, purpose of plating, etc. Moreover, in the plating factory, the results of each work in the series of works are observed, and as required by them, some processes are changed or added.

The most basic processes are as follows.

Polishing -- cleaning -- water washing -- pickling -- water washing -- plating -- water washing -- drying -- finishing

In practice, some processes for similar works using similar chemicals exist, and in many cases, because of the different purpose of a process, the process is called by a different name. However, from the viewpoint of wastewater treatment, the wastewater quality and conditions of discharge are the considerations which should be taken into account. Therefore, plating processes will be described only briefly.

(1) Polishing

Processes before plating are called "pre-treatment". Polishing can be done by hand or using a machine. It is carried out to remove rust of the plain metal surface enough to ensure a smooth and bright plated surface. In general, buff polishing by hand or using a machine is done. This method of polishing uses an abrasive, and the used washing water is discharged as wastewater.

Barrel polishing is done mainly by wet type rotary polishing or vibration barrel polishing, and concentrate polishing liquid waste and washing water waste are discharged.

(2) Cleaning

Cleaning is carried out to remove externally attached contaminants such as oil, dust or dirt, abrasive caught on the plain metal surface, etc. In the case of an exclusive enterprise which works on a processing fee basis, it happens frequently that the part to be plated as furnished from the entrusting enterprise is contaminated with oil in the press process or is applied with oil on the surface for rust prevention. In such a case, cleaning process is the first process. Roughly speaking, cleaning is classified as solvent cleaning, alkali cleaning, and electrolysis in an alkali solution. In recent years, acid cleaning has been used frequently along with the spread of automatic plating equipment, because rust removal and smut removal can be done simultaneously and the contaminants which can hardly be removed by alkali cleaning can be removed (smut: non-metal impurity contained in a metal, or insoluble component of a dissimilar metal).

From solvent cleaning, solvent waste is generated. From alkali cleaning or acid cleaning, cleaning liquid waste after renewal and washing water waste are discharged as wastewater.

(3) Pickling

Pickling is carried out to remove the oxide film on the plain metal surface and activate the surface. For the activation, sulfuric acid or hydrochloric acid is generally used singly. Chemical polishing uses a number of chemicals for the kinds of plain metals, but in practice, the number is not so large. Electropolishing is a special method except for stainless steel and has been used rarely in recent years.

From this process, cleaning liquid waste after renewal and washing water waste are discharged.

(4) Plating

Plating is done mainly by electroplating of copper, nickel, chrome, zinc or tin. Electroplating uses electrolysis of a metal salt solution to form metal films on the cathode. Raking method and barrel method are available. In the former, the object to be plated is mounted to the cathode in the electrolytic cell, and in the latter, many and small objects are rotated in a barrel. Chemical plating (non-electroplating) uses a reducing agent on the catalytic active surface to allow complex ions to be reduced and precipitated as metal. It is indispensable for the manufacture of automobiles, OA apparatus, optical machines, and PCB substrates.

From this process, plating liquor waste after renewal and washing water waste are discharged.

(5) Drying

Plated products are washed in chilled water and warm water. Drying in the subsequent stage is done in a hot air. In the case of small parts, a centrifuge or the like is used.

From this process, chilled water waste and warm water waste are discharged.

Fig. 2.2.1 shows typical processes for nickel-chrome plating, Fig. 2.2.2 for zinc plating, Fig. 2.2.3 for PCB substrates manufacturing, and Fig. 2.2.4 for plating on plastic parts.

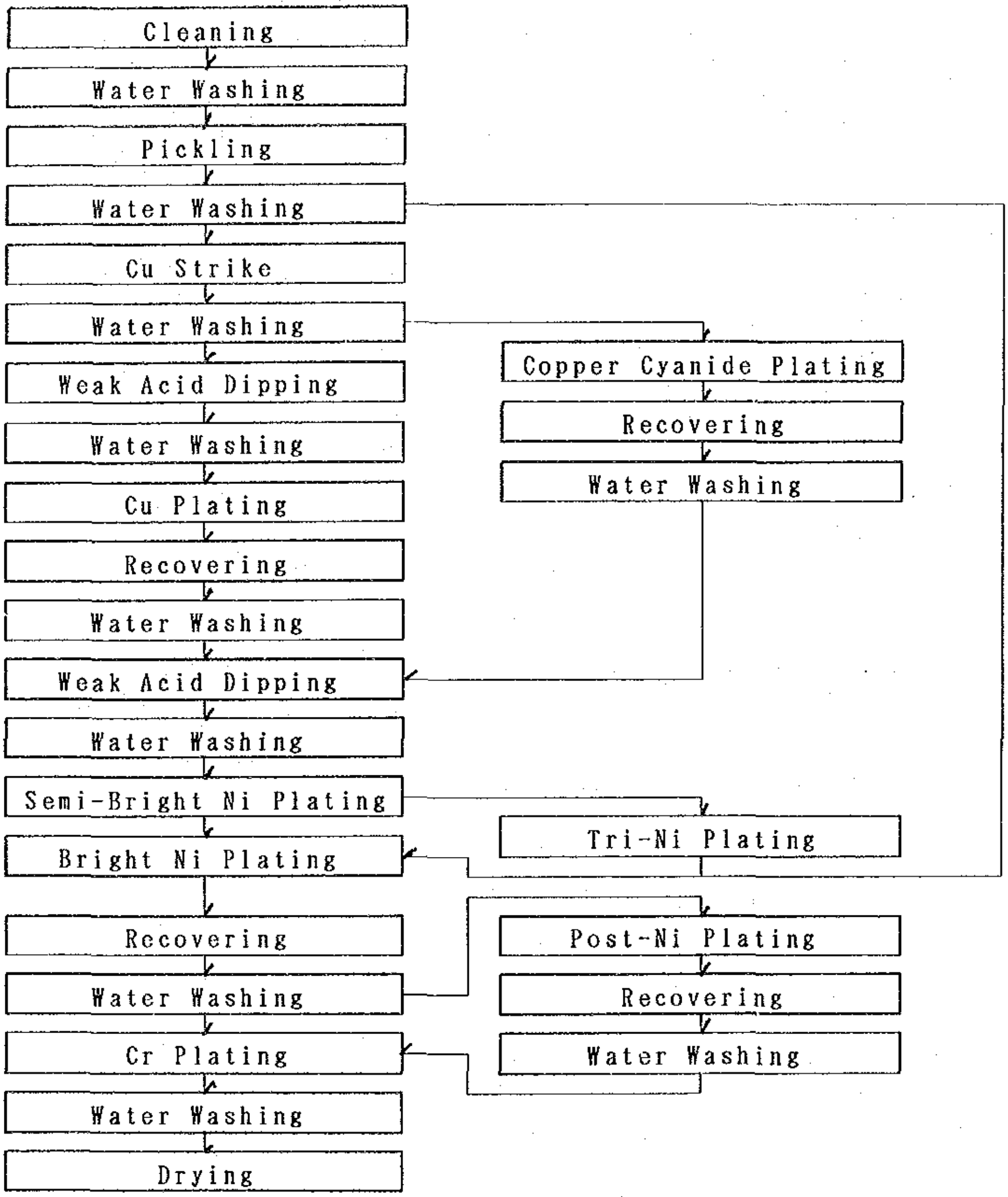


Fig. 2.2.1. Typical Process for Nickel-Chrome Plating(Reference1)

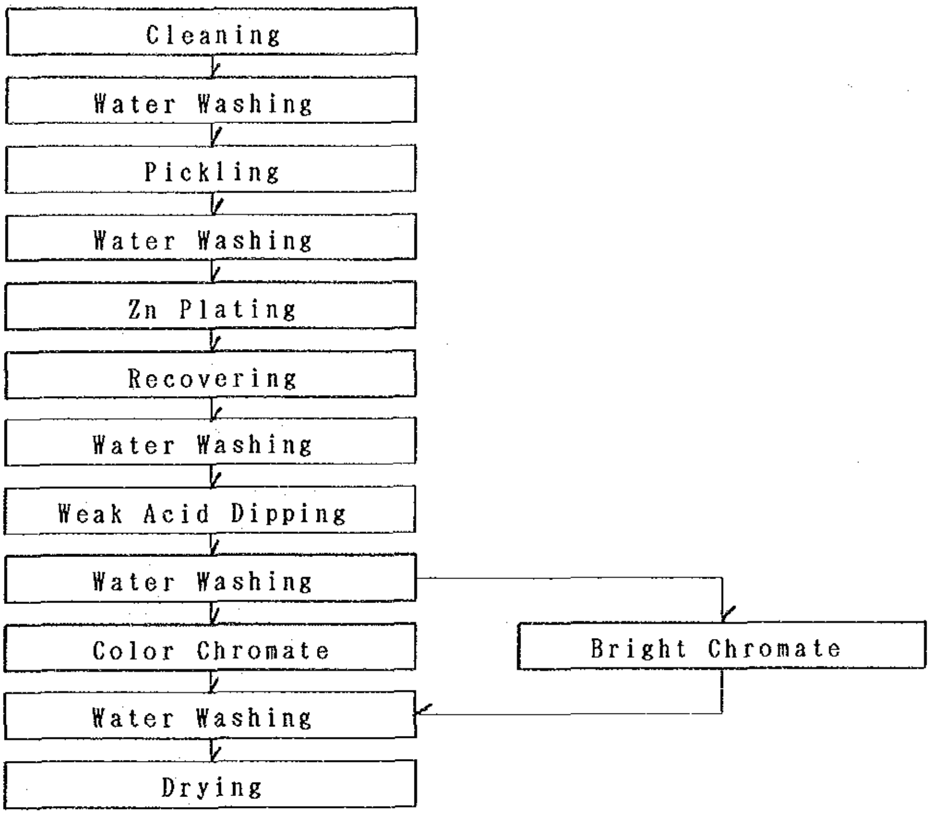


Fig. 2.2.2. Typical Process for Zinc Plating(Reference 1)

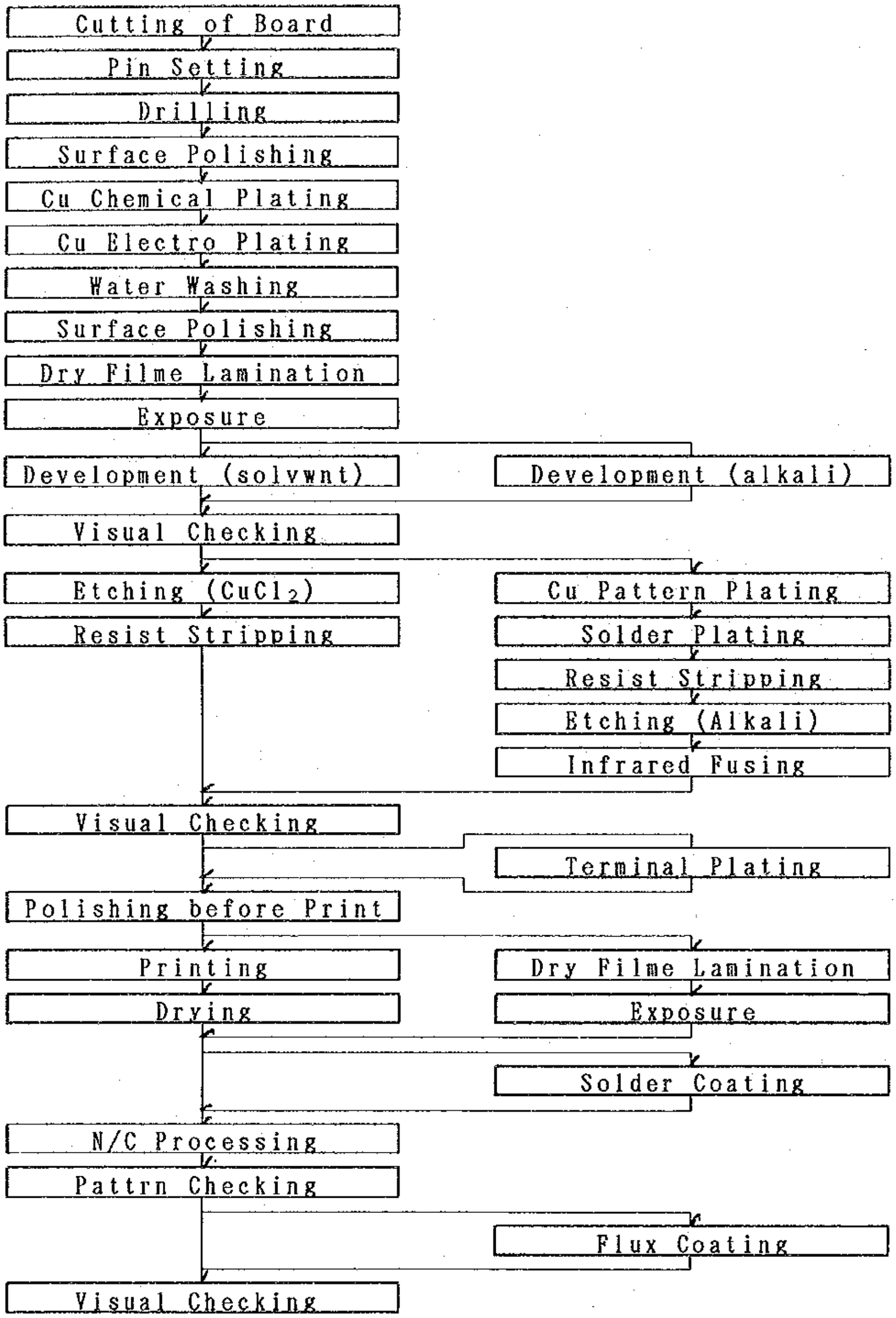


Fig. 2.2.3. Typical Process for P C B Manufacturing(Reference 1)

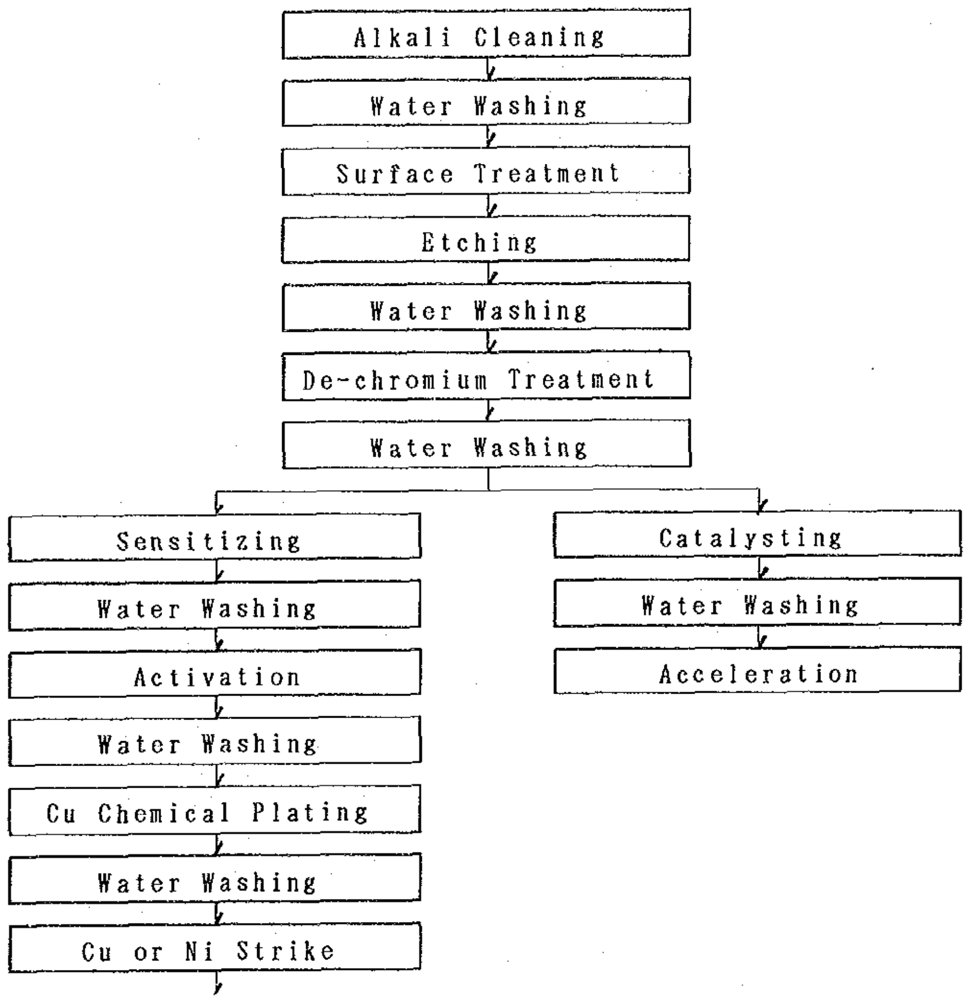


Fig. 2.2.4. Typical Process for Plating on Plastic Parts(Reference 1)

2.2.2 Properties of Plating Wastewaters (Reference 3)

Plating wastewaters are classified roughly into concentrate wastewater discharged after renewal from each process and dilute washing wastewater.

The concentrate wastewater is discharged after renewal of the bath liquor and therefore is called "renewal wastewater". The washing wastewater is discharged continuously during the plating work, and therefore, is called, "continuous wastewater". The continuous wastewater is a dilution of the bath liquor in the preceding process. It is almost the same in composition as the bath liquor, but its concentration differs with the type of water washing. Wastewater treatment is done mainly on the continuous wastewater.

Normally, the bath liquor contains, in addition to the main components of the chemicals used, trace components called "impurity". Moreover, many of these chemicals are changed while being used due to oxidation by electrolysis, oxidation with air, self-oxidation of reducing agents, etc. Further, the treatment tank of each process receives deliveries from the previous process due to insufficient water washing, substances attached to the object to be plated, substances eluted from the object to be plated, reverse flows from the exhaust duct, splashes, substances eluted from the tank, piping, auxiliary apparatus, etc. When examining the wastewater treatment, it is important to grasp the changes of wastewater composition with these substances.

The liquor to be used in the plating processes is prepared by the plating factory for itself in a few cases, but is prepared by purchasing from manufacturers of plating chemicals in most cases.

The manufacturers do clarify the composition of only main components of chemicals, and therefore, it is necessary upon purchase to obtain sufficient information of the components related to the wastewater treatment, treatability, etc.

(1) Polishing wastewater

Chemicals used for barrel polishing include media, soap, activating agent, complex agent, etc. and therefore, it is significant to take care in the wastewater treatment. It is advisable to avoid mixing with general plating wastewater.

Table 2.2.1. shows composition of the chemicals used for wet type barrel polishing.

Table 2.2.1. The Composition of Chemicals for Wet Type Barrel Polishing(Reference 3)

Kinds of raw materials	Main harmful compound		Cautious items
Fe	Polishing for under plating	I	alumina, arandom, Na_3PO_4, Na_3CO_3, activator
		II	Na_3PO_4, Na_3CO_3, sodium, gluconate, soap, complex compound
	Polishing for upper plating	I	Na_3PO_4, Na_3CO_3, activator
		II	Na_3CO_3, Na_2SO_4, soap
Zn, Al, solder	Polishing for upper plqting		Na_3PO_4, soap, (complex compound)

(2) Cleaning wastewater

Alkali cleaning agents which are available on the market contain, in general, several surface activating agents and chelating agents added to alkali salts. Low temperature cleaning agents have high concentrations of mixed substances as compared with high temperature cleaning agents and therefore, require special care in the treatment.

Moreover, there are deliveries of chrome from jigs and elutes of chrome in the case of electro cleaning by anodic or periodic reverse current (PR) method.

Table 2.2.2. shows harmful components and some points to be cared about of alkali cleaning agents. Table 2.2.3 shows harmful components and some points to be cared about of acid cleaning agents.

(3) Pickling wastewater

Acids for activation produce few problems in the wastewater

Table 2.2.2. Harmful Components of Alkali Cleaning Agents(Reference 3)

Type of Cleaning	Bath Making Time		Renew Time		
	Concentration (g/l)	C O D (mg/l)	Concentration (g/l)	C O D (mg/l)	Using Trem (Month)
Dipcleaning	30	1,453	—	3,454	10
Dipcleaning	50	269	52	5,550	0.5
Dipcleaning	100	2,140	150	10,000	12
(-)Electrocleaning	50	461	—	908	4
(-)Electrocleaning	50	4,005	47	3,600	3
(PR)Electrocleaning	50 (ml/l) + NaOH 50 g/l	13,000	71 (ml/l)	11,142	36

Table 2.2.3. Harmful Components and Cautious Items on Acidic Cleaning Agent(Reference 3)

Main harmful compound	Cautious items
H_2SO_4 (pH) Surface active agent (COD)	○ The agent aimed at cleaning more mainly than rust preventatives has activator and high COD. ○ Because of disolubed raw material, the liquor becomes high concentration and debates the activity of acid. ○ Activator prevents sedimentation of metal sludge.

treatment. Special acids or mixed acids are used with easily shaved steels, special alloys or when it is desired to prolong the activating condition as far as possible.

In the chemical polishing liquor, the plain metal is dissolved at a considerably high concentration, and therefore, adequate care is needed in the treatment not only of renewal wastewater but also of washing wastewater. Some chemical polishing liquors contain an oxidizing agent which easily generates oxygen gas, etc. and may cause metal hydroxides in the sedimentation tank of the wastewater treatment plant to float up.

Especially, it is to be noted that any liquor containing hydrogen peroxide generates oxygen gas in a bursting manner.

Table 2.2.4. shows harmful components and some points to be cared about of activating acids. Table 2.2.5 shows harmful components and some points to be cared about of chemical polishing liquors.

Table 2.2.4. Harmful Components and Cautious Items on Active Acid(Reference 3)

Main harmful compound	Cautious items
H_2SO_4, HCl (pH) HF, H_2SiF_6 (F) Surface active agent (COD)	○ Take care that it is difficult to move F ions, it is good to treat the high concentration wastewater by batch system. ○ The method using activating agent is used sometimes.

Table 2.2.5. Harmful Components and Cautious Items on Chemical Polishing Liquor(Reference 3)

kinds of raw materials	Main harmful compound	Cautious items
Steel	$C_2O_4H_2$, H_2O_2, (COD, O_2) acid, NH_4F, H_2O_2 (F, N, O_2)	○ O_2 gas often float the sludge because of H_2O_2, decomposition. ○ F can be removed by $Ca(OH)_2$ as CaF_2.
Cu, Cu alloy	H_2SO_4, H_2O_2 (COD, O_2) HNO_3, H_2SO_4 (pH, N) H_2CrO_4, H_2SO_4 (Cr, pH)	○ Same caution above is paid for H_2O_2. ○ It is not used for chrom plating. ○ Take care not to become high Cu concentration.
Aluminium	H_3PO_4, HNO_3 (P, N, pH)	○ Take care that concentration of P is high.

(4) Plating wastewaters

A. Copper plating liquor

a. Copper cyanide plating liquor

This plating liquor has unique features which cannot be found in other plating liquors, and is used widely. Since it contains a cyanide, scrupulous care is needed in the wastewater treatment. Especially, it is to be noted that if it contacts an apparatus made of iron material, it dissolves iron little by little, or if iron ion is brought due to insufficient water washing in the pretreatment process, it forms iron-cyanide complex ion which is difficult to dissolve.

Table 2.2.6. shows harmful components and some points to be cared about of copper cyanide plating liquors.

Table 2.2.6. Harmful Components and Cautious Items on Copper Cyanide Plating Liquor (Reference 3)

Main harmful compound	Cautious items
Cu (Cu) CN (CN) Surface active agent (COD)	○ Take care not to carry in the bath and to separate the chanel, because it is difficult to decomposit cyanide complex such as Fe. Ni. ○ COD is not so high (300 ～ 500 mg/l in normal liquor).

b. Copper sulfate plating liquor

This type of plating is highly expected as pollution-free plating. However, when it is directly applied, the adhesion is poor. Therefore, it requires pretreatment such as copper cyanide striking, nickel striking or the like. Moreover, bright nickel plating, directly applied on the copper sulfate plating, sometimes shows poor adhesion. An effective measure to avoid this is activation with ammonia persulfate. It is to be noted, however, that it is difficult to remove heavy metals in the wastewater,

c. Pyrophosphate plating liquor

This type of plating is used frequently as non-cyanide copper plating or bright copper plating for decoration purpose. Because of the capability of leveling PCB substrates and of good physical properties, it has become popular. However, the liquor contains much phosphorus and pyrophosphate is oxidized to ortho-phosphate. Therefore, in recent years, the wastewater treatment h as become a problem.

Table 2.2.7. shows harmful components and some points to be cared about of the pyrophosphate plating liquor.

Table 2.2.7. Harmful Components Cautious Items on Copper Pyrophosphate Plating(Reference 3)

Main harmful compound	Cautious items
Cu (Cu) $H_4P_2O_7$, orthophsphoric acid (P) ammonium (N)	○ It is difficult to precipitate Cu_{2+} directly. After removing of $P_2O_7-^{3+}$ and PO_4^{2-} by adding Ca^{2+}, and ajust pH. ○ The reaction of $P_2O_7-^{3+} \rightarrow PO_4^{2-}$ can be promoted by partialy heating, anode current density, additive, unproper ammonium.

B. Nickel plating liquor

a. Watt type nickel plating liquor

The nickel plating liquor, most frequently used at present, is the watt type nickel plating liquor added with various agents. The COD concentration is below 2000 mg/lit. in this case, but since the liquor is hardly renewed, the value may become abnormally high. Moreover, if nickel cyanide complexes which are difficult to decompose are produced.

b. The sulfanilic acid nickel plating liquor

The sulfanilic acid nickel plating liquor containes a large quantity of sulfanilic acid but the taken off amount is small because this liquor lasts long and long time plating as electro-casting.

C. Chrome plating liquor

The chrome plating liquor is either 6-valent chrome bath composed mainly of chromic anhydride, or 3-valent chrome bath composed mainly of chrome sulfate (or chrome chloride). Because of the color tone, brittleness and difficult plating to large thicknesses, 3-valent chrome plating liquor is used still very little.

Table 2.2.8. shows harmful components and some points to be cared of the chrome plating liquor.

Table 2.2.8. Harmful Components Cautious Items on Chrome Plating Liquor(Reference 3)

Main harmful compound		Cautious items
Cr	(Cr^{6+}, Cr^{3+})	○ Take care that excess of reduction agent has a bad influence on the reaction $Cr^{6+} \rightarrow Cr^{3+}$.
	(Pb)	○ The concentration of fluoride added in chrome plating liquor has not a influence on wastewater treatment, but take care that one contained in exchaust gass has a bad influence on plating.
	(P)	○ Take care washing of anode, because the anode-side becomes lead chromate (Cr & Cr^{6+}).
ammonium	(N)	○ It is often necessary to remew the liquor that can easily dissolve Pb, Zn etc. and has a bad influence as impurities.

D. Zinc plating liquor

a. Zinc cyanide plating liquor

This plating liquor has many advantages as compared with other plating liquors, and therefore, is used in many fields. However, it contains cyanide at high concentration and requires scrupulous care in the wastewater treatment. From the viewpoint of less pollution, cyanide liquors at medium and low concentrations have become popular.

Table 2.2.9. shows harmful components and some points to be cared about of the zinc cyanide plating liquor.

Table 2.2.9. Harmful Components and Cautious Items on Zinc Cyanide Plating Liquor(Reference 3)

Main harmful compound		Cautious items
CN	(CN)	○ Fe disolubed in liquor becomes cyanide complex, when water washing can not be done completely. Do not carry the dipping liquor into the bath parfectly.
Zn	(Zn)	○ There is a tendency for low cyanide bath to have high concentration of COD based on brightening agent, and to have high concentration of nitrogen.
NaOH	(pH)	○ Take care not to depend on power of self-cleaning, because COD becomes high concentration.
additive	(COD)	dissolve Pb, Zn etc. and has a bad influence as impurities.

b. Zincate plating liquor

Zinc is only the substance which is a problem in the waste-water treatment. However, many organic agents are added to suppress the influence of metal impurities, and therefore, the COD concentration is generally rather higher.

c. Acidic zinc plating liquor

Ammonium chloride bath, potassium chloride bath, sulfate bath, etc. are available, but for the plating of utensils, ammonium chloride bath is used frequently. Recently, potassium chloride bath which is free from the problem of nitrogen has attracted attention. Moreover, it is preferable from the viewpoint of less pollution that the concentration of zinc metal has been progressingly low.

Table 2.2.10. shows h armful components and some points to be cared of the acidic zinc plating liquor.

Table 2.2.10. Harmful Components and Cautious Items on Acidic Zinc Plating Liquor(Reference 3)

Main harmful compound	Cautious items
Zn (Zn) NH_4Cl (N) additive (COD) additive (COD)	○ It is difficult for Zn to become hydroxide, if you only thin and make pH adustment the ammonium bath is high concentration of nitrogen 1,000 mg/l. ○ COD of standard liquor is not high concentration, it is no problem. high concentration of nitrogen. ○ Take care not to depend on power of self-cleaning, because COD becomes high concentration. dissolve Pb, Zn etc. and has a bad influence as impurities.

d. Chromate liquor

Chromating following zinc plating serves to give brightness for better appearance and to improve corrosion resistance remarkably. Rarely, chromating is used to prevent discoloration of aluminum, copper, copper alloy, etc. and to improve corrosion resistance. Along with the increase in the quantity of work, zinc and 3 -valent chrome are increased, and a method of control to increase the concentrations of various acids is carried out.

Table 2.2.11. shows the composition of the chromate liquor.

Table 2.2.11. The Composition of the Chromate Liquor(Reference 3)

Components \ Kinds		A	B	C	D	E	F
CrO_3	(g/l)	3	1	10	5	10	1
H_2SO_4	(mg/l)	0.25	0.2	5	2	5	
HNO_3	(mg/l)	2	0.2	2 ～ 20	2	30 ～ 40	17.5
NH_4F	(g/l)				2	1 ～ 2	
HF	(mg/l)						2
HBF_4	(g/l)			20			
$(COOH)_2$	(g/l)				20		
NaH_2PO_2	(g/l)						0.2

E. Tin plating liquor

Alkaline bath, sulfate bath, fluoroborate bath and neutral bath are available. Any bath other than alkaline bath is added with considerable amounts of organic agents, and therefore, the COD concentration is high. Some baths contain complexing agent, foaming organic substance, etc. which interfere with wastewater treatment. Therefore, adequate investigation and appropriate addressing are required. For post-treatment to tin plating, soda phosphates are used.

F. Alumite treating liquor

Alumite treatment means an anodic oxidation film treatment to be applied on aluminum. By electrolysis in a liquid such as oxalic acid, sulfuric acid or chromic acid with an aluminum plate as the anode, oxygen is generated and produces an oxidation film, which has, although porous, high electric insulation, corrosion resistance and wear resistance, on the aluminum surface. After corrosion protection by pressurized treatment using super-heated vapor, this plate is used for tableware and other goods. Further, it is colored with organic dyes or inorganic pigments.

G. Chemical plating liquor

Any chemical plating liquor is added with organic substances as complexing agent or stabilizing agent for metal ions. In the wastewater treatment, not only the COD concentration is high, but also metal separation is difficult in many cases. Moreover, excess complexing agent chelates metal ions in other wastewaters, making their settling impossible in many cases. Therefore, classified wastewater treatment in necessary, not to speak of, and it is also necessary to take adequate care at any place where the treated water is mixed with any other wastewater.

a. Chemical copper plating liquor

This liquor is used frequently for decorative plating of plastics, and through hole plating of PCB substrates. Complexing agent is indispensable. Reducing agent frequently used is formalin. The copper concentration to be used is as low as 2-3 mg/lit., but copper treatment cannot be done by dilution and pH adjustment. The COD value in the concentrate exceeds 10,000 mg/lit.. For the treatment of renewal wastewaters, batchwise method such as thermal decomposition is suited.

b. Chemical nickel plating liquor

This liquor contains much organic substances and reducing agents. Therefore, the COD value is highest among plating liquors. A method using soda hypophosphite as reducing agent, called Ni-P alloy plating, is used in most cases. The COD value just after preparation of the bath is as high as 10,000 - 30,000 mg/lit.. In the plating liquor for plastics plating, soda hypophosphate is changed to orthophosphate and the COD concentration in the renewal wastewater reaches 50,000 - 60,000 mg/lit. as phosphorus.

H. Plating stripping agent

In case of failure in plating, or for repairing a plated article, it becomes necessary to strip the existing plating. Plating stripping by electrolytic or chemical method is available. According to the combination between the metal to be stripped and the base metal, the composition of the stripping chemical varies, and there are a variety of kinds.

In any of bath electrolytic and chemical methods, basic components are four such as oxidizing agent, oxidation promoting agent, base metal dissolution preventing agent, and eluted metal masking or settling preventing agent.

In many cases, there are much components of which wastewater treatment is difficult, the metal concentrations are high, and chelating exists, requiring scrupulous care in the wastewater treatment.

Table 2.2.12 shows an example of the composition of plating stripping agents.

Table 2.2.12. The Composition of Plating Stripping Agents(Reference 3)

Stripping Agent	Raw material	Component	
Ni, Co, Cu, Cd	Fe, SUS	nitro fragrant NaCN (NaOH	60 g/l 120~180 g/l 0~ 25 g/l)
Ni, Co, Cu	Fe, SUS, Brass	nitro fragrant compound ethylenediamine sulfer compound	40 g/l 70 g/l proper quantity
Ni, Cu, others	SUS, Al	Conc. HNO_3	500~1,000 ml/l
Ni	Fe, SUS, Cu, Brass, Al, Zn	H_2SO_4 water	50~60 vole %. 40~50 vole %
Ni, Co, Ca	Cu, Brass	H_2SO_4 nitro fragrant compound sulfer compound	50~100 g/l 100 g/l 4 g/l
Ni	Zn	H_2SO_4 H_3PO_4 H_2CrO_4	40 w%(electrolysis) 20 w% 5 w%(leaving water)
Cu	Fe, SUS	NaOH sulfer compound	100 g/l 150 g/l
Cu, Ag, Au	Fe, SUS, Ni	NaCN NaOH	90~150 g/l 15 g/l
Cu, Brass	Fe, SUS	$(NH_4)_2SO_4$	100 g/l
Cu, brass, Zn, Sn	Fe, SUS	$Cu_2P_2O_7$ $K_4P_2O_7$	360 w%(electrolysis) 90 g/l
Cr, Zn	Fe, Ni, Cu	HCl	5~20 wx %
Cr, Pb, Sn	Fe, Ni, SUS	NaOH	100~150 g/l(electrolysis)
Pb, Sn, Pb-Sn	Fe, Cu, Brass	HBF_4 H_2O_2	120 ml/l 60 ml/l
Ni, Cu, Cr, Brass, Cd, Sn	SUS, Fe	nitric compound soluble amine carboxylic acid alkali halogenide	50~100 g/l(electrolysis) 30~100 g/l 30~100 g/l 5~ 20 g/l