FEASIBILITY STUDY REPORT
ON
TREATMENT AND RECOVERY
OF INDUSTRIAL WASTE WATER
IN
THE PEOPLE'S REPUBLIC OF CHINA

(SUMMARY)

MARCH 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

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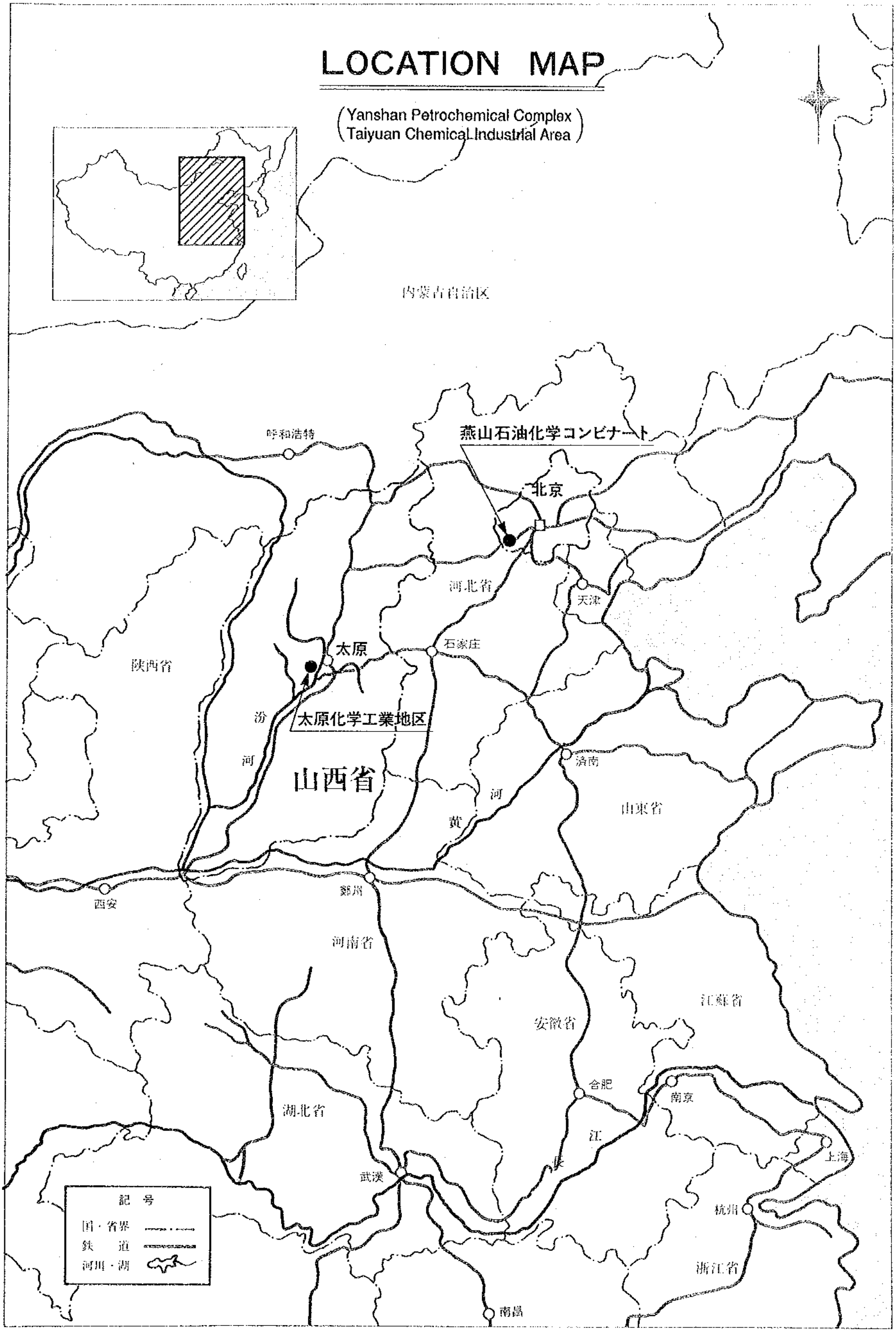
LOCATION MAP
(Yanshan Petrochemical Complex)
(Taiyuan Chemical Industrial Area)
内蒙古自治区
呼和浩特
燕山石油化学コンビナート
北京
河北省
天津
太原
石家庄
陝西省
太原化学工業地区
汾
河
山西省
済南
河
黄
山東省
西安
鄭州
河南省
江蘇省
安徽省
合肥
南京
湖北省
江
長
上海
武漢
杭州
浙江省
南昌
記号
国・省界
鉄道
河川・湖

ABSTRACT

ABSTRACT

1. Outline of Waste Water Treatment and Recovery Project

1.1 Yanshan district

(1) General

1) Outline of case study

① Case 1

- Volume of recovered water by primary treatment : 11,426 m^3/day
- Volume of recovered water by recovery system : 14,974 m^3/day

② Case 2

- Volume of recovered water by primary treatment : 0 m^3/day
- Volume of recovered water by recovery system : 26,400 m^3/day

2) Total required fund

① Case 1 : 416,080,000 yuan

(construction cost : 374,460,000 yuan)

② Case 2 : 465,470,000 yuan

(construction cost : 418,950,000 yuan)

3) Schedule

It takes two years to construct the above.

4) Time of starting a commercial operation

A commercial operation starts in January, 1996.

(2) Outline of waste water treatment and recovery system

1) Preparatory treatment facilities (common to cases 1 and 2)

① Types of applicable waste water : 7 types

② Total volume of treated water : 3,756 m^3/day

③ Treating method : line switching over, oil separation, liquid oxidation

④ Construction cost : 101,290,000 yuan

2) Waste water treatment plant additional treatment facilities (cases 1 and 2)

① Types of applicable waste water : 2 types

② Total volume of treated water : 46,174 – 57,600 m^3/day

③ Treating method : contact oxidation, sedimentation

④ Construction cost : 88,760,000 – 107,910,000 yuan

3) Primary treatment and recovery facilities (case 1)

① Types of applicable waste water : 8 types

② Total volume of recovered water : 11,426 m^3/day

③ Treating method : neutralization, sand filtration, coagulative pressurized floatation, activated carbon, oil adsorption

④ Construction cost : 53,750,000 yuan

4) Recovery facilities (cases 1 and 2)

① Types of applicable waste water : 2 types

② Total volume of recovered water : 14,974 – 26,400 m^3/day

③ Treating method : coagulative sedimentation, sand filtration, fine filtration, reverse osmosis film

④ Construction cost : 127,050,000 – 209,740,000 yuan

1.2 Taiyuan district

(1) General

1) Outline of case study

① Case 1A, 1B

- Volume of recovered water by primary treatment : 41,085 m^3/day
- Volume of recovered water by recovery system : 8,915 m^3/day
- Volume of recovered water for agriculture : 24,118 – 34,118 m^3/day

② Case 2A, 2B

- Volume of recovered water by primary treatment : 0 m^3/day
- Volume of recovered water by recovery system : 50,000 m^3/day
- Volume of recovered water for agriculture : 24,118 – 34,118 m^3/day

2) Total required fund

① Case 1A : 748,290,000 yuan

(construction cost : 669,500,000 yuan)

② Case 1B : 808,490,000 yuan

(construction cost : 723,700,000 yuan)

③ Case 2A : 875,100,000 yuan

(construction cost : 783,550,000 yuan)

④ Case 2B : 943,870,000 yuan

(construction cost : 845,400,000 yuan)

3) Schedule

It takes two years to construct the above.

4) Time of starting a commercial operation

A commercial operation starts in January, 1996.

(2) Outline of waste water treatment and recovery system

1) Preparatory treatment facilities (common to cases 1A, 1B, 2A, and 2B)

① Types of applicable waste water : 21 types

② Total volume of treated water : 15,629 + 47,458* ~ 59,564* m^3/day

(*: neutralization at inlet of Nanyan waste water treatment plant)

③ Treating method : neutralization, coagulative sedimentation, deep aeration, oil separation, coagulative pressurized floatation, liquid oxidation, waste liquid burning, ammonia stripping

④ Construction cost : 273,870,000 yuan

2) Luocheng waste water treatment plant facilities (cases 1A, 1B, 2A, and 2B)

① Types of applicable waste water : 1 type

② Total volume of treated water : 39,450 – 64,500 m^3/day

③ Treating method : neutralization, coagulative sedimentation

④ Construction cost : 33,070,000 – 45,070,000 yuan

3) Primary treatment and recovery facilities (common to cases 1A and 1B)

① Types of applicable waste water : 16 types

② Total volume of recovered water : 41,085 m^3/day

③ Treating method : sand filtration, coagulative sedimentation, oil adsorption, activated carbon

④ Construction cost : 118,690,000 yuan

4) Recovery facilities (cases 1A, 1B, 2A and 2B)

① Types of applicable waste water : 2 types

② Total volume of recovered water : 8,915 – 50,000 m^3/day

③ Treating method : coagulative sedimentation, sand filtration, fine filtration, reverse osmosis film

④ Construction cost : 67,670,000 – 366,200,000 yuan

5) Recovery facilities for agriculture (1) (cases 1A, 1B, 2A and 2B)

① Types of applicable waste water : 2 types

② Total volume of recovered water for agriculture : 12,690 – 34,118 m^3/day

③ Treating method : coagulative sedimentation, sand filtration, fine filtration, reverse osmosis film

④ Construction cost : 78,680,000 – 199,870,000 yuan

6) Recovery facilities for agriculture (2) (common to cases 2A and 2B)

① Types of applicable waste water : 3 types

② Total volume of recovered water for agriculture : 11,428 m^3/day

③ Treating method : sand filtration

④ Construction cost : 4,330,000 yuan

7) Sludge treatment facilities (common to cases 1A, 1B, 2A and 2B)

① Applicable sludge : sludge containing organic matter

② Volume of sludge treated : 100 tons/day

③ Treating method : fluidized incinerator

④ Construction cost : 28,160,000 yuan

2. Financial Evaluation

2.1 Yanshan district

Financial internal rate of return, excluding construction cost of the new production facilities which will be the source of profit from increase in production, is as described below. Figures in ( ) indicate allowable investment amount of the new production facilities in each case.

Case 1 : 56.4% (about 700 million yuan)

Case 2 : 44.2% (about 600 million yuan)

Since the construction cost for the waste water treatment and recovery facilities are about 400 million yuan, the construction cost of those facilities will have to be reduced.

2.2 Taiyuan district

Financial internal rate of return, excluding construction cost of the new production facilities which will be the source of profit from increase in production, is extremely low as described below.

In order to produce a surplus for the construction cost of the new production facilities, this rate of return should be increased to 40%. Figures in ( ) indicate the rate of reduction of construction cost and variable cost for that purpose.

Case 1A : –2.0% (56%)

Case 1B : 1.6% (53%)

Case 2A : –10.5% (63%)

Case 2B : –6.2% (60%)

Therefore, in order to realize the economic efficiency in the Taiyuan district, more than 50% of expenses should be reduced.

2.3 Economic Evaluation

The value of the economic internal rate of return is close to the financial internal rate of return in both districts.

Indirect benefits as follows are obtained from this project.

(1) Increase of employment opportunities

(2) Practical use of resources and improvement of environment

(3) Contribution to development of regional economy

2.4 Overall Evaluation and Conclusion

(1) Reduction of pollutant

Some waste water contains very high concentration of pollutant. That means waste water treatment becomes more expensive and more useful substances are discharged wastefully. It will be necessary to make efforts to reduce pollutant also by taking measures for the origin.

(2) Modification of recovered water quality standard

In order to reduce the construction cost and operation expenses, utilization of recovered water will have to be studied and water quality standard modified.

(3) Reduction of required water volume

When required water volume is decreased by increasing the rate of recovery of boiler, process and cooling water, volume of waste water will decrease and water shortage will be improved in the future. This should be actively studied.

(4) Increase of primary-treated and recovered water

Primary treatment and recovery facilities are cheaper than recovery facilities using reverse osmosis film, both in construction and operation expenses.

Increasing the volume of primary-treated and recovered water and minimizing the recovery system will have to be studied by modification of recovered water quality standard and searching for waste water with relatively good quality.

(5) Utilization of machines and equipment made in China

Excluding specific machines and equipment, it will be necessary to adopt machines and equipment made in China to reduce the construction cost, and total construction cost including cost of field construction will have to be calculated according to the actual situation in China.

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CONTENTS

CONTENTS (cont.)

VOLUME I INTRODUCTION

1. Preface

This report was compiled as a final report for "The Study on the Industrial Waste Water Treatment and Recovery Project in the People's Republic of China", implemented by Japan International Cooperation Agency and scheduled from March 1989 to March 1991. This report is based on, and revising the interim report prepared in July 1990, by incorporating the result of discussion at the third field survey and the result of the study in Japan continued thereafter.

2. Background of the Study

(1) The People's Republic of China is not blessed with abundant water resources. Average water volume per capita is only 1/4 of the world level and the amount of rainfall varies remarkably depending on seasons and regions.

(2) Particularly in the northern district of China, the yearly average rainfall is only 400 - 800mm and it is concentrated from June to August. Therefore, some industrial cities having large population are suffering serious water shortage.

In these districts, not only industrial water but also residential water cannot be supplied sufficiently, which remarkably prevents development of agriculture and industries and growth of cities.

(3) On the other hand, underground water was developed to solve such water shortage and consequently land subsidence and other problems have occurred.

Deterioration of surface water due to industrial waste water or residential waste water and other environmental problems have been also pointed out.

(4) The Chinese government regards recovery of industrial and residential waste water for new water resources as one of effective solutions of water shortage in the northern district of China.

And intends to introduce Japanese waste water treatment techniques, in particular recovery techniques actively.

(5) Under such circumstances, the Chinese Government requested the Japanese Government technical cooperation for feasibility study on treatment and recovery of industrial waste water in both industrial districts of Bejing Yanshan and Shanxi Taiyuan.

To answer the request, Scoope of Work was agreed between the Japan International Cooperation Agency and State Science and Technology Commission of the People's Republic of China and the Study has been done to fulfil the Scope of Work.

3. Purpose of the Study

The study team has investigated technical and economic feasibility for introduction of industrial waste water treatment and recovery system into the northern industrial district of China under cooperation with Chinese counterpart.

Actually the team has made following investigations to solve the industrial water shortage in the two largest chemical industrial districts as described in Chapter 4.

(1) Investigation of current situation in those districts

(2) Comparison and evaluation of waste water treatment and recovery systems

(3) Proposal and financial/economic analysis for optimum systems

Study methods and other techniques have been transferred to the Chinese counterpart through the Study.

4. Objective Areas of the Study

Study will be made in 2 districts as follows.

Location map of each district is shown in Fig. 1 and Fig. 2.

- Beijing Yanshan Petrochemical Complex
- Shanxi Taiyuan Chemical Industrial Area

Major factories investigated in these areas are as follows.

(1) Beijing Yanshan Petrochemical Complex

1) Oil refinery factory

2) Chemical factory No. 1

3) Chemical factory No. 2

4) Chemical factory No. 3

5) Polyester factory

6) Oil refinery factory waste water treatment plant

7) Chemical factory waste water treatment plant

Fig.- 1 Map of Yanshan Petrochemical Complex

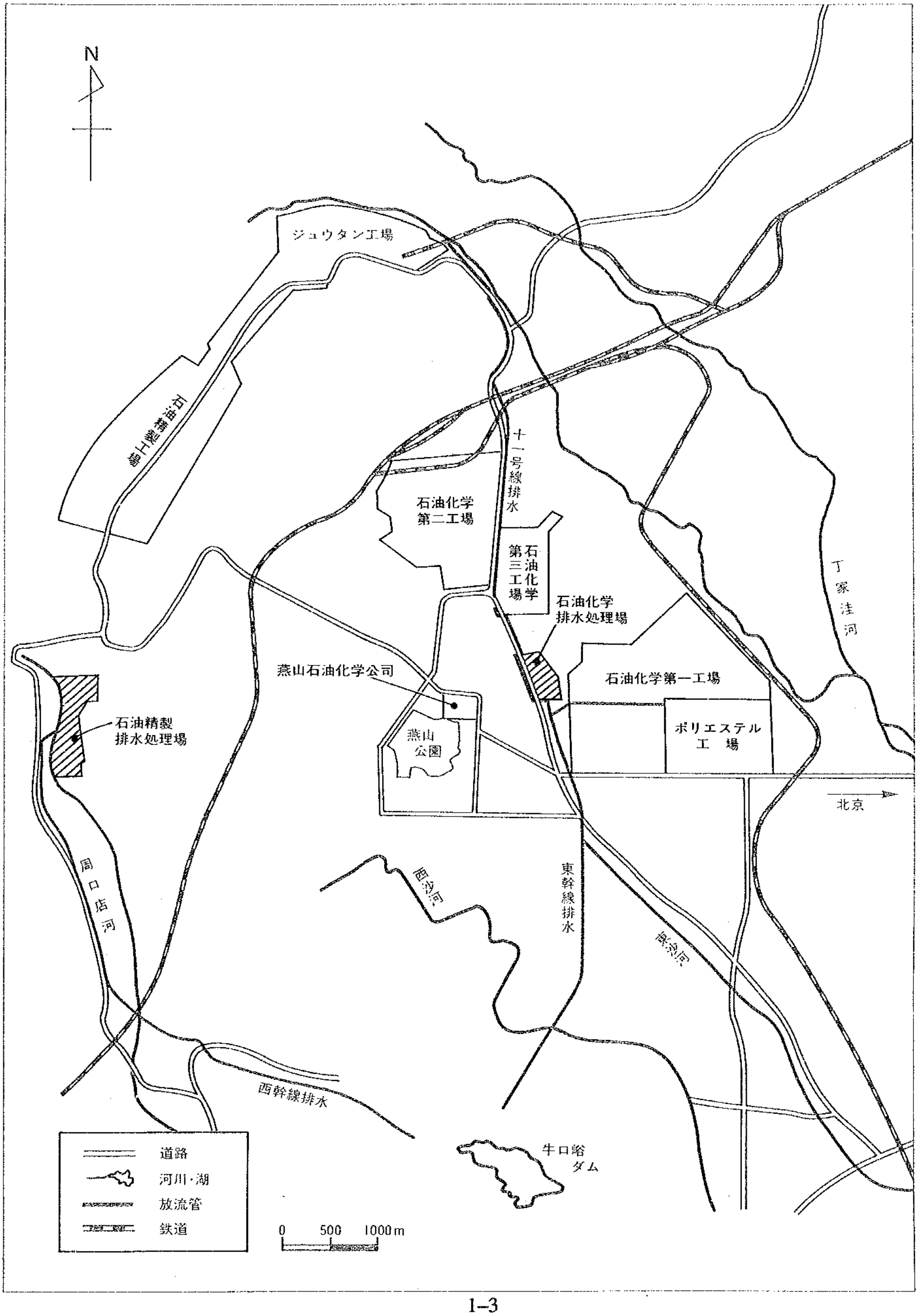
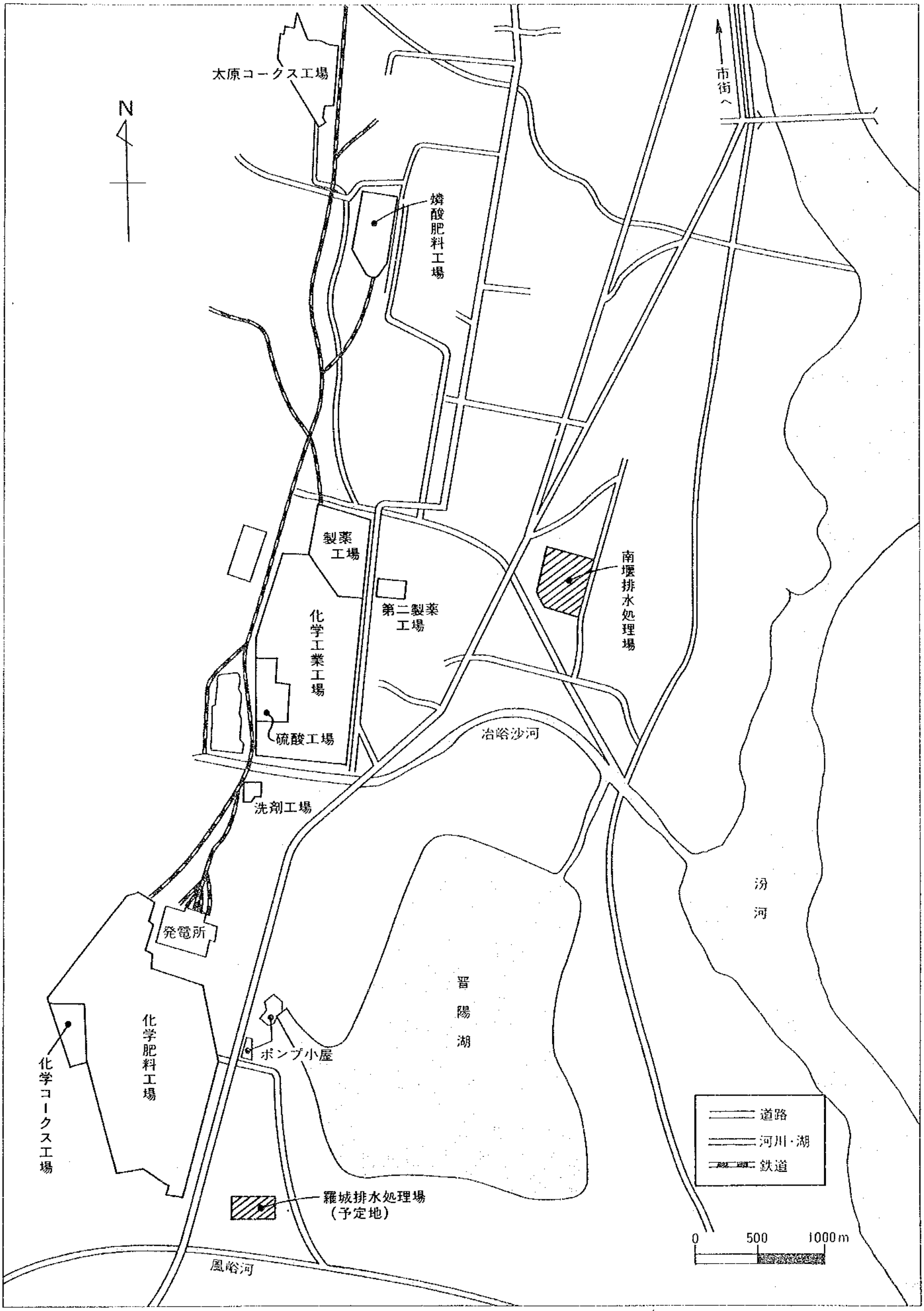


Fig.- 2 Map of Taiyuan Chemical Industrial Area



(2) Shanxi Taiywan Chemical Industrial Area

1) Chemical factory

2) Sulfuric acid factory

3) Phosphate fertilizer factory

4) Pharmaceutical factory

5) Detergent factory

6) Chemical fertilizer factory

7) Chemical coke factory

8) Nanyan waste water treatment plant (under construction)

9) Luocheng waste water treatment plant (under planning)

5. Scope of the Study

Scope of the Study is as follows.

(1) Investigation of current situation and future plan in objective areas

(2) Study of techniques and systems to be used for waste water treatment and recovery

(3) Implemental plan for introduction of waste water treatment systems and recovery systems

(4) Financial and economic analysis and overall evaluation of waste water treatment, and recovery systems

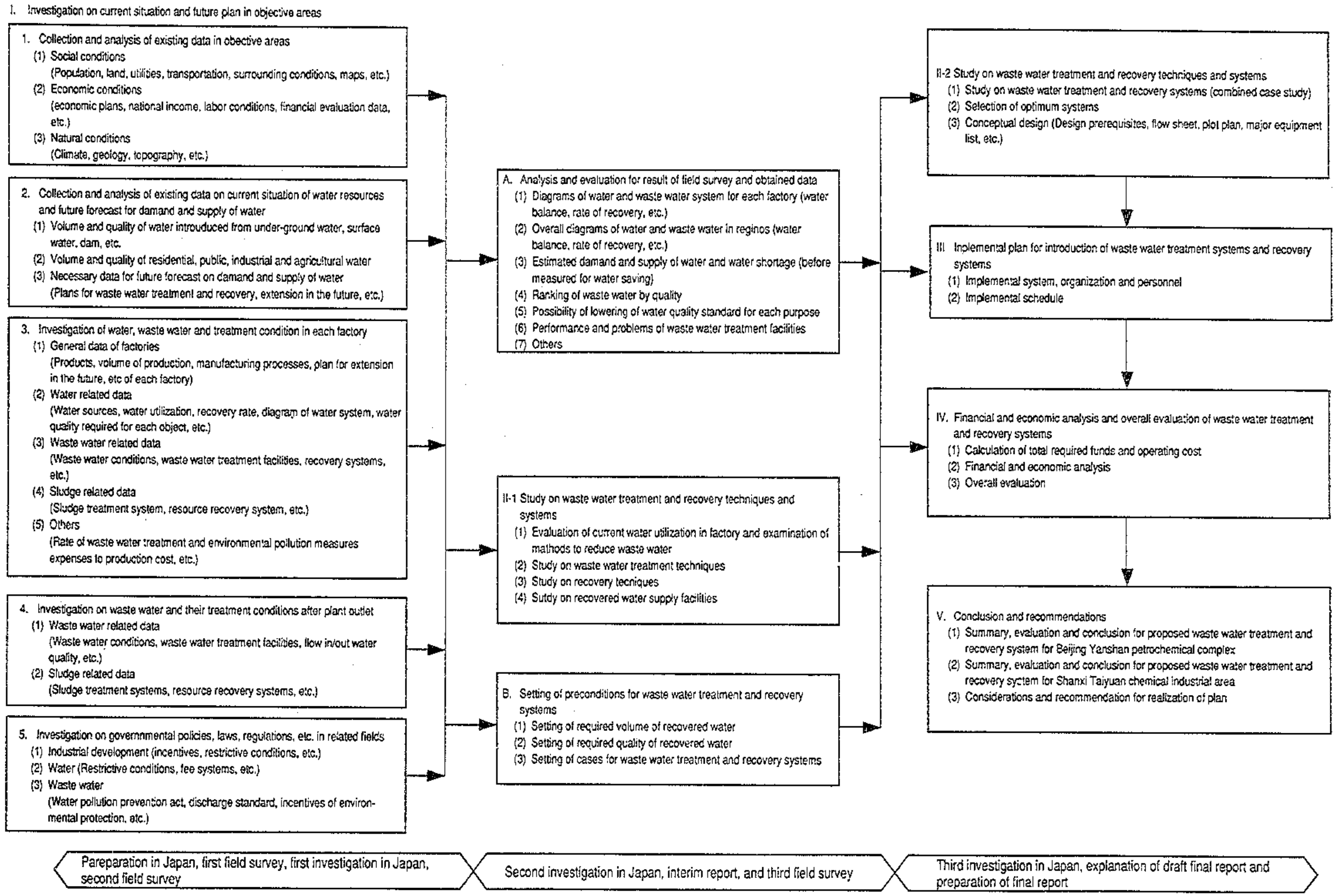
(5) Conclusion and recommendation

6. Study Methods and Procedures

6.1 Flow chart of the study methods and procedures

Relation among applicable scope of this study and related investigation, analysis and examination factors are shown in Fig. 3. These works are made progress, stage by stage and systematically.

Fig. 3 Flow Chart of the Study Methods and Procedures



6.2 Method of study of techniques and systems regarding waste water treatment and recovery

Interrelation among general investigations, analysis and study factors is shown in the Fig.3. Following factors have close interrelation with the study of techniques and systems related with the waste water treatment and recovery which are the major factors in the study and require systematic approach.

① Method of reducing quantity of water

② Method of recovering waste water with good quality by primary treatment

③ Method of preparatory treatment of waste water with mal-quality.

④ Current condition or plan for final waste water treatment facilities and anticipated changes after various measures

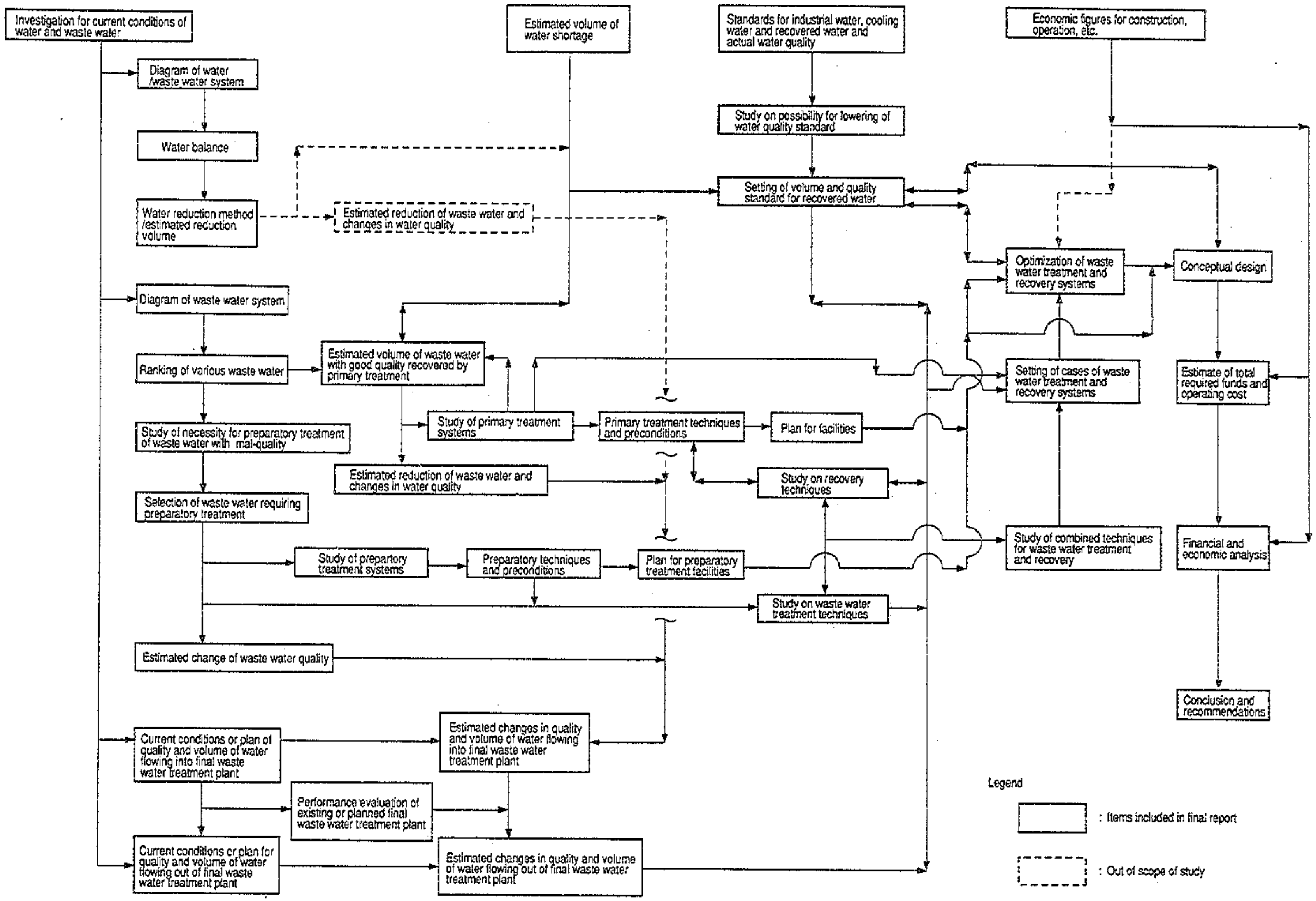
⑤ Study of recovery systems for water flowing out of final waste water treatment facilities

⑥ Various case studies and optimization

⑦ Technical and economic evaluation of above items

Above various factors, major study items of them, and method of studies are shown in Fig. 4.

Fig. 4 Flow Chart of Study on Techniques and Systems of Waste Water Treatment and Recovery



VOLUME II CURRENT SITUATION AND FUTURE PLAN IN THE OBJECTIVE AREAS

1. Current Situation and Future Prospect for Demand and Supply of Water

1.1 Water volume from each water source

(1) Yanshan district

Total volume of surface water (introduced from dam) and underground water and the total of these two water resources in this district are as follows:

1) Surface water	:	157,008 m^3/day
2) Underground water	:	28,584 m^3/day
Total	:	185,592 m^3/day

(2) Taiyuan district

Total volume of underground water (well water and spring water) and city water and the total of these two water resources in this district are as follows:

1) Underground water	:	95,000 - 100,000 m^3/day
2) City water	:	20,000 - 25,000 m^3/day
Total	:	about 120,000 m^3/day

1.2 Water volume by applications

(1) Yanshan district

Breakdown of use of water by water sources and applications are shown below:

1) Residential water

① Residence sections	:	48,048 m^3/day
② Production sections	:	26,568 m^3/day
Total	:	74,616 m^3/day

Surface water : 56,016 m^3/day

Underground water : 18,600 m^3/day

2) Industrial water

① Total: 110,976 m^3/day

- Surface water : 100,992 m^3/day
- Underground water : 9,984 m^3/day

(2) Taiyuan district

Breakdown of use of water by water sources and applications are shown below:

1) Residential water

① Total: 20,000 - 25,000 m^3/day

- City water : 10,000 m^3/day
- Underground water : 10,000 - 15,000 m^3/day

2) Industrial water

① Total : 95,000 - 100,000 m^3day

- City water : 10,000 - 15,000 m^3/day
- Underground water : 85,000 - 90,000 m^3/day

1.3 Conditions of water utilization

(1) Yanshan district

Volume of industrial water used in this district is as follows.

① Circulating cooling water:		1,761,336 m^3/day
(Rate of recovery	: 98.6%)	
② Boiler water :		46,032 m^3/day
(Rate of recovery	: 0%)	
③ Process water :		38,520 m^3/day
(Rate of recovery	: 0%)	
Total	:	1,871,160 m^3/day
(Rate of recovery	: 94.1%)	

(2) Taiyuan district

Volume of industrial water used in 7 factories in this district is as follows.

① Circulating cooling water:			795,638 m^3/day
(Rate of recovery	:	91.9%)	
② Boiler water :			19,748 m^3/day
(Rate of recovery	:	30%)	
③ Process water :			15,660 m^3/day
(Rate of recovery	:	38.7%)	
Total	:		831,046 m^3/day
(Rate of recovery	:	89.4%)	

1.4 Future forecast for demand and supply of water

(1) Yanshan district

Increase of demand for water required for attaining the 8th 5-year plan in this district is estimated as follows:

① Industrial water	:	22,320 m^3day
② Residential water	:	4,080 m^3day
Total	:	26,400 m^3/day

On the other hand, possibility of development of water resources in the future is little, and therefore it is considered that efforts should be made to save water and introduce such facilities that use water as little as possible, and recovery of waste water will become more important in the near future.

(2) Taiyuan district

Increase of demand for water required for attaining the future plan in this district is estimated as follows:

1) 7 factories covered by the study

①	Make-up water for cooling water	:	28,480 m^3day
②	Make-up water for boiler water	:	4,598 m^3/day
③	Make-up water for process water	:	4,548 m^3/day
④	Residential water	:	2,577 m^3/day
	Total	:	40,203 m^3/day

2) Other factories, etc.

① Total : About 10,000 m^3/day

3) Total in this district ; 50,000 m^3/day

Since there is no possibility of water resource development in the future, making efforts to save water will be necessary, and only solution will be to depend on making waste water as a resource in the near future.

2. Situation of Waste Water

2.1 Situation of discharged waste water

(1) Yanshan district

Volume and quality of water of 74 points were analyzed as follows in this district.

① Primary analysis (9 items) :

waste water of 73 kinds

② Detailed analysis for preparatory treatment (28 items):

waste water of 15 kinds

③ Detailed analysis for recovery (39 items):

waste water of 4 kinds

④ Daily variation analysis (9 items) :

waste water of 2 kinds

Volume and quality of above waste water are shown in Table 1 corresponding to primary analysis items.

(2) Taiyuan district

Volume and quality of water of 77 points were analyzed as follows in this district.

① Primary analysis (8 items):

waste water of 82 kinds

② Detailed analysis for preparatory treatment (34 items):

waste water of 14 kinds

③ Detailed analysis for recovery (33 items):

waste water of 10 kinds

④ Daily variation analysis (6 - 8 items):

waste water of 4 kinds

Volume and quality of above waste water are shown in Table 2 corresponding to primary analysis items.

2.2 Waste water treatment facilities

2.2.1 Waste water treatment facilities in factories

(1) Yanshan district

There are 3 units of waste water treatment facilities in factories of this district as follows.

① Oil refinery factory

A21 → Decyanides column → Deammonia column → Treated water (A23)

② Chemical factory No. 3

E52 → Oil separator (API) → Oil separator (CPI) → Treated water (E53)

③ Polyester factory

F56 → Sedimentation pond → Mixing tank → Neutralization tank →
→ treated water (F60)

Table 1 (1) Quality of Waste Water in Yanshan Petrochemical Complex

Sampling Point	Tag No	FLOW m3/D	pH	CONDUCT' μs/cm	W.TEMP °C	S.SOLID mg/L	COD-Mn mg/L	COD-Cr mg/L	EXTR.OIL mg/L	TOC mg/L	NH3-N mg/L
OIL REFINERY											
NO.1 DSTLL-OIL	A01	192	7.2	700	37	41	42	452	220	30	
NO.2 DSTLL-OIL	A02	432	8.3	100	35	4300	350	1530	4400	65	
NO.2 DSTLL-ALK	A13	48	9.5	900	15	3	8	15	9	5	
NO.3 DSTLL-OIL	A10	408	9.7	600	37	66	220	691	2000	66	
NO.3 DSTLL-ALK	A14	24	9.0	800	14	27	30	313	4300	11	
NO.1 FCC-OIL	A04	672	7.8	700	34	100	49	292	670	12	
NO.1 FCC-ALK	A15**	24	10.3	6650	28	102	7333	11941	79	3020	1450
NO.1 FCC-S	A18	240	9.4	3400	42	1	2000	2504	430	450	
NO.2 FCC-OIL	A05	1056	8.1	900	35	120	74	399	1100	10	
NO.2 FCC-ALK	A16	24	6.2	700	12	51	60	71	2200	13	
NO.2 FCC-S	A19	384	9.6	2100	43	13	1800	2626	320	160	
Deresin	A06	1032	8.1	800	23	90	75	481	450	28	
Reform	A07	120	8.1	400	13	2	10	43	10	6	
DEWAX. k&B	A08	1824	7.5	900	31	76	36	462	120	44	
HYDROF-OIL	A09	120	6.5	800	16	69	40	309	77	13	
HYDROF-ALK	A20	48	8.1	800	28	110	55	383	800	20	
Furfurl EX.	A03	168	5.6	500	65	40	170	310	90	76	
MOLEX	A11	336									
Oil Blend-Load	A22	528	7.7	900	22	11	38	290	51	31	
Oil Strage	A12	1920	9.0	800	48	160	52	383	1000	18	
BLW-DWN FRM R.S	A24	3600	8.2	800	16	2100	99	1708	4900	19	
DESULFUR IN	A21**	672	9.3	3271	30	14	1366	2414	103	484	675
DESULFUR OUT	A23	672	10.5	700	44	17	930	1284	60	1200	
REFINERY WASTE WATER TREATMENT											
ALK Contain W	B26**	120	10.1	800	42	241	883	2514	1430	373	685
S Contain W	B27	432	9.9	1100	28	33	1100	1855	130	430	
Storage T.IN	B28**	672	10.3	1000	77	78	697	1594	113	240	475
Oil Contain W	B25**	13200	9.6	603	28	191	199	890	1069	55	35
Oil Sep.OUT	B29	13200	9.3	500	30	1100	620	2225	1600	390	
Sec.DAF.OUT	B30**	13200	9.5	571	30	50	90	354	69	197	40
	B30-1++	6000	6.9	693	10	42	30	152	6	15	
Sec.Aer.	B31	13200	7.9	400	27	83	37	160	32	14	
Filter OUT	B32**	13200	8.9	552	26	13	32	66	8	20	100
	B31++	19200		492	22	70	35	158	24	14	
	B32++	19200		596	21	22	31	93	8	18	

** Average of Primary and Detailed Analysis
++ Collected data during the third field survey

Table 1 (2) Quality of Waste Water in Yanshan Petrochemical Complex

Sampling Point	Tag No.	FLOW m3/D	pH	CONDUCT' μs/cm	W.TEMP °C	S.SOLID mg/L	COD-Mn mg/L	COD-Cr mg/L	EXTR.OIL mg/L	T O C mg/L	NH3-N mg/L
CHEMICAL FACTORY NO.1											
Power Supply	C33	1200	9.0	700	30	18	26	240	22	6	
Cracking	C34	240	11.1	900	22	19	67	260	12	50	
Oil Strage	C35	1200	7.6	800	10	100	46	524	46000	9	
EG-NO.3	C38	1440	8.5	900	72	2.5	11000	19227	18	4300	
EG-NO.1	C36**	240	8.9	300	56	1	16333	22076	7	5733	<0.1
EG-NO.2	C37**	96	5.9	700	19	7	10625	13818	28	3713	0.2
Waste Heater	C76	192	9.1	200	68	<0.5	1	121	14	180	
Benzene	C39	1200	8.9	900	25	3.6	65	868	87	34	
P-xylene	C40	240	8.4	900	19	28	24	163	27	11	
W.W.South	C75	1680	8.2	1000	8	10	96	325	34	42	
W.W.North	C41	2640	8.8	900	31	410	47	670	1700	12	
W.W.Pump Out	C42	4560	5.4	100	21	130	510	2099	400	200	
CHEMICAL FACTORY NO.2											
Phen.Acet NO.1	D43	240	13.2	3800	8	62	10	139	15	5	
Phen.Acet NO.2	D44	216	8.4	19000	21	510	3100	1620	84	2000	
BLW-DWN FRM CT	D45	24	8.5	6000	7	8	9	38	6	6	
Polystyrene	D46	6240	8.2	900	10	43	15	92	12	16	
PolyPro	D47	3600	7.8	900	31	31	11	62	73	7	
CHEMICAL FACTORY NO.3											
Alkye-Benzene	E48	480	9.0	10600	37	16000	350	3463	240	11	
Wax Cracking	E49	720	6.2	900	16	15	6	33	76	37	
Boiler											
BLR Miscellany	E50	24	6.7	900	11	1	4	29	6	3	
BLR Regenerate	E73	96	7.3	1000	7	1	3	13	25	10	
BLW-DWN. FRM BLR	E74	216	7.4	900	20	2	3	10	12	3	
Lube Oil W.	E51	840	10.2	800	13	15	15	250	100	4	
	E52	2880	9.4	500	17	420	47	583	920	4	
	E53**	2880	9.6	353	17	82	21	243	72	9	211
POLYESTER FACTORY											
Sediment IN	F56**	792	4.3	300	45	934	330	3822	44	1143	<0.1
Recrystal	F54	312	11.1	31800	47	24	310	3723	23	1100	
Oxidation	F55	480	3.4	800	39	<0.5	370	1632	40	500	
Sediment OUT	F58	792	10.8	3900	35	14	680	4744	30	900	
Polyester DWN	F57	192	6.9	2009	12	10	1600	2190	11	660	
Polyester	F63	72	6.4	700	70	1	2700	6165	200	1800	
Mix.Tank IN	F59	984	11.6	6000	32	12	530	3595	20	790	
Neutral OUT	F60**	984	9.5	2109	27	16	918	5105	13	1509	<0.1
CHEMICAL WASTE WATER TREATMENT											
W.W. Chem No.1	G61**	7200	5.7	793	26	51	426	1067	66	253	0.3
W.W. Chem No.2	G62**	10320	11.5	1005	15	81	331	959	82	236	3
W.W. Chem No.3											
W.W. Polyester											
Dom. Sewage	G64**	17016	8.4	693	10	42	30	152	6	15	12
Oil Sep OUT	G65	21384	8.6	200	16	84	670	2301	190	620	
Newtral OUT	G66	21384	9.5	600	19	92	1100	2666	170	670	
DAF OUT	G67**	21384	9.5	377	20	45	711	2005	83	410	18
Mix.T OUT	G68	19824	9.5	100	17	61	760	2152	130	200	
New Sed OUT	G69	21504	7.8	500	14	30	77	283	19	55	
C-Aer.OUT	G70	9216	8.0	200	14	38	300	920	37	200	
R-Aer.OUT	G71	7680	8.1	1000	9	190	520	1227	42	310	
FILTER OUT	G72**	38400	8	607	14	33	29	261	5	28	100

** Average of Primary and Detailed Analysis

Table 2 (1) Quality of Waste Water in Taiyuan Chemical Industrial Area

Sampling Point	Tag No.	FLOW m3/D	p H	CONDUCT' μs/cm	W.TEMPS. °C	SOLID mg/L	COD-Mn mg/L	COD-Cr mg/L	EXTR.OIL mg/L	T O C mg/L	OTHERS mg/L	mg/L
N-T Coke F	W01	7500	8.5	400	28	9	55		7	16		
N-T Metals F		90										
N-Tro Hydro.Tm		300										
N-T.Pro Mech.F		50										
N-T. Phos.Fert.F												
N-TPF-Superphos	L11	12	0.3	68100	30	2300	33		26	1100		
N-TPF-Tita.Diox	L12	1460	1.6	5800	26	380	100		2	5		
N-TPF-Trso.Phos	L13	168	9.7	4000	31	1900	7		3	69		
N-TPF-Quso.Phos	L14	144	7.0	100	27	15	1		0	3		
	L14++		4.0-5.5	4000		300		60	3			
N-TPF-Gas	L15	120	7.4	100	38	16	8		1	6		
N-TPF-Fluosili	L16	144	0.1	67300	36	3200	28		3	37		
N-TPF-Boiler	L17	48	6.8	2100	37	190	16		1	3		
Others		504										
N-O-TPF-N	W02**	2432	0.9	18463	25	3171	44	226	16	14		
N-O-TPF-S	W03	168	2.4	2400	22	2400	7		8	4		
N-T. Glass Bot.F		626										
N-Pro.CIRI		352										
N.Transf.F		250										
N-T. Boiler.F		322										
N-O-TPF/TT/TCB	W18	3982	1.3	20200	22	530	76		13	26		
N-Y.Resi Quart	W04**	9610	7.8	100	16	55	30	90	8	22		
XI YU COAL MINE												
N-XCMD-R.W.	W05	940	8.8	100	11	1420	58		17	34		
N-XCMD-Mine/R.W.	W06	860	8.6	600	14	260	40		1	5		
PHARMACEUTICAL F.												
N-O-TP-Boiler	W07	750	8.1	300	31	1200	3		15	2		
N-O-TP-Agent	W08	280	8.0	300	20	4	2		1	4		
	W08++				24							
N-TP-Chloromy												
N-TP-C-Nitrif	Ly8	4.8	12.1	31900	32		4200		1300	5750		
N-TP-C-Brom.Con	Ly10	1.2	0.1	67300	8	770	80000		41700	61600		
N-TP-C-Acetyl	Ly11	3.6	3.8	2700	5	12	840		75	2460		
N-TP-C-Imine	Ly12-1	3.3	6.9	52600	6	2600	2700		2200	1630		
	Ly12-2	3.3	0.9	67400	3	780	18000		8000	50400		
N-TP-C-Product	Ly13	0.7										
N-TP-Acid W.OUT	Ly9	16.9	5.8	1700	23							
N-TP-Others												
N-TP-De Well	W09	3500	7.2	1200	23	49	100		39	80		
N-O-TP-New W	W10**	3000	4	1544	27	105	269	1215	108	421		
N-O-TP-Acid W	W11**	820	0.3	45867	18	1340	20043	114904	1279	23099		
N-O-WjB-N	W21**	21252	2.4	1595	17	291	147	313	15	61		
N-O-T2P	W12**	2920	7.7	325	20	12	8	31	4	5		
	W12++				24							
N-O-TCISM.Stat	W13	1420	8.1	100	19	13	8		2	33		
	W13++		2.3-13			2306		869				
N-T-Chem. F												
N-TC-8-Merceri	Lh14**	480	12.2	46400	65	7267	1217	2390	18	553		
N-TC-8-Dcl.E	Lh15**	14	8.9	233	38	4	17667	28100	1287	7157		
N-TC-14-Saponif	Lh16**	24	12.9	67067	84	1733	133333	438000	1460	150667		
N-TC-12-TDI	Lh17	480	6.4	5400	27	360	170		13	31		
N-TC-5-Gas	Lh18**	480	9.4	394	26	293	50	32	2	93		
	Lh18++				29							
N-TC-4-Phenol-E	Lh19	240	8.0	200	36	28	420		63	209		
N-TC-7-CI.A	Lh20	144	7.1	200	25	13	8		2	50	C2H3ClO2	HAc
	Lh20++		6.5-7.1			47		502			411	731
N-TC-7-BZ.CI	Lh21	144	8.2	200	28	66	9		3	5	C6H5Cl	C6H6
	Lh21++		6.8-8.2			109		302			34	47
N-TC-11-PVC	Lh53	720	0.4	67700	34	18	49		3	80	Hg	
	Lh53++										0.099	
N-TC-Others		13834										
N-TC-Others		50										
N-T.S.Acid F												
N-TSA-N	W14**	3000	1.6	6977	31	116	94	161	2	18	Hg	
	W14++										0.048	
N-TSA-S	W15	1440	6.3	400	19	2	16		2	0		
N-OUT-VS-N	W19	870	6.8	1000	19	13	79		58	152		
N-O-TC-Sum	W20	21000	7.2	6700	29	2080	73		11	76		
N-T Detergent F												
N-TD-Synthsiz		118										
N-TD-Product	Ld24	382	10.8	3600	29	4800	120		490	134		
N-O-TD-We	W16**	500	10.8	1067	18	1179	100	416	205	81		
N-TD-Fragment	Ld25	200	7.6	100	26	37	19		82	19		
N-TD-Others												
N-O-TD-E	W17	310	8.0	100	16	5	5		16	6		
N-O-WJB-S	W22**	22680	1.5	11346	27	280	118	461	22	116		
N-O-Sum	W23**	43932	2	4995	22	277	157	550	20	118		

** Average of Primary and Detailed Analysis
++ Collected data during the third field survey

Table 2 (2) Quality of Waste Water in Taiyuan Chemical Industrial Area

Sampling Point	Tag No.	FLOW m3/D	p H	CONDUCT' µs/cm	W.TEMP °C	S.SOLID mg/L	COD-Mn mg/L	COD-Cr mg/L	EXTR.OIL mg/L	T O C mg/L	NH3-N mg/L	Cl mg/L
S-T.C.I.Coke F												
S-TCIC-C. Prod	Lj28	600	9.1	11400	42	34	1100		95	445		
S-TCIC-Amno.Vap	Lj29	240	8.9	16500	69	17	130		30	447		
S-0-TCIC-N1300	W24	600	8.2	6500	18	51	220		6	54	600	
S-0-TCIC-S	W25**	2000	8.4	167	31	6	4	33	2	18		
	W25++				33							
S-T.Fertl.F												
S-TF-N1 Pump H	Lf30	2880	6.1	1200	27	120	26		4	4		
S-TF-N3 Pump H	Lf31	3360	8.5	700	24	7	4		1	2		
	Lf31++				47							
S-TF-N4 Pump H	Lf32	1560	8.6	100	21	10	4		2	3		
	Lf32++				37							
S-TF-N23 Pipe-N	Lf50**	7800	9.4	408	32	90	13	43	4	3	33	
S-TF-Desulfur	Lf33	210	9.5	19500	33	39	1100		2	610		
S-TF-W.Scrub	Lf34	480	8.4	100	21	7	7		2	21		
	Lf34++				28							
S-TF-Sodi.C-S	Lf35	210	9.0	3500	28	12	4		3	3		
S-TF-N6 Pump H	Lf39**	4800	8.4	400	16	8	3	10	2	2		
S-TF-N1 Road	Lf40	7700	8.7	500	20	51	44		6	14		
S-TF-Sodi.C-N	Lf36	3840	8.9	66500	38	220	7		7	9	2593	7500
	Lf36++					5500		831				
S-TF-Cup.Scrub	Lf38	360	9.6	30000	20	15	8		9	79	5333	
	Lf38++				40-45							
S-TF-Sod.C/CW.S	Lf37**	4800	9.1	24501	43	58	35	421	8	13	2600	6000
S-TF-Nitric A	Lf41	1680	0.7	66800	13	130	120		94	5		
S-TF-Amnon Nit	Lf42	360	10.7	4600	20	180	23		7	0	3000	
S-TF-N8 Pump H	Lf45**	2400	10.2	533	23	203	6	37	3	9	40	
	Lf45++		8.2-8.7	500	26	203		37	3			
S-TF-Con.Nit.A	Lf46	720	1.5	18600	22	200	20		30	5		
S-TF-N5 Pump H	Lf48	7640	8.5	100	12	21	15		13	3	78	
	Lf48++				26							
S-TF-N2 Road	Lf51**	12800	10.7	4233	24	143	13	60	14	4	92	
S-TF-N7 Pump H	Lf43	2400	8.6	3700	19	19	8		5	5		
	Lf43++				42							
S-TF-Methylamin	Lf44**	196	11.5	700	53	850	498	958	25	649	9893	
S-TF-Methanol	Lf47	24	7.3	200	30	1700	46000		2950	40100		
S-TF-Catalyst	Lf49	480	10.7	1000	32	500	7		5	45		
S-TF-N3 Road	Lf52**	3100	10.9	1467	29	216	417	1031	6	474	625	
S-TF-Others		4800										
S-TF-N3 Gate	Lf54**	36200	9.6	902	31	183	57	125	11	37	112	70
S-0-TF/TCIC	W27	41000	8.7	2600	34	170	95		8	41	403	764
S-TF-Out R.Q.		4000										70
S-0-Sum	W26**	45000	9.1	5692	29	206	35	212	5	19	367	280

** Average of Primary and Detailed Analysis
++ Collected data during the third field survey

(2) Taiyuan district

There are 2 units of waste water treatment facilities in factories as follows in this district.

① No. 1 pharmaceutical factory

Untreated water tank → Sand removal unit → Conditioning tank → Deep aeration →
→Floatation → treated water (W9)

② Chemical coke factory

Lj28 → Oil separator → Conditioning tank → Trickling tower → Sedimentation tank No. 1 → Aeration tank → Sedimentation tank No. 2 → treated water (W24)

2.2.2 Final waste water treatment facilities

(1) Yanshan district

Two waste water treatment plants in this district are summarized as follows.

1) Oil refinery waste water treatment plant

① Design flow rate : 1,300 m^3/H (31,200 m^3/D)

② Actual flow rate : 400 - 600 m^3/H (9,600 - 14,400 m^3/D)

③ Composition of major facilities

Oxidation desulfurization, oil separator, floatator, aeration sedimentation, sedimentation, filtration

2) Petrochemical waste water treatment plant

① Design flow rate : 1,825 m^3/H (43,800 m^3/D)

② Actual flow rate : 2,000 m^3/H (48,000 m^3/D)

③ Composition of major facilities

Oil separator, neutralization, floatator, mechanical screen, aeration sedimentation, aeration, sedimentation, filtration

(2) Taiyuan district

Plan for the Nanyan waste water treatment plant is summarized as follows.

① Design flow rate : 60,000 m^3/D

② Actual flow rate : 44,100 m^3/D (exclusive of use of waste water for agricultural irrigation)

③ Composition of major facilities

Screen, sedimentation tank No. 1, conditioning tank, aeration tank, sedimentation tank No. 2.

3. Policies, Laws, and Others of Related Fields

3.1 Industrial development related policies, laws, etc.

(1) Yanshan district

1) Incentives for new industrial development plans is unavailable in the Yanshan petrochemical complex.

2) Industrial development is restricted under the restrictions of funds, electricity, water and land.

In particular for water, increasing the current level of availability is impossible for the municipality of Beijing.

(2) Taiyuan district

1) Incentives for new industrial development plans is unavailable in the Taiyuan chemical industrial area.

2) Industrial development is restricted by the air pollution which has become serious due to use of coal, and shortage of water resources.

3.2 Water related policies, laws, etc.

Water resources (underground water and surface water) are owned by the nation. The nation imposes strict duty to control and save industrial, agricultural and residential water, while it guides and supervises for rational drawing up of underground water to avoid drying up of water source and subsidence of ground.

(1) Yanshan district

1) Underground water varies remarkably depending on the climate and seasons. With the progress of pollution of the downstream water source, regulations on drawing up have become severer year by year.

2) As the water demand-supply condition in Beijing has become tight, increasing of surface water supply to this district is impossible.

3) Rate of fresh water is about 0.4 yuan/T. When a volume indices of water established by the municipality of Beijing to each company is exceeded, excess fee of several ten times than normal one is imposed.

(2) Taiyuan district

1) Each company owes a duty of water saving and planned use and prohibited from increasing the volume of underground water drawn up.

2) The department in charge of control of water gives strict instructions to restrict volume of water used to each unit. When the result exceeds the estimated level, excess fee of approximately twice than normal one is imposed.

3) Rate of fresh water is about 0.5 yuan/T. When the specified volume is exceeded, excess fee of about twice than normal one is imposed.

3.3 Waste water related policies and regulations

(1) Common policies and regulations

1) Standards for waste water and surface water have been established so as to prevent water pollution and dues system and penalty system for excess of specified level have been enforced.

2) The nation has a guideline and aid as follows for companies which follow the environment protection measures.

① When existing old facilities are modified to meet waste water standards, a subsidy is granted to cover all expenses.

② A duty to facilitate environmental protection facilities to meet the waste water standard is imposed for new plants.

③ When a plant is constructed or modified, production facilities and environmental protection facilities should be proceed with simultaneously at the stages of design, construction and operation.

(2) Yanshan district

1) The waste water regulation of the municipality of Beijing is applied to this district. The current applicable regulation corresponds to Class 3 but it may be intensified in the future. Therefore the waste water quality should be improved.

   The highest level of allowable discharge concentration standard applies respectively to the oil refinery factory and chemical factory.

2) Penalty is imposed for each water quality item and degree of excess (No. of times) when the standard is exceeded. The fine can be as expensive as 2 yuan/T at the highest.

3) The waste water excess fee amounted to 1,937,000 yuan in 1989.

(3) Taiyuan district

1) Volume and quality of waste water from each company are closely watched and penalty is imposed when the standard level for them is exceeded. The national standard is applied now to waste water discharge but original standard of the municipality of Taiyuan is under examination.

2) Advice is given to a factory where the standard is exceeded. When the situation is not improved within the specified days of allowance, a large sum of penalty is imposed.

   Taiyuan Chemical Company has been advised improvement by the administrative organization and is constructing a Nanyan waste water treatment plant.

3) The rate of waste water discharge within the standard level is 0.05 yuan/T. Penalty of 0.1 yuan/T is imposed to excess below 10 times than standard value and 0.2 yuan/T to excess over 10 times.

4) Penalty from excess waste water amounted to 4,090,000 yuan in 1989.

VOLUME III TECHNOLOGY, SYSTEMS AND PRECONDITIONS FOR TREATMENT AND RECOVERY OF WASTE WATER

1. Study on Technology and Systems for Treatment and Recovery of Waste Water

1.1 Current situation of water utilization in factories and waste water reduction methods

1.1.1 Water reduction methods and estimated reduction volume

(1) Effect of water reduction

When considering waste water treatment and recovery systems, reduction of water quantity, if possible, will be very effective countermeasures. The followings are major advantages of reduction of water quantity.

① By reducing the volume of water, water shortage will be less and the scale of waste water treatment and recovery systems can be also reduced (reduction of construction cost).

② Expenses for water can be reduced.

③ Waste water is reduced and final waste water treatment facility will be operated with a margin.

(2) Water reduction methods

① Water flow rate is thoroughly controlled and unnecessary use is avoided for saving water.

② Water leakage due to defective facilities and other loss are minimized for saving water.

③ Boiler water (steam-condensed water), which is water with quality in substance, is fully recovered.

④ Process water is fully recovered according to uses.

⑤ For cooling water, indirect cooling (heat exchanger) system is adopted entirely to improve the rate of recovery or air cooling heat exchanger (air fin cooler) is introduced to reduce the volume of cooling water.

(3) Estimated reduction volume of water

Based on experience in Japan, possible volume of water reduction is estimated as follows.

1) Yanshan district

①	Saving of overall water	(5%)	: 5,100 m^3/day (excluding boiler water and process water)
②	Recovery of boiler water	(40%)	: 18,400 m^3/day
③	Recovery of process water	(10%)	: 3,800 m^3/day
	Total		: 27,300 m^3/day

2) Taiyuan district

①	Saving of overall water	(5%)	: 2,100 m^3/day (excluding cooling water and boiler water)
②	Improvement of cooling water recovery rate	(91.9 → 95%)	: 22,700 m^3/day
③	Improvement of boiler water recovery rate	(30 → 40%)	: 2,000 m^3/day
	Total		: 26,800 m^3/day

If the water reduction as described above is possible, water shortage in the Yanshan district will be covered by this means. The water reduction accounts for about 54% of water shortage estimated in the future in the Taiyuan district. Thus the water reduction is supposed to be remarkably effective.

However these reduction methods are limited to the scope within processes. To study them quantitatively, detailed water use condition, each waste water discharge point, water volume, and water quality should be grasped and processes will have to be studied.

Such investigations are out of the scope of this study, and the estimated water reduction volume is presented only as reference data and not included in the following studies.

However, it is proposed to compare it with the final result of this study and examine as a promising alternative on the part of China.

1.2 Study on waste water treatment techniques

1.2.1 Considerations about waste water treatment

(1) Necessity of upstream treatment (close to discharge source)

1) Prevention of water contaminant, in particular harmful substances from diffusion

2) Prevention of water contaminant, in particular harmful substances from being lost due to accidents, or troubles

(2) Necessity of separating waste water and drainage systems

1) Clean waste water/drainage system (primary waste water): directly discharged to public water area

2) Polluted waste water/drainage system (secondary waste water): discharged to public water area after treatment

1.2.2 Classification of waste water by quality

(1) Classification of waste water by types

Relation between 3 largest water quality factors, which are important for waste water treatment and recovery, and primary analysis items is as follows.

① Organic matter concentration: CODMn (CODCr)

② Salt concentration: Conductivity

③ Solid matter concentration: SS

Concentration of each water quality factor is classified as shown in Table 3.

Table 3 Classification of Waste Water Concentration

Classification of Concentration	Organic matter CODMn(mg/ℓ)	Salt Conductivity (μs/cm)	Solid matter SS(mg/ℓ)
High concentration	CODMn≧500	Conductivity≧5,000	SS≧100
Medium concentration	500>CODMn≧50	5,000>Conductivity>500	100>SS≧10
Low concentration	50>CODMn	500>Conductivity	10>SS

Waste water was classified into 27 types according to the classification of concentration as shown in the above table.

Results of classification of each waste water in the Yanshan and Taiyuan districts according to the types are shown in Tables 4 and 5.

Based on the classification results by types of waste water, necessity of preparatory treatment of waste water with mal-quality and possibility of primary treatment and recovery of waste water with good quality were also investigated.

(2) Selection of waste water with mal-quality requiring preparatory treatment

Waste water with mal-quality which presumably require preparatory treatment was selected based on the criteria for judgment as follows.

①	High organic matter content waste water	: $COD_{Mn} \geqq 1,000$ mg/ℓ
②	High salt content waste water	: Conductivity $\geqq 10,000$ µs/cm
③	High solid-matter content waste water	: SS $\geqq 500$mg/ℓ
④	High oil content waste water	: (Yanshan) Oil content $\geqq 1,000$ mg/ℓ
		(Taiyuan) Oil content $\geqq 100$ mg/ℓ
⑤	High nitrogen content waste water	: NH_3-N $\geqq 500$ mg/ℓ
⑥	High mercury content waste water	: Hg $\geqq 0.005$ mg/ℓ
⑦	PH	: 5 > PH and PH > 10

When the above standard is applied, 40 types of waste water in the Yanshan and 42 types of waste water in the Taiyuan district are covered.

Table 4 Classification of Waste Water by Types (Yanshan)

Organic matter/salt content \ SS	Suspended Solid (SS; mg/ℓ)		
	Ⓐ Low solid matter 10>SS	Ⓑ Medium solid matter 100>SS≧10	Ⓒ High solid matter SS≧10
① High organic matter/ high salt content		F59	A15*1, D44
② High organic matter/ medium salt content	A18, C37*1, C38, F63	A8, A19, A21*1, A23, B27, B28*1, F57, F58, F60*1, G66	B26*1, B29, G71
③ High organic matter/ low salt content	C36*1	G65, G67*1, G68, G70	C42
④ Medium organic matter/high salt content		F54	E48
⑤ Medium organic matter/medium salt content	F55	A3, A6, A10, A16, B30*1, C34, C39, C75, G61*1, G62*1, G69	A5, A12, A20, A24, B25*1
⑥ Medium organic matter/low salt content			A2, F56*1
⑦ Low organic matter/ high salt content	D45		
⑧ Low organic matter/ medium salt content	A13, E50, E73, E74	A1, A9, A14, A22, B32*2, C33, C40, D43, D46, D47, E49, E51, G72*2, G64*1	A4, C35, C41, E52
⑨ Low organic matter/ low salt content	A7, C76	B31, E53*1	
Remarks	High organic matter content : COD_{Mn}≧500 (mg/ℓ) Medium organic matter content : 500>COD_{Mn}≧50 Low organic matter content : 50>COD_{Mn} High salt content : Conductivity≧5,000 (μs/cm) Medium salt content : 5,000>Conductivity≧500 Low salt content : 500>Conductivity Note: Only primary analysis at sampling point → Only primary analysis values. Detailed analysis also → average values are adopted. *1 Detailed preparatory treatment analysis *2 Detailed recovery analysis		

Table 5 Classification of Waste Water by Types (Taiyuan)

Note: *1 : Detailed preparatory treatment analysis
*2 : Detailed recovery analysis

Organic matter/salt content \ SS	Suspended Solid (SS; mg/ℓ)		
	Ⓐ Low solid matter 10>SS	Ⓑ Medium solid matter $100 > SS \geqq 10$	Ⓒ High solid matter $SS \geqq 10$
① High organic matter/ high salt content		Lf33, Lj28	Lh14[*1], Lh16[*1], Ly10, Ly_{12-1}, Ly_{12-2}, W11[*1]
② High organic matter/ medium salt content		Ly11	
③ High organic matter/ low salt content	Lh15[*1]		Lf47
④ Medium organic matter/high salt content		Lj29, W24	Lh17, Lℓ2, W14[*1], W18, W20, W22[*2], W23[*2], Lf36, Lf41
⑤ Medium organic matter/medium salt content	W1	W19, W9	Ld24, W10[*1], W16[*1], W21[*2], Lf44[*1], Lf52[*1], Lf54[*1], W27
⑥ Medium organic matter/low salt content		Lh19, Lh20, Lh21	Lh18[*2], W5, W13
⑦ Low organic matter/ high salt content		Lh53, Lf37[*1], Lf38	Lℓ1, Lℓ6, W2[*1], Lf46, W26[*1]
⑧ Low organic matter/ medium salt content	Lf31	Lf35, Lf40, Lf43	Lℓ3, Lℓ7, W3, W6, Lf30, Lf42, Lf45[*2], Lf49, Lf51[*1], Lℓ4
⑨ Low organic matter/ low salt content	W15, W17, W8, Lf34, Lf39[*2], W25[*2]	Ld25, Lℓ5, W12[*2] W4[*2], Lf32, Lf48, Lf50[*2]	W7
Remarks	High organic matter content : $COD_{Mn} \geqq 500$ (mg/ℓ) Medium organic matter content : $500 > COD_{Mn} \geqq 50$ Low organic matter content : $50 > COD_{Mn}$ High salt content : Conductivity $\geqq$ 5,000 (μs/cm) Medium salt content : 5,000 > Conductivity $\geqq$ 500 Low salt content : 500 > Conductivity Note: Only primary analysis at sampling point → Only primary analysis values. Detailed analysis also → average values are adopted.		

1.2.3 Waste water requiring preparatory treatment and applied techniques

Necessity of preparatory treatment was judged and assumed treating techniques were investigated based on the quality of waste water with mal-quality, selected according to the standard as described in the previous paragraph, and influence exerted on the downstream.

(1) Yanshan district

1) Oil refinery factory

① A8 waste water : Oil separation (waste water from ketone/benzene plant)

② A15 waste water : Line switched over to desulfurization process flow-in water (A21) system

(No. 1 FCC alkali waste water)

2) Petrochemical factory

① C36 waste water :
② C37 waste water :
Liquid oxidation (waste water from EG plant)

③ F54 waste water :
④ F55 waste water :
⑥ F57 waste water :
Liquid oxidation (waste water from polyester plant)

(2) Taiyuan district

1) Northern district

① Lℓ1 waste water :
② Lℓ6 waste water :
Coagulative sedimentation (waste water from phosphate fertilizer factory)

③ Lℓ2 waste water : Neutralization (waste water from phosphate fertilizer factory)

④ Lh53 waste water : Sulfide coagulative sedimentation (waste water from PVC plant)

⑤ W14 waste water : Sulfide Coagulative sedimentation (waste water from sulfuric acid factory)

⑥ W10 waste water : Deep aeration (neutral waste water from pharmaceutical factory)

⑦ W11 waste water : Neutralization (acid waste water from pharmaceutical factory)

⑧ W13 waste water : Neutralization (waste water from chemical industry supply and marcketting station)

⑨ W23 waste water : Neutralization (Nanyan waste water treatment plant inlet water)

⑩ W16 waste water : Oil separation, coagulative pressurized floatation (waste water from detergent factory)

⑪ Lym waste water : Waste liquid burning (waste water and waste liquid from pharmaceutical factory)

⑫ Lh15 waste water :
⑬ Lh16 waste water :
⑭ Lh55 - 57 waste liquid :
Waste liquid burning (waste water and waste liquid from chemical factory)

2) Southern district

① Lf42 waste water : Ammonia stripping, neutralization, $NH_4C\ell$ recovery (waste water from chemical fertilizer factory)

② Lf38 waste water : Ammonia stripping, neutralization, $NH_4C\ell$ recovery (waste water from chemical fertilizer factory)

③ Lf44 waste water : Ammonia stripping, coagulative sedimentation, $NH_4C\ell$ recovery (waste water from chemical fertilizer factory)

④ Lf36 waste water : Ammonia stripping, coagulative sedimentation, $NH_4C\ell$ recovery (waste water from chemical fertilizer factory)

⑤ Lf47 waste water : Liquid oxidation (waste water from chemical fertilizer factory)

1.3 Study on recovery techniques

1.3.1 Allowable quality standard for recovered water

(1) Judgement of quality for recovered water

Recovered water will be used to make-up circulating cooling water according to the plan. Considerations should be given to the following points when judging the water quality.

1) Quality should be as low as possible (cheapening of recovery system).

2) Unless there is no specific problem, the water quality should not be higher than that of the current industrial water.

3) Upper limit value should be investigated from thc viewpoint of facilities, operation and health (with consideration given to corrosion and fouling).

(2) Allowable quality standard for recovered water

Standard (original standard) for the quality of recovered water was acquired during the first field survey. However, when establishing the standard for the quality of recovered water (allowable quality), considerations should be given to the following facts:

1) The water is used as cooling water,

2) Such a type of cooling water is enough in essence that chemical is added to industrial water (to withstand corrosion and prevent fouling) and the quality of industrial water is enough,

3) Industrial water which meets the Chinese surface water environmental quality standard (Class IV, general industrial water) is enough, and,

4) Current quality of industrial water (underground water) is presenting no specific problems, and following steps should be taken:

① Upper limit shall be adapted for each water quality item of the individual quality standards for the industrial water, cooling water and recovered water (original standard), Chinese surface water environment quality standard, and for the industrial water (underground water) under the current situation.

② Water quality items shall be only those described in recovered water quality standard (original standard).

③ However, since there are only a small number of items of recovered water quality standard (original standard) about the Taiyuan district, same water quality items and figures as those of the standard for the Yanshan district shall be used and above ① and ② shall be applied.

Comparison between the quality standard (set values) for recovered water prepared based on the above prerequisites, and the quality standard for recovered water for the Yanshan and Taiyuan districts which was agreed by the third field survey are shown in Table 6.

Table 6 Comparison Between Set Values of Recovered Water Quality Standard and New Standard

Standard / Water quality items	Yanshan district		Taiyuan district	
	Set value	New standard	Set value	New standard
1. Turbidity (Degree)	9.5	5	50	5
2. PH	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5
3. Conductivity (μs/cm)	800	600	800	800
4. Total Hardness (mg/ℓ)	525	250	440	400
5. Total Alkality (mg/ℓ)	150	150	510	250
6. CODcr (mg/ℓ)	50	50	20	20
7. Oil (mg/ℓ)	3	3	0.5	0.5
8. SS (mg/ℓ)	5	5	20	5
9. Iron (Fe) (mg/ℓ)	0.5	0.1	0.5	0.3
10. SiO_2 (mg/ℓ)	5	4–5	50	50
11. Cl^- (mg/ℓ)	250	100	250	100
12. TDS (mg/ℓ)	780	600	1,000	1,000
13. SO_4^{2-} (mg/ℓ)	250	100	250	200
14. Ca^{2+} (mg/ℓ)	80	80	200	100
15. Copper (Cu) (mg/ℓ)	1.0	1.0	1.0	0.1
16. NH_3-N (mg/ℓ)	–	10	20	10
17. NO_2-N (mg/ℓ)	1.0	1.0	20	–
18. NO_3-N (mg/ℓ)	20	20	20	–
19. Cyanide (CN) (mg/ℓ)	0.2	0.2	0.2	–
20. Mercury (Hg) (mg/ℓ)	0.001	0.001	0.001	–
21. Arsenic (As) (mg/ℓ)	0.1	0.1	0.01	–
22. Total No. of bacilli (Quantity/mℓ)	–	5,000	–	100
23. Residual chlorine(mg/ℓ)	–	0.5	–	0.5–1.0
24. Water temperature (°C)	–	25–28	–	25–28
25. Mg^{2+} (mg/ℓ)	–	–	–	50
26. Colour (Degree)	–	–	–	15
27. Mn (mg/ℓ)	–	–	–	0.3
28. Al (mg/ℓ)	–	–	–	1.0
29. DO (mg/ℓ)	–	–	–	2
30. BOD (mg/ℓ)	–	–	–	10
31. Total Phophate (mg/ℓ)	–	–	–	0.5

1.3.2 Recovery methods of waste water with good quality by primary treatment and recoverable volume

Classification of waste water by water quality, types of waste water and standard for quality of recovered water were compared, treating methods assumed, and possibility of recovery was judged. The result is shown below.

(1) Yanshan district

1) Oil refinery factory

①	A13 waste water	: volume recovered	: 43.2 m^3/day (PH conditioning)
②	A7 waste water	: volume recovered	: 108 m^3/day (Sand filtration)
③	A22 waste water	: volume recovered	: 475 m^3/day (Coagulative pressurized floatation, sand filtration, activated carbon)
	Total	: volume recovered	: 626 m^3/day

2) Chemical factory

①	C33 waste water	: volume recovered	: 1,080 m^3/day (PH conditioning, sand filtration, activated carbon)
②	D46 waste water	: volume recovered (② and ③)	: 8,856 m^3/day (Coagulative pressurized floatation, sand filtration, activated carbon)
③	D47 waste water	:	
④	E49 waste water	: volume recovered	: 648 m^3/day (Coagulative pressurized floatation, sand filtration)
⑤	E50 waste water	: volume recovered	: 21.6 m^3/day (Sand filtration)
⑥	E74 waste water	: volume recovered	: 194.4 m^3/day (Oil adsorption)
	Total	: volume recovered	: 10,800 m^3/day

3) Total of Yanshan district

① Oil refinery factory : volume recovered : 626 m^3/day

② Chemical factory : volume recovered : 10,800 m^3/day

Total : volume recovered : 11,426 m^3/day

(2) Taiyuan district

1) Northern district

① Lℓ5 waste water : volume recovered : 108 m^3/day (Sand filtration)

② W7 waste water : volume recovered : 675 m^3/day (Coagulative sedimentation, sand filtration)

③ W8 waste water : volume recovered : 252 m^3/day (Sand filtration)

④ W12 waste water : volume recovered : 2,628 m^3/day (Sand filtration)

⑤ Lh18 waste water : volume recovered : 432 m^3/day (Coagulative sedimentation, sand filtration)

⑥ W15 waste water : volume recovered : 1,296 m^3/day (Activated carbon)

⑦ W17 waste water : volume recovered : 279 m^3/day (Oil adsorption)

⑧ W1•W4 waste water: volume recovered : 15,399 m3/day (Sand filtration, activated carbon)

Total : volume recovered : 21,069 m^3/day

2) Southern district

① W25 waste water : volume recovered : 1,800 m^3/day (Sand filtration)

② Lf34 waste water : volume recovered : 432 m^3/day (Sand filtration)

③ Lf39 waste water : volume recovered : 4,320 m^3/day (Sand filtration)

④ Lf31 waste water : volume recovered : 3,024 m^3/day (Sand filtration)

⑤ Lf32 waste water : volume recovered : 1,404 m^3/day (Sand filtration)

⑥ Lf48 waste water : volume recovered : 6,880 m^3/day (Sand filtration, activated carbon)

⑦ Lf45 waste water : volume recovered : 2,160 m^3/day (Coagulative sedimentation, sand filtration)

Total : volume recovered : 20,016 m^3/day

3) Total of Taiyuan district

① Northern district : volume recovered : 21,069 m^3/day

② Southern district : volume recovered : 20,016 m^3/day

Total : volume recovered : 41,085 m^3/day

1.4 Study on combined techniques for waste water treatment and recovery

Preparatory treatment of waste water with mal-quality, primary treatment and recovery of waste water with good quality, treatment of waste water and recovery, etc. are combined in each district as described below:

(1) Yanshan district

1) Oil refinery factory

Locational relation of treatment processes is shown in Fig. 5.

2) Petrochemical factory

Locational relation of treatment processes is shown in Fig. 6.

(2) Taiyuan district

1) Northern district

Locational relation of treatment processes is shown in Fig. 7.

2) Southern district

Locational relation of treatment processes is shown in Fig. 8.

Fig. 5 Locational Relations among Waste Water Treatment and Recovery Systems (Yanshan Oil Refinery)

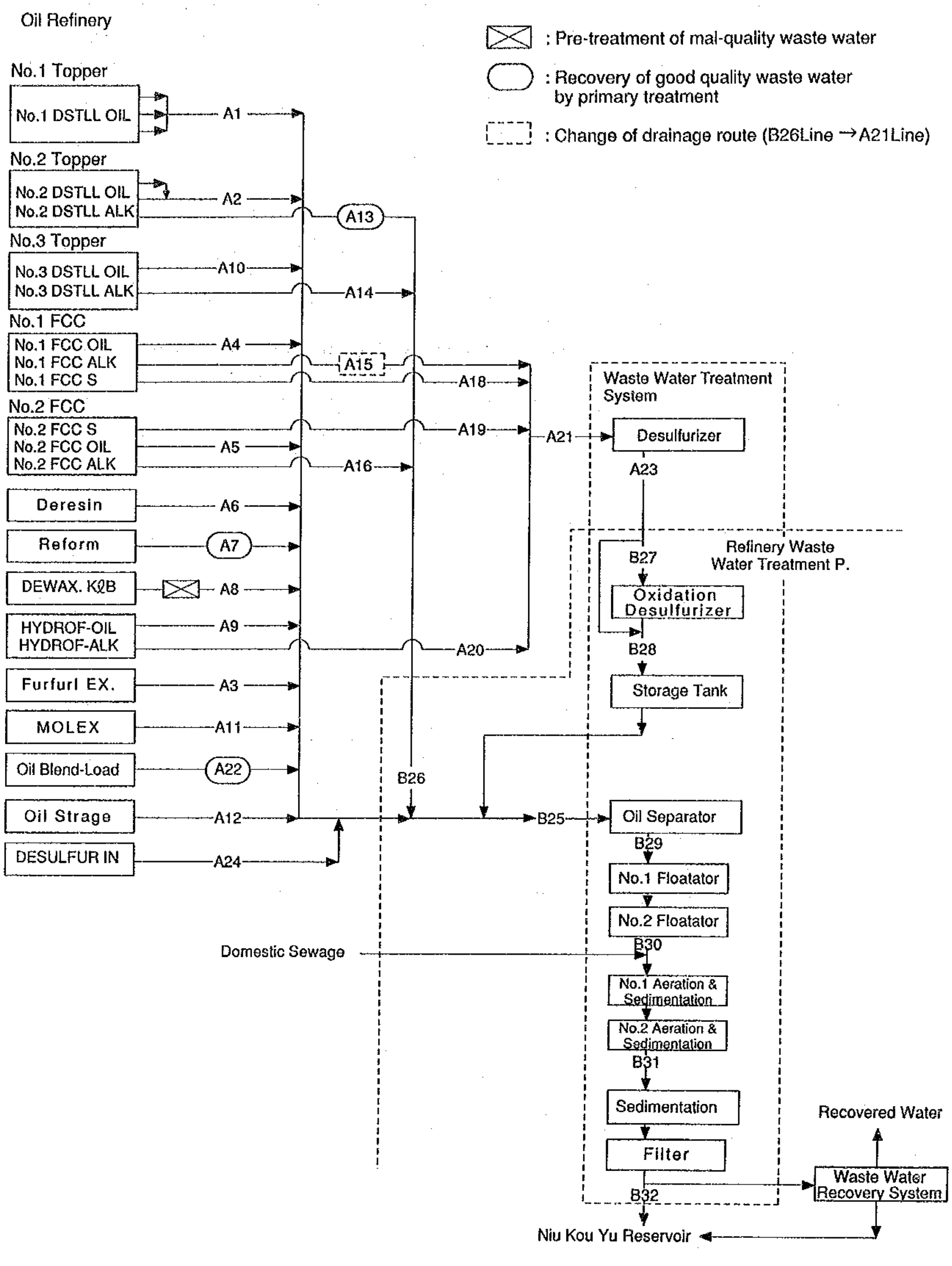


Fig. 6 Locational Relations among Waste Water Treatment and Recovery Systems (Yanshan Petrochemical Factory)

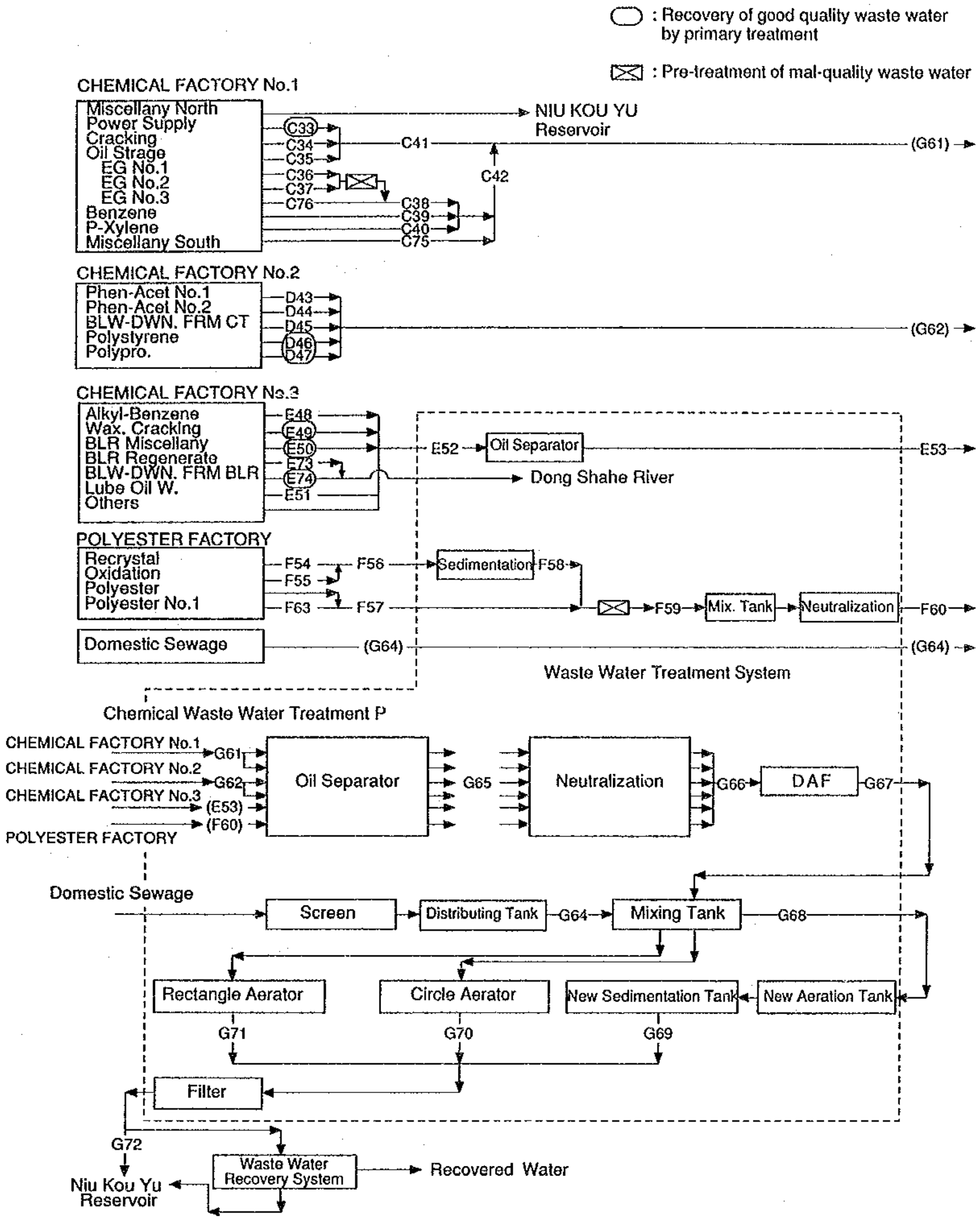


Fig. -7(1) Locational Relations Among Waste Water Treatment and Recovery Systems (Taiyuan North) Case 1

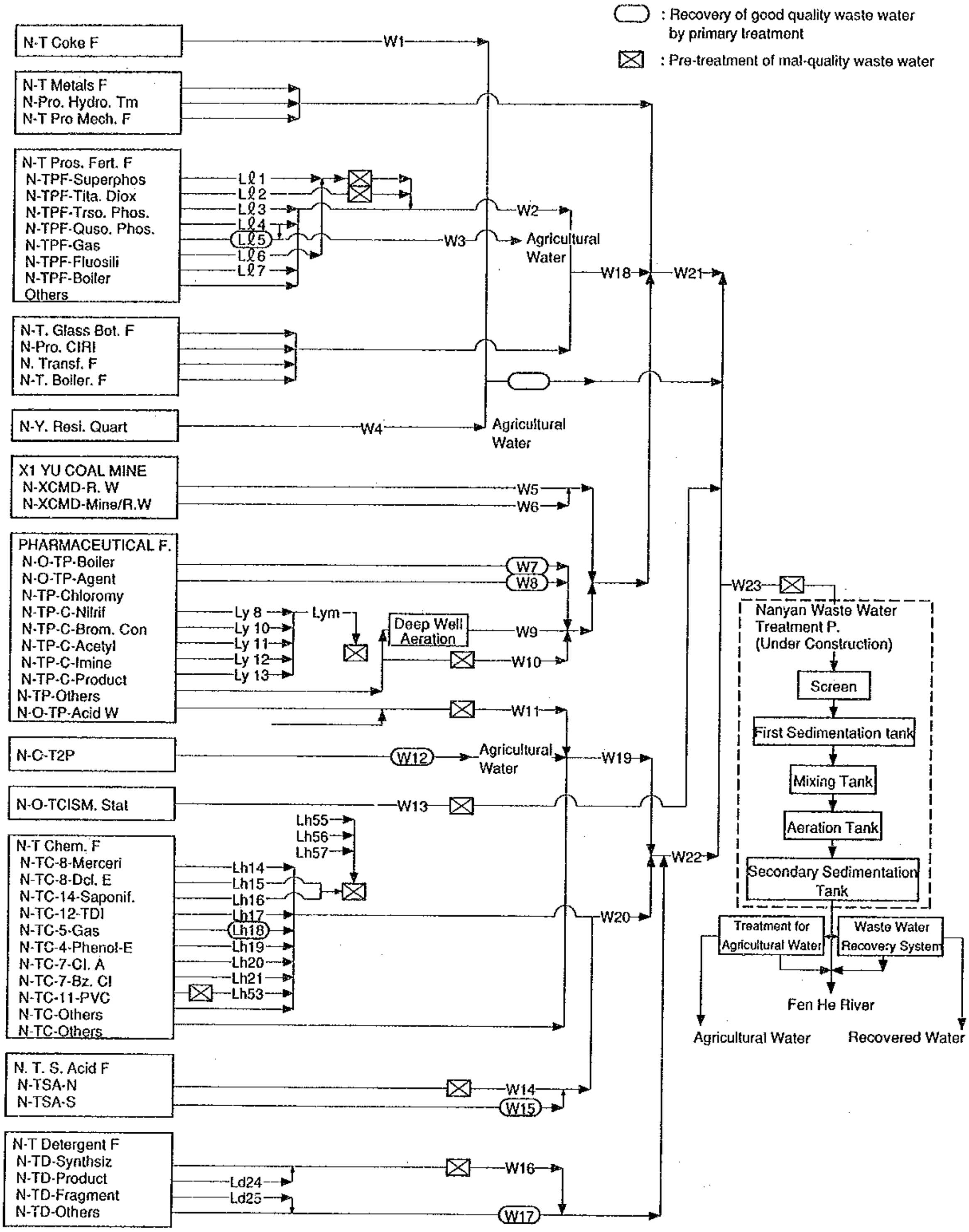


Fig. -7(2) Locational Relations Among Waste Water Treatment and Recovery Systems (Taiyuan North) Case 2

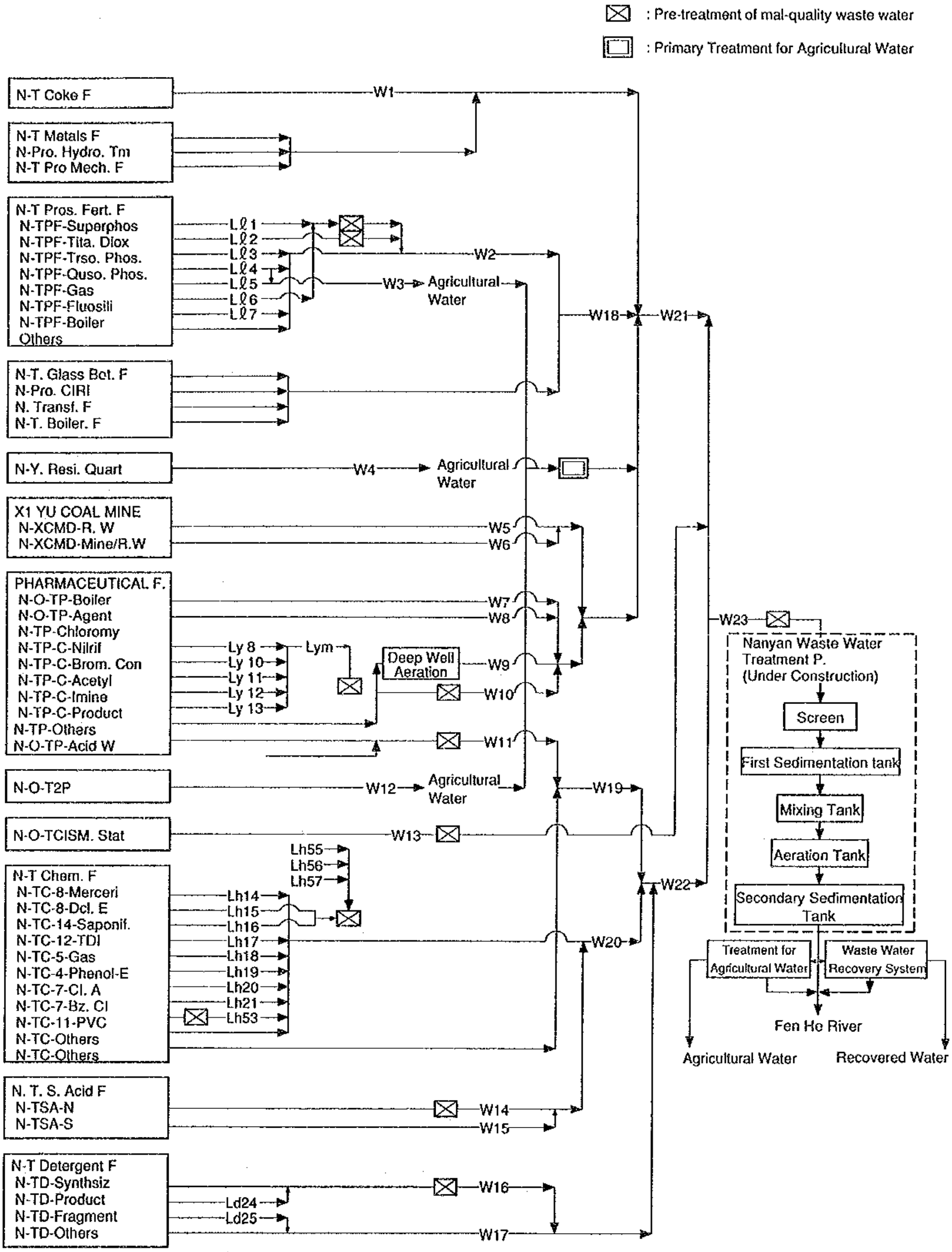
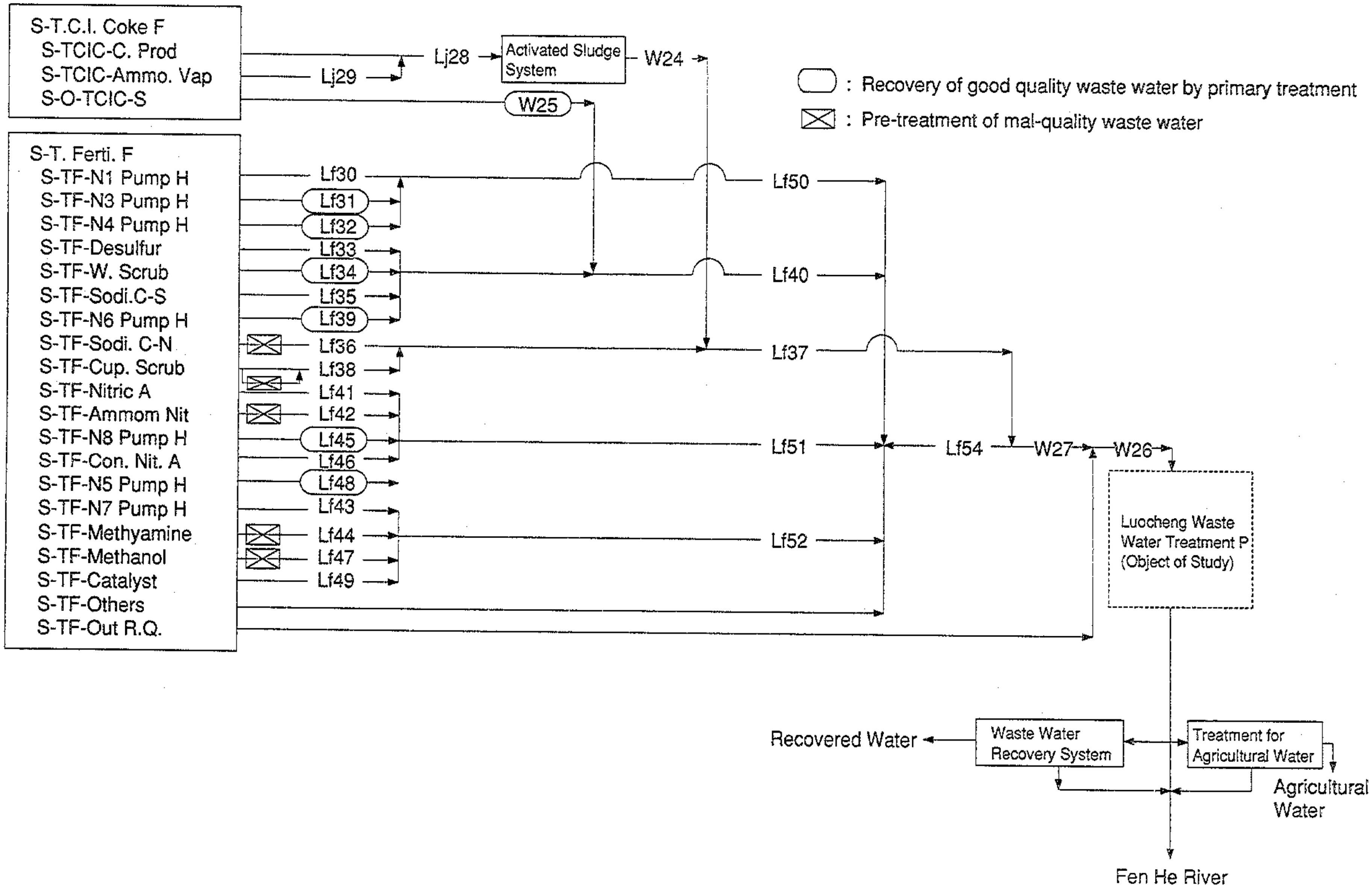


Fig. 8 Locational Relations among Waste Water Treatment and Recovery Systems (Taiyuan South)



2. Preconditions for Treatment and Recovery of Waste Water

2.1 Preconditions for waste water treatment system

2.1.1 Estimated changes in volume and quality of waste water flowing into final waste water treatment plants

Volume and quality of waste water flowing into final waste water treatment plants will be changed under the influence of preparatory treatment of waste water with mal-quality and recovery after primary treatment of waste water with good quality. Result of the estimation is shown below.

(1) Yanshan district

1) Oil refinery waste water treatment plant

Changes in the volume and major quality of waste water flowing in after various treatments are shown in Table 7.

Table 7 Summary of Changes in Volume and Quality of Waste Water Flowing in

Figures in ( ) indicate pollution load (kg/day)

Case \ Volume/quality	Flow rate (m^3/day)	Conductivity (μs/cm)	SS (mg/ℓ)	COD_{Mn} (mg/ℓ)	COD_{cr} (mg/ℓ)	Oil (mg/ℓ)
Current condition	19,200	631	145 (2,784)	146 (2,803)	660 (12,672)	737 (14,150)
Case 1	18,573	632	149 (2,777)	151 (2,802)	680 (12,633)	755 (14,016)
Case 2	19,200	631	145 (2,780)	146 (2,809)	660 (12,665)	737 (14,146)

Note: Case 1 includes primary treatment and recovery and the case 2 does not.

2) Petrochemical waste water treatment plant

Changes in the volume and major quality of waste water flowing in are shown in Table 8 for each case as in those of oil refinery waste water treatment plant.

Table 8 Summary of Changes in Volume and Quality of Waste Water Flowing in

Figures in ( ) indicate pollution load (kg/day)

Volume/quality \ Case	Flow rate (m^3/day)	Conductivity (μs/cm)	SS (mg/ℓ)	COD_{Mn} (mg/ℓ)	COD_{cr} (mg/ℓ)	Oil (mg/ℓ)
Current condition	38,400	807	57 (2,189)	266 (10,210)	674 (25,894)	43 (1,651)
Case 1	27,600	887	77 (2,119)	181 (4,993)	629 (17,365)	59 (1,619)
Case 2	38,400	807	57 (2,173)	134 (5,146)	466 (17,905)	43 (1,651)

Note: The values of the volume and quality are those at the junction point (2) including domestic waste water from residential area.

(2) Taiyuan district

1) Nanyan waste water treatment plant

Changes in the volume and major quality of waste water flowing in after various treatment are shown in Table 9.

Table 9 Summary of Changes in Volume and Quality of Waste Water Flowing in

Figures in ( ) indicate pollution load (kg/day)

Volume/quality \ Case	Flow rate (m^3/day)	Conductivity (μs/cm)	SS (mg/ℓ)	COD_{cr} (mg/ℓ)	Oil (mg/ℓ)
Case 1A	47,458	4,622 (14,281)	301 (10,773)	227 (595)	13
Case 1B	47,458	4,622 (14,281)	301 (10,773)	227 (595)	13
Case 2A	52,064	4,342 (13,465)	259 (10,127)	195 (589)	11
Case 2B	59,564	3,997 (13,560)	227 (10,427)	175 (597)	10
Current condition	43,932	4,995 (14,774)	336 (24,341)	554 (1,722)	39

Notes: 1. Case 1 includes primary treatment and recovery and the case 2 does not.

2. The volume of agricultural water in the Southern district in the case A is at the rate of 10,000 m^3/day and that in the case B at 20,000 m^3/day.

2) Luocheng waste water treatment plant

Changes in the volume and major quality of waste water flowing in are shown in Table 10 for each case as those in the Nanyan waste water treatment plant.

Table 10 Summary of Changes in Volume and Quality of Waste Water Flowing in

Figures in ( ) indicate pollution load (kg/day)

Volume/quality Case	Flow rate (m^3/day)	Conductivity (μs/cm)	SS (mg/ℓ)	COD_{cr} (mg/ℓ)	Oil (mg/ℓ)
Case 1A	39,450	6,674	232 (9,162)	75 (2,939)	4 (161)
Case 1B	39,450	6,674	232 (9,162)	75 (2,939)	4 (161)
Case 2A	64,500	4,455	144 (9,313)	55 (3,541)	3 (176)
Case 2B	57,000	4,831	162 (9,238)	57 (3,241)	3 (169)
Current condition	45,000	5,692	206 (9,270)	212 (9,540)	5 (225)

2.1.2 Estimated changes in volume and quality of water flowing out of final waste water treatment plants

Estimated changes in volume and quality of water flowing out of each final waste water treament plant corresponding to volume and quality of waste water flowing in is shown below.

(1) Yanshan district

1) Oil refinery waste water treatment plant

Comparison between estimated result of volume and quality of water flowing out and various standards for waste water is shown in Table 11.

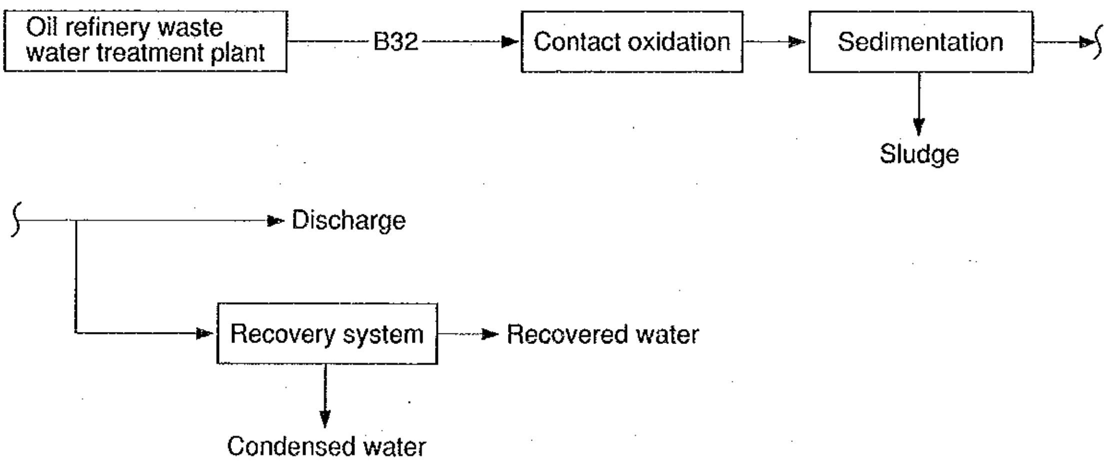
Table 11 Volume and Quality of Water Flowing out of Oil Refinery Waste Water Treatment Plant

Case	Flow rate (m^3/day)	Conductivity (μs/cm)	SS (mg/ℓ)	CODcr (mg/ℓ)	Oil (mg/ℓ)	Cl^- (mg/ℓ)	TDS (mg/ℓ)	NH_3-N (mg/ℓ)
Current condition	13,200 13,200	600 600	191 13	890 66	1,069 8	121 30	1,091 1,155	35 100
Case 1	18,574 18,574	632 632	149 14	680 112	755 8	102 102	899 899	28 22
Case 2	19,200 19,200	631 631	145 15	660 116	737 8	99 99	870 870	28 25
Standard for oil refinery waste water Standard of Beijing (class 3, existing) Standard of Beijing (class 2, existing)			200 100 70	200 100 80	20 10 5		 1,200 900	

Note: Upper line indicate conditions of flow-in water and the lower line those of flow-out water.

According to the result of the above table, CODcr and oil contents represent unsatisfactory level requiring additional treatment. Contact oxidation method was considered to solve this problem.

System of this method is as follows.



Estimated water quality discharged after the contact oxidation and sedimentation treatment is shown in Table 12.

Table 12 Estimated Water Quality Flowing out after Additional Treatment

Case	Flow rate	Conductivity	SS	CODcr	Oil	Cl^-	TDS	NH_3-N
	(m^3/day)	(μs/cm)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)
Case 1	18,574 18,574	632 632	14 14	112 70	8 5	102 102	899 899	22 20
Case 2	19,200 19,200	631 631	15 15	116 70	8 5	99 99	870 870	25 20

Note: The upper line indicate the flow-in conditions (water flowing out of existing wate water treatment plant) and the lower line the flow-out conditions (water flowing out after additional treatment).

2) Petrochemical waste water treatment plant

Comparison between estimated result of volume and quality of water flowing out of petrochemical waste water treatment plant and various standards for waste water is shown in Table 13.

Table 13 Volume and Quality of Water Flowing out of Petrochemical Waste Water Treatment Plant

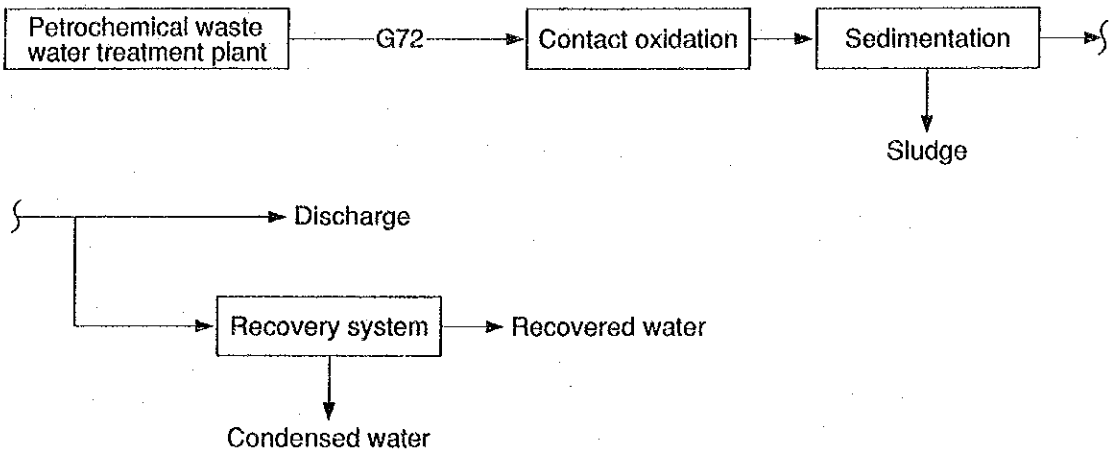
Case	Flow rate	Conductivity	SS	CODcr	Oil	Cl^-	TDS	NH_3-N
	(m^3/day)	(μs/cm)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)
Current condition	38,400 38,400	807 600	57 33	674 261	43 5	– 84	– 682	– 21
Case 1	27,600 27,600	887 887	77 32	629 176	59 5	184 184	1,539 1,539	31 27
Case 2	38,400 38,400	807 807	57 33	466 189	43 5	132 132	1,106 1,106	22 19
Standard for petrochemical waste water Standard of Beijing (class 3, existing) Standard of Beijing (class 2, existing)			100 100 70	200 100 80	10 10 5		 1,200 900	

Notes: 1. Upper line indicate flow-in conditions and the lower line flow-out conditions.

2. Figures of flow-in conditions are those at conjunction point (2) including domestic waste water from residential area.

According to the result of the above table, CODcr represents unsatisfactory level requiring additional treatment. Contact oxidation method was also considered as in the case of oil refinery waste water treatment plant.

System of this method is shown below.



Estimated quality of water flowing out after the contact oxidation and sedimentation treatment is shown in Table 14.

Table 14 Estimated Quality of Water Flowing out after Additional Treatment

Case	Flow rate	Conductivity	SS	CODcr	Oil	Cl⁻	TDS	NH_3-N
	(m^3/day)	(μs/cm)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)
Case 1	27,600 27,600	887 887	32 32	176 75	5 3	184 184	1,539 1,539	27 25
Case 2	38,400 38,400	807 807	33 33	189 80	5 3	132 132	1,106 1,106	19 17

Note: The upper line indicate flow-in conditions (water flowing out of existing waste water treatment plant) and the lower line the flow-out conditions (water flowing out after additional treatment).

(2) Taiyuan district

1) Nanyan waste water treatment plant

Estimated volume and quality of water flowing out are shown in Table 15.

Table 15 Volume and Quality of Water Flowing out of Nanyan Waste Water Treatment Plant

Case	Flow rate	Conductivity	SS	CODcr	Oil	Cl^-	TDS	NH_3-N
	(m^3/day)	(μs/cm)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)
1A	47,458 47,458	4,622 4,622	301 65	227 39	13 7	1,670 1,670	3,747 3,747	36 31
1B	47,458 47,458	4,622 4,622	301 65	227 39	13 7	1,670 1,670	3,747 3,747	36 31
2A	52,064 52,064	4,342 4,342	259 61	195 39	11 6	1,524 1,524	3,492 3,492	31 27
2B	59,564 59,564	3,997 3,997	227 61	175 43	10 7	1,358 1,358	3,304 3,304	30 26

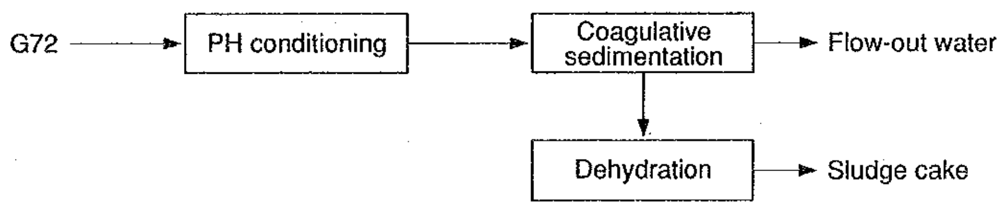
Note: Upper line indicate flow-in conditions and the lower line the flow-out conditions.

2) Luocheng waste water treatment plant

① Quality of flow-in water and assumed treatment technique

Volume and quality of waste water flowing into the Luocheng waste water treatment plant to be considered are as shown in Table 10.

Judging from this water quality, biological treatment as the primary and secondary waste water treatment before the treatment for recovery system and agricultural water will be unnecessary. Thus, a treatment system composed of the following units was considered.



② Estimated volume and quality of flow-out water

Estimated volume and quality of water flowing out of the Luocheng waste water treatment plant are shown in Table 16.

Table 16 Volume and Quality of Water Flowing out of Luocheng Waste Water Treatment Plant

Case	Flow rate	Conductivity	SS	CODcr	Oil	Cl^-	TDS	NH_3-N
	(m^3/day)	(μs/cm)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)	(mg/ℓ)
1A	39,450 39,450	6,674 6,674	232 48	75 45	4 2	342 342	4,197 4,197	62 62
1B	39,450 39,450	6,674 6,674	232 48	75 45	4 2	342 342	4,197 4,197	62 62
2A	64,500 64,500	4,455 4,455	144 30	55 33	3 2	256 256	3,033 3,033	43 43
2B	57,000 57,000	4,831 4,831	162 33	57 35	3 2	263 263	3,169 3;169	46 46

Note: The upper line indicate flow-in conditions and the lower line the flow-out conditions.

2.2 Preconditions for recovery systems

2.2.1 Setting of recovered water volume

(1) Yanshan district

Based on the water shortage, volume to be subjected to primary treatment and recovered volume, recovery system and recovered volume and volume of water flowing out of waste water treatment plants in this district, cases are assumed as shown in Table 17.

Table 17 Assumed Cases for Recovered Water Volume

(unit: m^3/day)

Case and breakdown of water volume	Oil refinery factory	Petrochemical factory	Total
Case 1 (primary treatment and recovery)			
① Water shortage	7,200	19,200	26,400
② Volume subjected to primary treatment and recovered	626	10,800	11,426
③ Volume flowing out of waste water treatment plants	18,574	27,600	46,174
④ Recovered volume by recovery system	6,574	8,400	14,974
Case 2 (recovery system only)			
① Water shortage	7,200	19,200	26,400
② Volume subjected to primary treatment and recovered	0	0	0
③ Volume flowing out of waste water treatment plants	19,200	38,400	57,600
④ Recovered volume by recovery system	7,200	19,200	26,400

(2) Taiyuan district

Based on water shortage, volume to be subjected to primary treatment and recovered volume, recovery system and recovered volume and volume of water flowing out of waste water treatment plants in this district, cases are assumed as shown in Table 17.

Table 18 Assumed Cases for Recovered Water Volume

(unit: m³/day)

Case		Breakdown of water volume	Northern district	Southern district	Total
1A	①	Water shortage			50,000
	②	Volume subjected to primary treatment and recovered	21,069	20,016	41,085
	③	Volume flowing out of waste water treatment plants	47,458	39,450	86,908
	④	Recovered volume by recovery system	0	8,915	8,915
	⑤	Volume for agricultural use *1	14,118	10,000	24,118
1B	①	Water shortage			50,000
	②	Volume subjected to primary treatment and recovered	21,069	20,016	41,085
	③	Volume flowing out of waste water treatment plants	47,458	39,450	86,908
	④	Recovered volume by recovery system	0	8,915	8,915
	⑤	Volume for agricultural use *1	14,118	20,000	34,118
2A	①	Water shortage			50,000
	②	Volume flowing out of waste water treatment plants	52,064	64,500	116,564
	③	Recovered volume by recovery system	11,000	39,000	50,000
	④	Volume for agricultural use *1	2,690	10,000	24,118
	⑤	Volume for agricultural use *2	11,428	0	
2B	①	Water shortage			50,000
	②	Volume flowing out of waste water treatment plants	59,564	57,000	116,564
	③	Recovered volume by recovery system	26,000	24,000	50,000
	④	Volume for agricultural use *1	2,690	20,000	34,118
	⑤	Volume for agricultural use *2	11,428	0	

Note: Volume for agricultural use *1 : Treatment of water flowing out of waste water treatment plants

Volume for agricultural use *2 : Individual treatment for W3, W4 and W12 waste water

2.2.2 Assumed cases for waste water treatment and recovery system

(1) Yanshan district

In this district, preparatory treatment is applied to waste water from the oil refinery factory (A8) and 5 types of waste water from the petrochemical factory (C36, C37, F54, F55 and F57), additional treatment is applied to water flowing out of both waste water treatment plants and then a recovery system is examined for the 2 following cases.

Case 1 : Primary treatment and recovery, recovery system (recovered water volume by recovery system: 14,974 m^3/day)

Case 2 : Recovery system (recovered water volume by recovery system: 26,400 m^3/day)

1) Assumed cases for waste water treatment and recovery system and water volume

Based on the above description, 2 cases and water volume for them are finally assumed. They are shown in Figs. 9 and 10.

Fig. 9 Waste Water Treatment and Recovery System (Case 1) (unit: m^3/day)

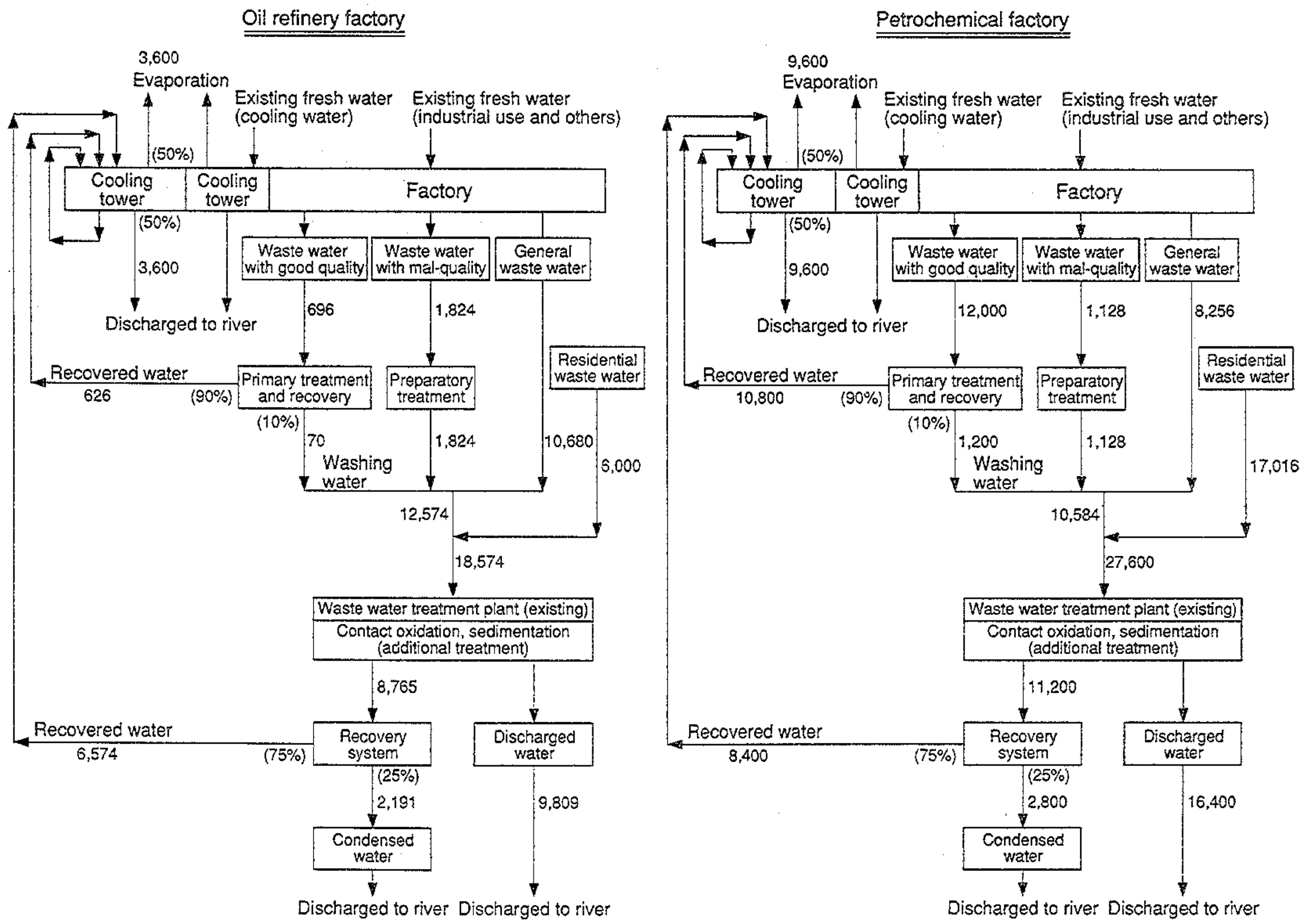
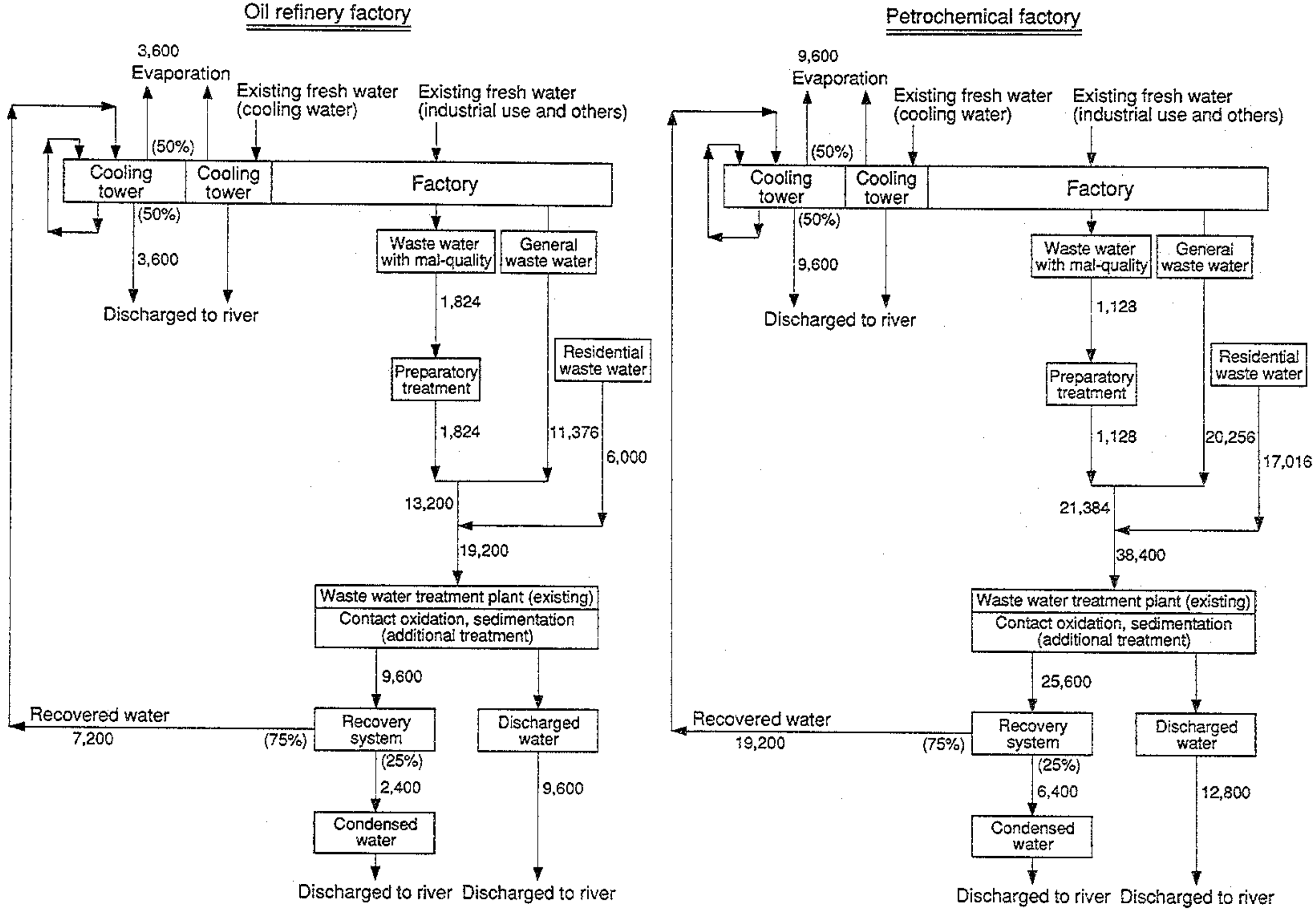


Fig. 10 Waste Water Treatment and Recovery System (Case 2) (unit: m^3/day)



(2) Taiyuan district

In this district, 12 types of waste water in the northern district (Lℓ1, Lℓ2, Lℓ6, Lym, W10, W11, W13, Lh15, Lh16, Lh53, W14, and W16) and 5 types of waste water in the southern district (Lf36, Lf38, Lf42, Lf44, and Lf47) are subjected to preparatory treatment and then recovery system is considered for the following 4 cases.

Case 1A : Primary treatment and recovery, recovery system (recovered water volume by recovery system: 8,915 m^3/day), and treatment of water for agricultural use (volume of agricultural water: 24,118 m^3/day)

Case 1B : Primary treatment and recovery, recovery system (recovered water volume by recovery system: 8,915 m^3/day) and treatment of water for agricultural use (volume of agricultural water: 34,118 m^3/day)

Case 2A : Recovery system (recovered water volume by recovery system: 50,000 m^3/day) and treatment of water for agricultural use (volume of agricultural water: 24,118 m^3/day)

Case 2B : Recovery system (recovered water volume by recovery system: 50,000 m^3/day) and treatment of water for agricultural use (volume of agricultural water: 34,118 m^3/day)

1) Assumed cases for waste water treatment and recovery system and water volume

Based on the above description, 4 cases and water volume for them are assumed finally. They are shown in from Fig. 11 to Fig. 14.

Fig. 11 Waste Water Treatment and Recovery System (Case 1A) (unit: m^3/day)

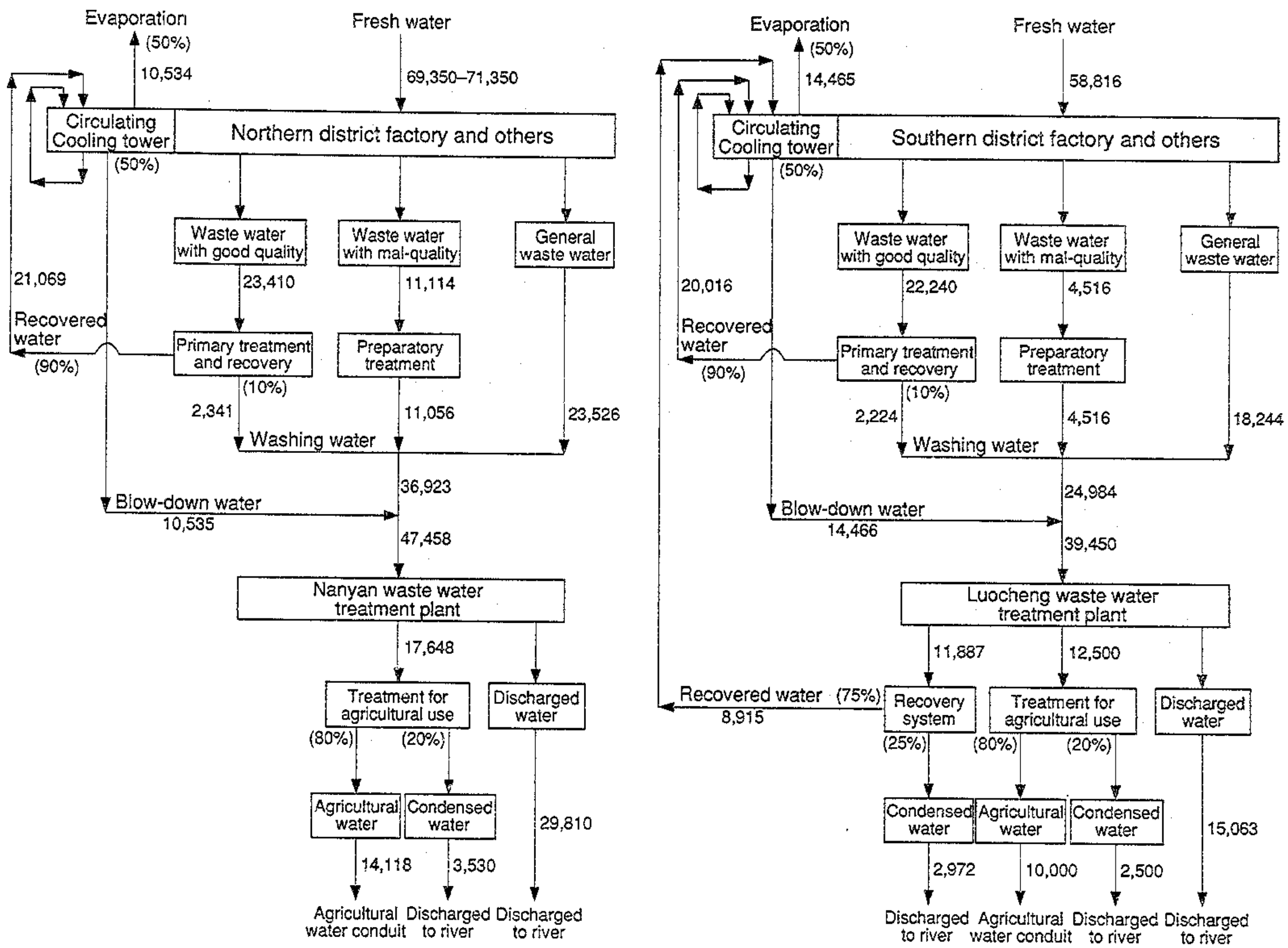


Fig. 12 Waste Water Treatment and Recovery System (Case 1B) (unit: m³/day)

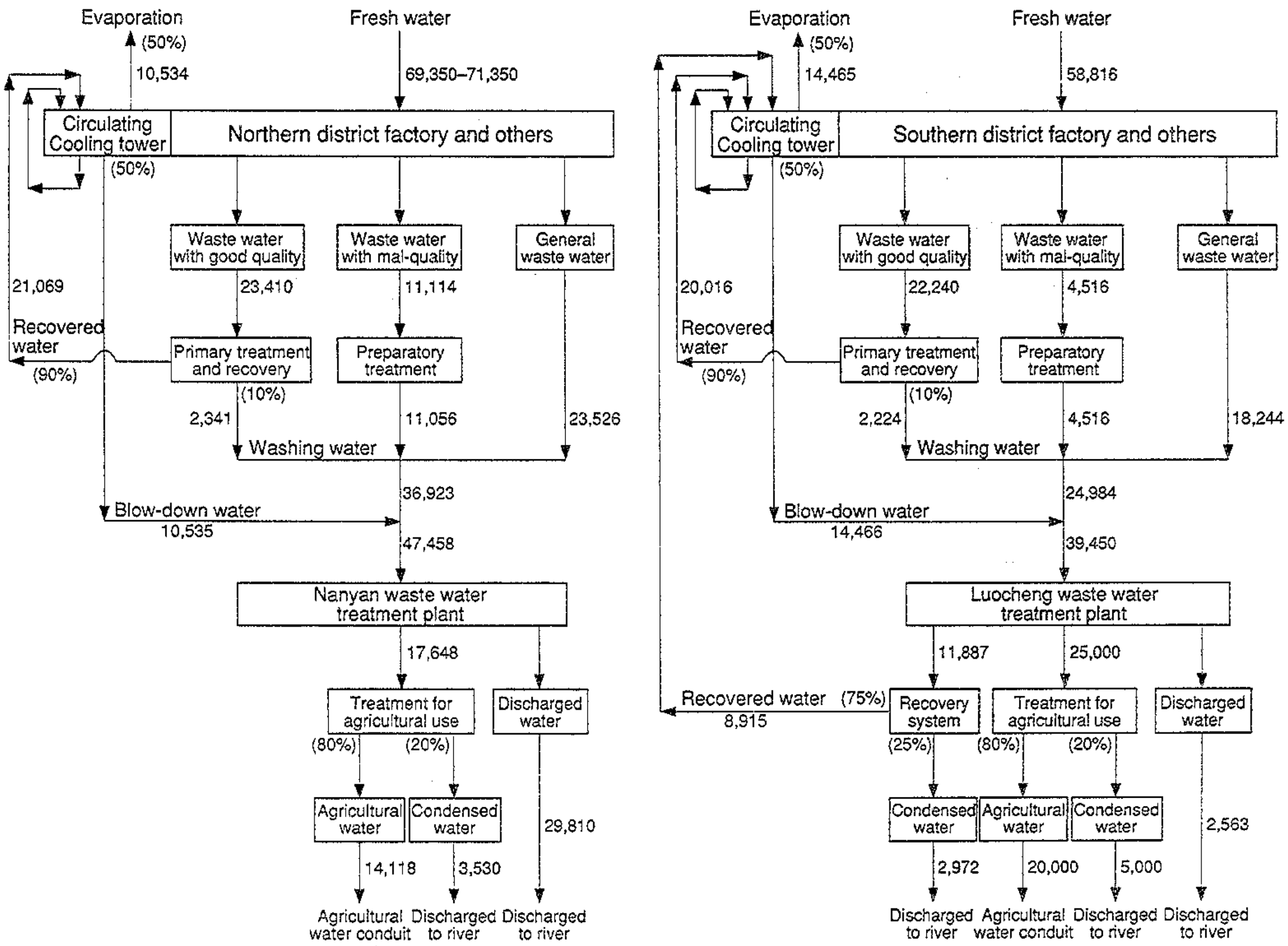


Fig. 13 Waste Water Treatment and Recovery System (Case 2A) (unit: m³/day)

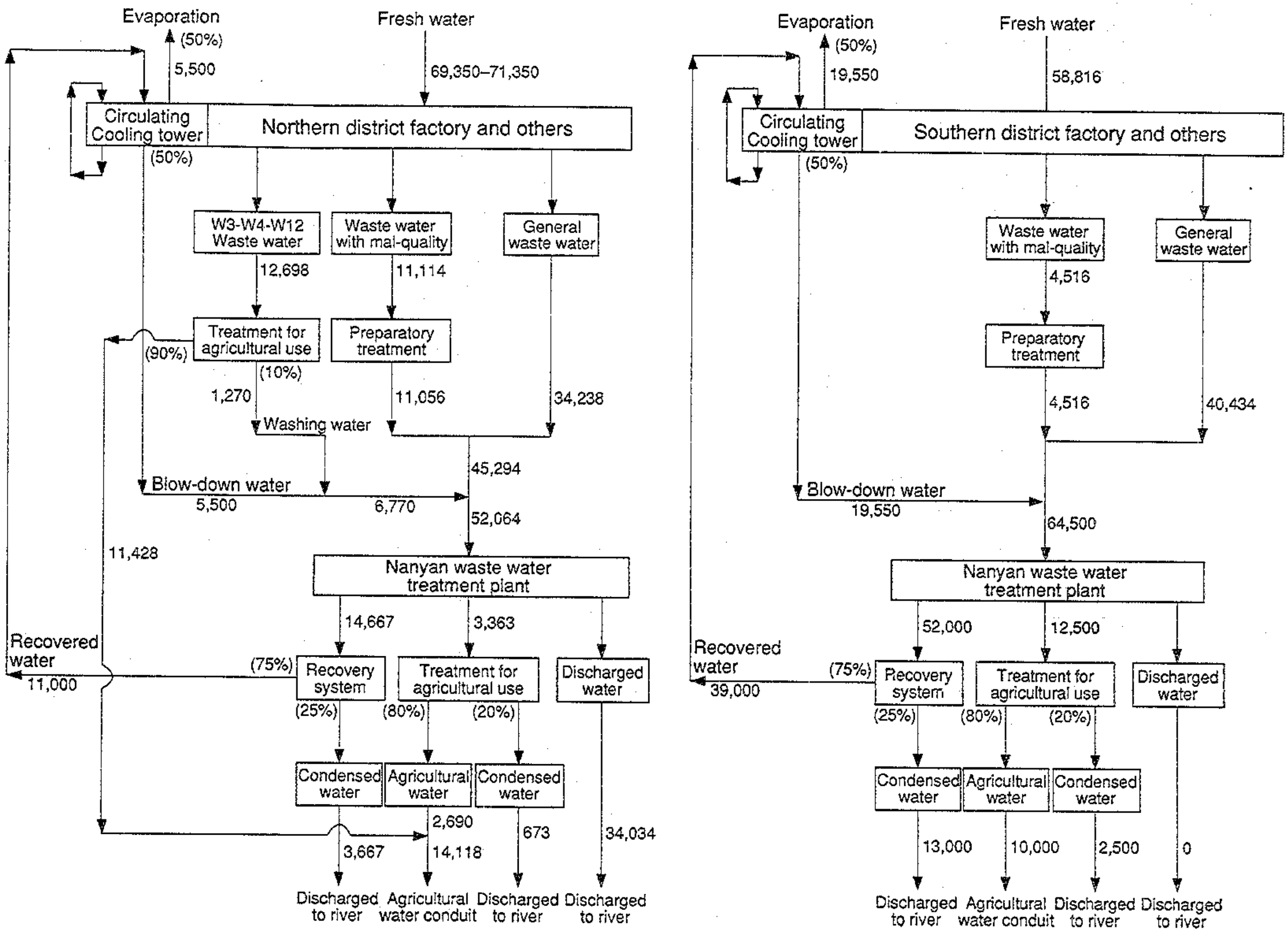
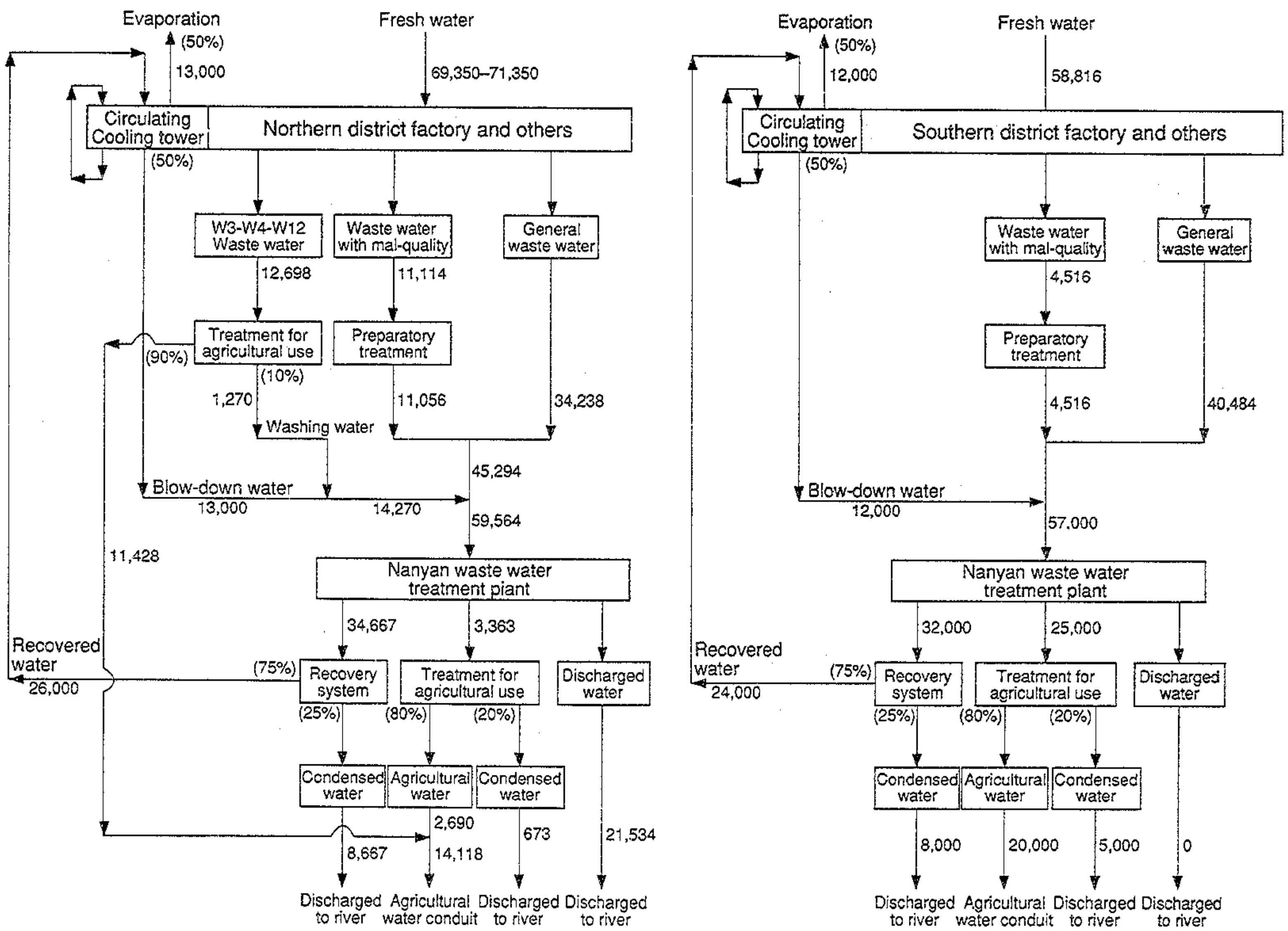


Fig. 14 Waste Water Treatment and Recovery System (Case 2B) (unit: m³/day)



2.2.3 Assumed cases for recovery system

(1) Yanshan district

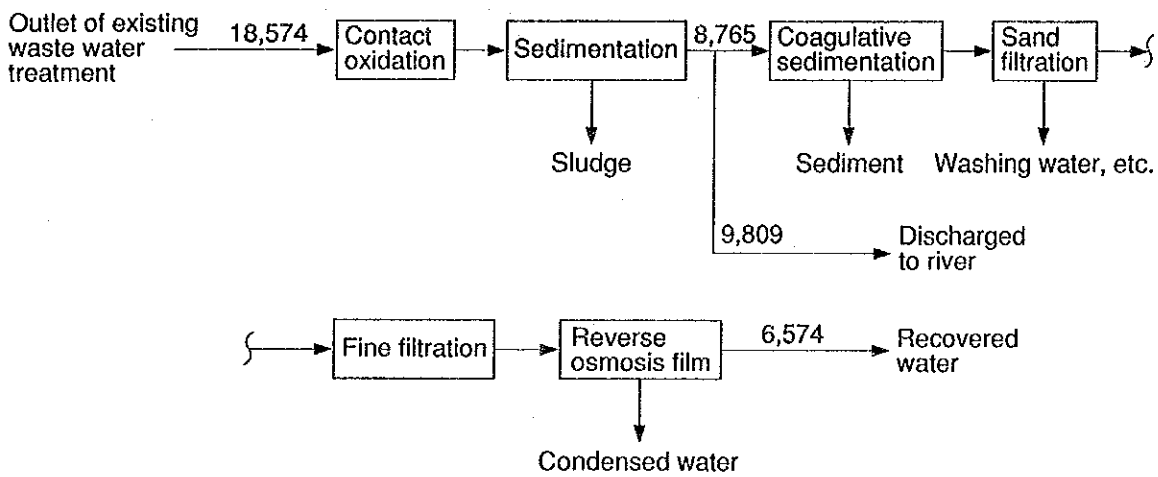
Composition of recovery systems are assumed for the cases 1 and 2 as shown below.

Preparatory treatment of waste water with mal-quality is applied for both cases.

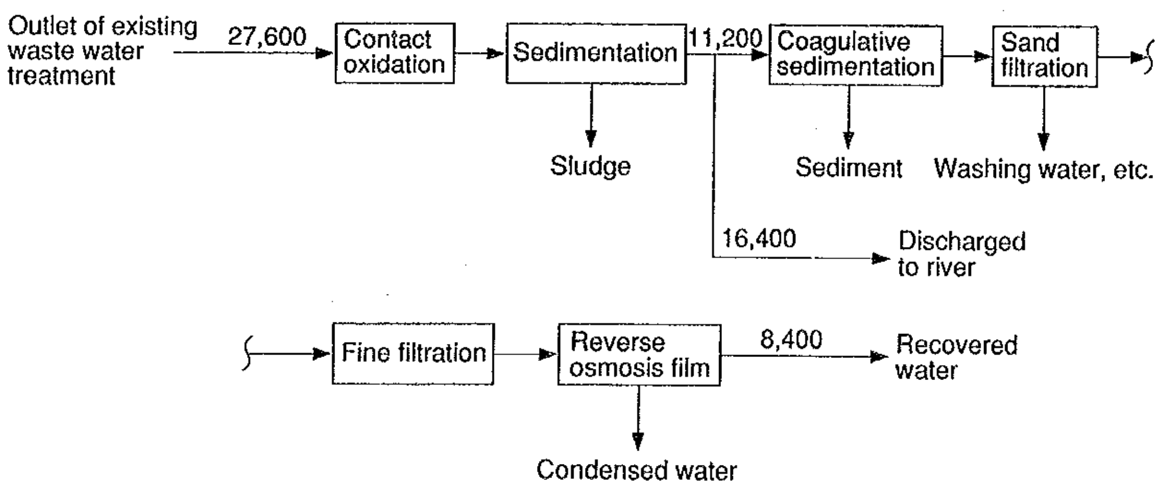
1) Case 1

(Unit: m^3/day)

① Oil refinery waste water treatment plant (additional treatment and recovery system)



② Petrochemical waste water treatment plant (additional treatment and recovery system)



③ Primary treatment and recovery of waste water with good quality from oil refinery factory, volume recovered: 626

ⓐ A13 waste water : PH conditioning, sand filtration (43)

ⓑ A7 waste water : sand filtration (108)

ⓒ A22 waste water : coagulative pressurized floatation, sand filtration, activated carbon (475)

④ Primary treatment and recovered of waste water with good quality from petrochemical factory, volume recovered: 10,800

ⓐ C33 waste water : PH conditioning, sand filtration, activated-carbon (1,080)

ⓑ D46, D47 waste water : coagulative pressurized floatation, sand filtration, activated carbon (8,856)

ⓒ E49 waste water : coagulative pressurized floatation, sand filtration (648)

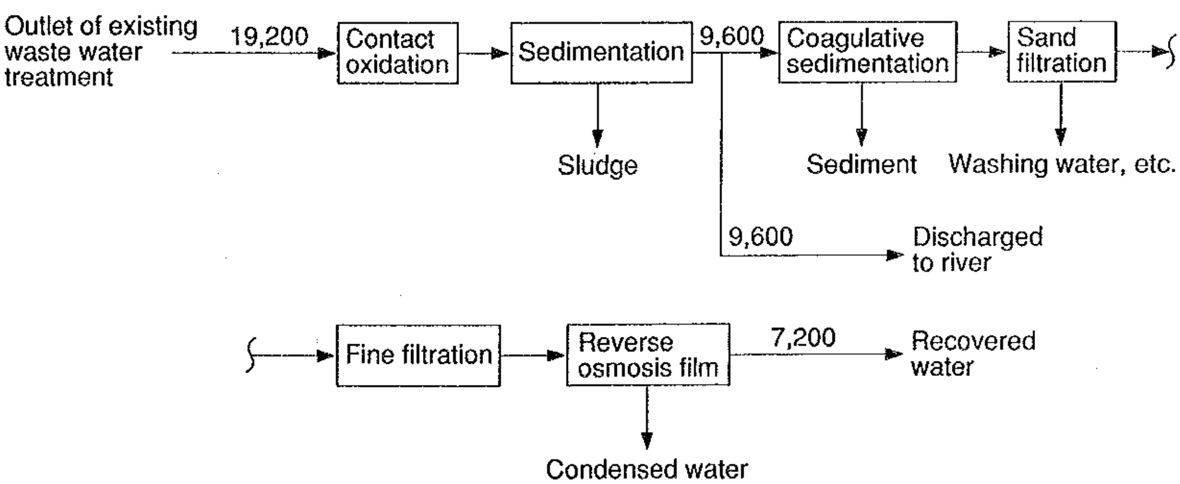
ⓓ E50 waste water : sand filtration (22)

ⓔ E74 waste water : oil adsorption (194)

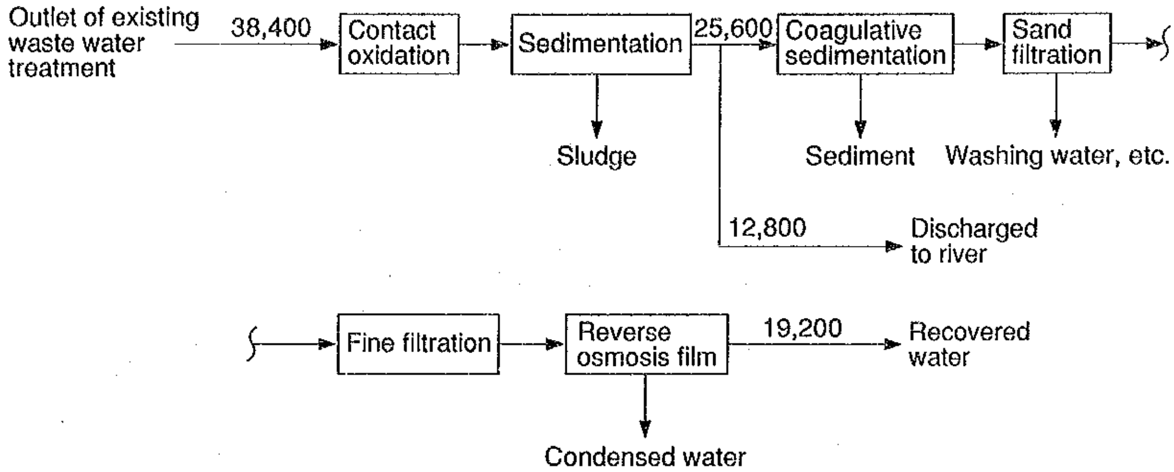
2) Case 2

(unit: m^3/day)

① Oil refinery waste water treatment plant (additional treatment and recovery system)



② Petrochemical waste water treatment plant (additional treatment and recovery system)



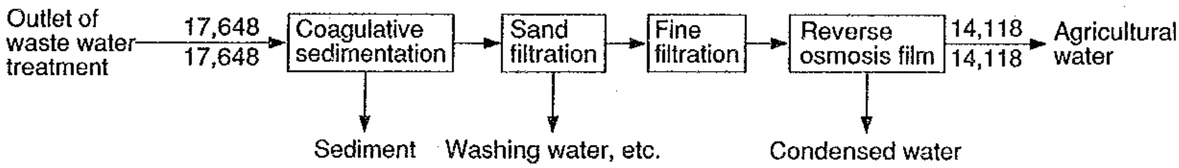
(2) Taiyuan district

Composition of recovery systems are assumed as below for the cases 1A – 2B. Preparatory treatment for waste water with mal-quality is applied commonly for all cases.

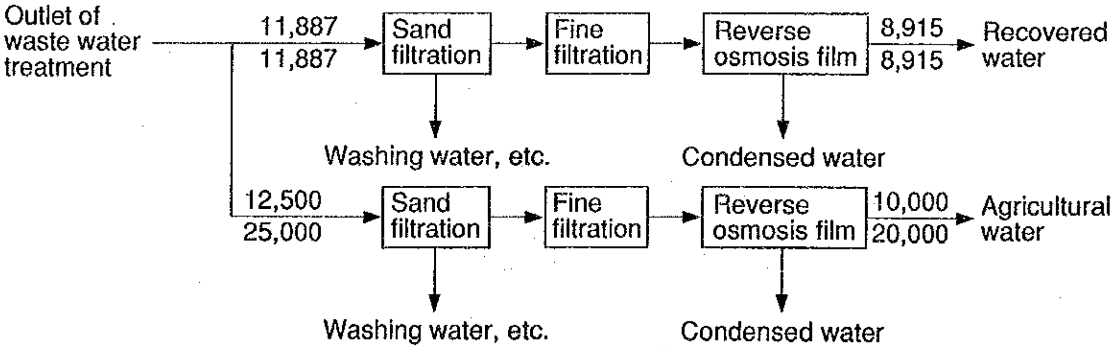
1) Case 1A and 1B

(unit: m^3/day)

① Nanyan waste water treatment plant (treatment for agricultural use)



② Luocheng waste water treatment plant (recovery system and treatment for agricultural use)



Note: Water volume of the upper line indicate that of the case 1A and the lower line that of the case 1B.

③ Primary treatment and recovery of waste water with good quality in northern district, volume recovered: 21,069 (common to cases 1A and 1B)

ⓐ	Lℓ5 waste water	:	sand filtration (108)
ⓑ	W1•W4 waste water	:	sand filtration, activated carbon (15,399)
ⓒ	W7 waste water	:	coagulative sedimentation (675)
ⓓ	W8 waste water	:	sand filtration (252)
ⓔ	W12 waste water	:	sand filtration (2,628)
ⓕ	W15 waste water	:	activated carbon (1,296)
ⓖ	W17 waste water	:	oil adsorption (279)
ⓗ	Lh18 waste water	:	coagulative sedimentation, sand filtration (432)

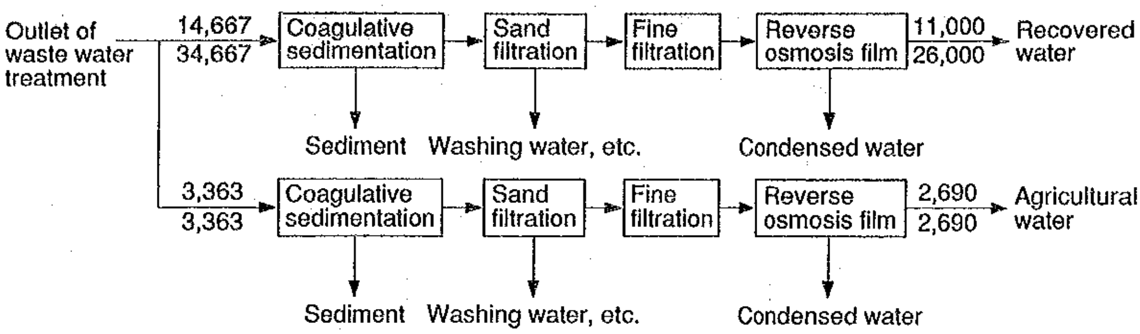
④ Primary treatment and recovery of waste water with good quality in southern district, volume recovered: 20,016 (common to cases 1A and 1B)

ⓐ	W25 waste water	:	sand filtration (1,800)
ⓑ	Lf34 waste water	:	sand filtration (432)
ⓒ	Lf39 waste water	:	sand filtration (4,320)
ⓓ	Lf31 waste water	:	sand filtration (3,024)
ⓔ	Lf32 waste water	:	sand filtration (1,404)
ⓕ	Lf48 waste water	:	sand filtration, activated carbon (6,880)
ⓖ	Lf45 waste water	:	coagulative sedimentation, sand filtration (2,160)

2) Case 2A and 2B

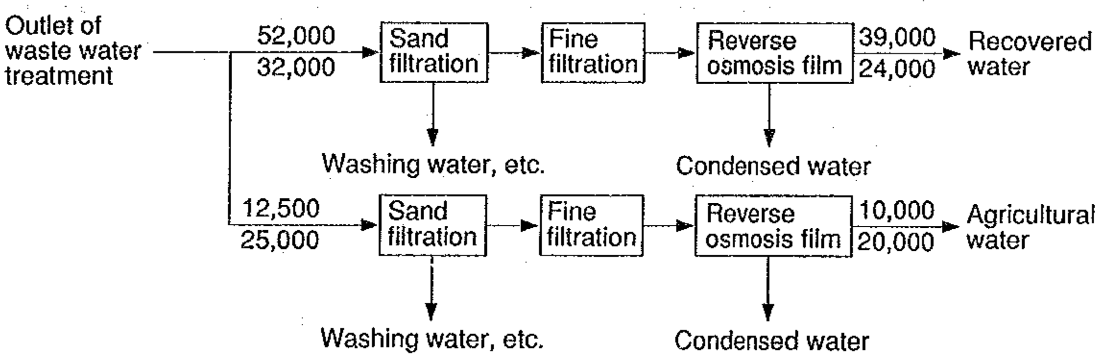
(unit: m^3/day)

① Nanyan waste water treatment plant (recovery system and treatment for agricultural use)



Note: Water volume of the upper line indicates that of the case 2A and the lower line that of the case 2B.

② Luocheng waste water treatment plant (recovery system and treatment for agricultural use)



Note: Water volume of the upper line indicates that of the case 2A and the lower line that of the case 2B.

③ Treatment of waste water with good quality in northern district for agricultural use (common to cases 2A and 2B)

W3•W4•W12 waste water : sand filtration (11,428)

VOLUME IV PLAN OF FACILITIES

In this volume, plan of facilities composed of the following items is proposed for various treatment systems of the waste water treatment and recovery as described below.

(1) System techniques and preconditions

(2) Flow sheet of facilities

(3) Plot plan of facilities

(4) Major equipment list

1. Preparatory Treatment Facilities

(1) Yanshan district

1) Oil refinery factory

① A8 waste water : oil separation

② A15 waste water : line switching over

2) Petrochemical factory

① C36, 37 waste water : liquid oxidation

② F54, 55, 57 waste water : liquid oxidation

(2) Taiyuan district

1) Northern district

① Lℓ1, 6 waste water : coagulative sedimentation

② Lℓ2 waste water : neutralization

③ Lh53 waste water : sulfide coagulative sedimentation

④ W14 waste water : sulfide coagulative sedimentation

⑤ W10 waste water : deep aeration

⑥ W11waste water : neutralization

⑦ W16 waste water : oil separation, coagulative pressurized floatation

⑧ W13 waste water : neutralization

⑨ Lym waste water : waste liquid burning

⑩ Lh15, 16, 55, 56, 57 waste water : waste liquid burning

⑪ W23 waste water : neutralization

2) Southern district

① Lf42 waste water : ammonia stripping, neutralization

② Lf44 waste water : ammonia stripping, coagulative sedimentation

③ Lf36 waste water : ammonia stripping, coagulative sedimentation

④ Lf38 (1) waste water : ammonia stripping, neutralization

⑤ Lf47 waste water : liquid oxidation

2. Final Waste Water Treatment Plant Facilities

(1) Yanshan district

1) Oil refinery waste water treatment plant : contact oxidation, sedimentation

2) Petrochemical waste water treatment plant : contact oxidation, sedimentation

(2) Taiyuan district

1) Luocheng waste water treatment plant : neutralization, coagulative sedimentation

3. Primary Treatment and Recovery Facilities

(1) Yanshan district

1) Oil refinery factory

① A7 waste water : sand filtration

② A13 waste water : neutralization, sand filtration

③ A22 waste water : coagulative pressurized floatation, sand filtration, activated carbon

2) Petrochemical factory

① C33 waste water : neutralization, sand filtration, activated carbon

② D46, 47 waste water : coagulative pressurized floatation, sand filtration, activated carbon

③ E49 waste water : coagulative pressurized floatation, sand filtration

④ E50 waste water : sand filtration

⑤ E74 waste water : oil adsorption

(2) Taiyuan district

1) Northern district

① Lℓ5 waste water : sand filtration

② W7 waste water : coagulative sedimentation, sand filtration

③ W8 waste water : sand filtration

④ W12 waste water : sand filtration

⑤ W15 waste water : activated carbon

⑥ W17 waste water : oil adsorption

⑦ Lh18 waste water : coagulative sedimentation, sand filtration

⑧ W1,4 waste water : sand filtration, activated carbon

2) Southern district

① W25 waste water : sand filtration

② Lf34 waste water : sand filtration

③ Lf39 waste water : sand filtration

④ Lf31 waste water : sand filtration

⑤ Lf32 waste water : sand filtration

⑥ Lf48 waste water : sand filtration, activated carbon

⑦ Lf45 waste water : coagulative sedimentation, sand filtration

4. Recovery System Facilities

(1) Yanshan district

1) Oil refinery factory : coagulative sedimentation, sand filtration, fine filtration, reverse osmosis film

2) Petrochemical factory : coagulative sedimentation, sand filtration, fine filtration, reverse osmosis film

(2) Taiyuan district

1) Northern district : coagulative sedimentation, sand filtration, fine filtration, reverse osmosis film

2) Southern district : sand filtration, fine filtration, reverse osmosis film

5. Recovery Facilities for Agriculture

(1) Taiyuan district

1) Northern district

① Recovery facilities for agriculture (1) : coagulative sedimentation, sand filtration, fine filtration, reverse osmosis film

② Recovery facilities for agriculture (2) : sand filtration

2) Southern district

① Recovery facilities for agriculture : sand filtration, fine filtration, reverse osmosis film

6. Sludge Treatment Facilities

(1) Taiyuan district

1) Northern district : fluidized incinerator

Refer to the study report for details of plan for each treatment facility.

VOLUME V IMPLEMENTAL PLAN FOR INTRODUCING WASTE WATER TREATMENT AND RECOVERY SYSTEM

1. Implemental System, Organization and Personnel

1.1 Promotion system of implementation

Preparatory treatment facilities, waste water treatment plant facilities, primary treatment and recovery facilities, recovery system facilities, and other facilities will be scattered over the factory, production plant and waste water plant areas in both districts. However, since design and operating conditions, construction schedule, construction cost and personnel of those facilities have close relation with each other, they should be progressed comprehensively in the overall districts. Therefore, organizing a project system as described below is proposed.

(1) Composition of project system

The project system shall be composed of related factory managers, waste water treatment plant managers, and managers in charge of water, accounting, environmental preservation, personnel, negotiation with outside of the corporation, procurement, construction, and facility preservation departments.

(2) Period of project duration

1) Period

From start of study on implemental plan to completion of test operation, that is, from April 1991 to December 1995.

2) Contents of implementation

① Evaluation of overall plan and preparation of implemental plan

② Preparation of implemental budget and securing of budgetary allocations

③ Overall procurement control of each treatment facility

④ Overall design and construction control

⑤ Making of organization plan and securing and education of personnel

1.2 Personnel plan

(1) Yanshan district

As shown in Table 19, 406 persons was assumed for the case 1 and 362 person for the case 2.

(2) Taiyuan district

As shown in Table 20,900 persons was assumed for the case 1A, 924 persons for the case 1B, 936 persons for the case 2A and 984 persons for the case 2B.

All of the personnel shall be secured by 2 months prior to start of test operation (3 months prior to commercial operation). Some personnel at the rate of 1/50 shall study and be trained in Japan for 1 month.

Table 19 Summary of Personnel Plan for Yanshan District

Item \ Case	Case 1			Case 2		
	Office work	Operation control	Mainte-nance	Office work	Operation control	Mainte-nance
1. Oil refinery factory						
① Preparatory treatment	0	0	0	0	0	0
② Primary treatment/recovery	0	16	0	0	0	0
③ Additional treatment	0	0	0	0	0	0
④ Recovery system	17	84	36	17	84	36
Subtotal	17	100	36	17	84	36
Total	153			137		
2. Petrochemical factory						
① Preparatory treatment	0	48	4	0	48	4
② Primary treatment/recovery	0	56	4	0	0	0
③ Additional treatment	0	0	0	0	0	0
④ Recovery system	17	88	36	17	120	36
Subtotal	17	192	44	17	168	40
Total	253			225		
Subtotal for Yanshan	34	292	80	34	252	76
Total for Yanshan District	406			362		

Table 20 Summary of Personnel Plan for Taiyuan District

Item \ Case	Case 1A			Case 1B			Case 2A			Case 2B		
	Office work	Operation control	Mainte-nance	Office work	Operation control	Mainte-nance	Office work	Operation control	Mainte-nance	Office work	Operation control	Mainte-nance
1. Northern district												
① Preparatory treatment	0	132	20	0	132	20	0	132	20	0	132	20
② Primary treatment/recovery	0	72	8	0	72	8	0	0	0	0	0	0
③ Recovery for agriculture (2)	0	0	0	0	0	0	0	44	8	0	44	8
④ Recovery system	0	0	0	0	0	0	16	88	36	24	124	44
⑤ Recovery for agriculture (1)	16	88	36	16	88	36	0	40	16	0	40	16
⑥ Sludge treatment	4	15	4	4	15	4	4	15	4	4	15	4
Sub-total	20	307	68	20	307	68	20	319	84	28	355	92
Total		395			395			423			475	
2. Southern district												
① Preparatory treatment	0	156	24	0	156	24	0	156	24	0	156	24
② Primary treatment/recovery	0	76	8	0	76	8	0	0	0	0	0	0
③ Luocheng waste water treatment plant	17	64	36	17	64	36	25	80	52	25	80	52
④ Recovery system	4	38	20	4	38	20	4	74	36	4	54	28
⑤ Recovery for agriculture	4	38	20	4	54	28	4	38	20	4	54	28
Sub-total	25	372	108	25	388	116	33	348	132	33	344	132
Total		505			529			513			509	
Subtotal for Taiyuan district	45	679	176	45	695	184	53	667	216	61	699	224
Total for Taiyuan district		900			924			936			984	

Note: Recovery for agriculture (1) : Originated from water outlet of Nanyan waste water treatment plant
Recovery for agriculture (2) : Originated from combined W3, W4, and W12 waste water

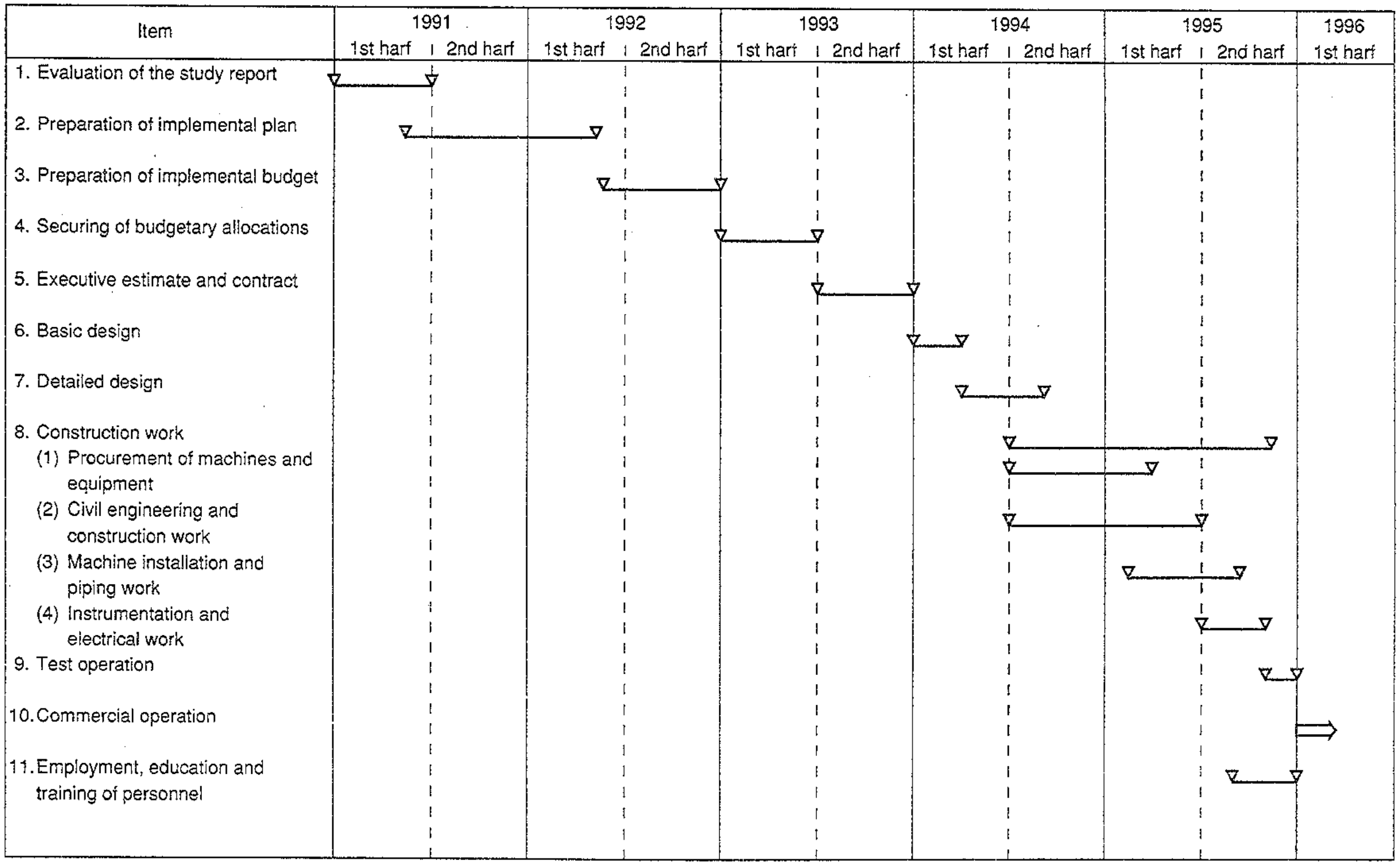
2. Implemental Schedule

Implemental schedule for introducing waste water treatment and recovery systems is as described below, for both districts.

As a precondition for making out the implemental schedule, it was assumed to complete the project within the period of the 8th 5-year plan (by the end of December 1995). Overall schedule (procedure and progress) is shown in Table 21. Outline of the schedule is summarized below.

(1)	Evaluation of the study report	:	Jan. '91	–	June '91
(2)	Preparation of implemental plan	:	Apr. '91	–	Mar. '92
(3)	Preparation of implemental budget	:	Apr. '92	–	Dec. '92
(4)	Securing of budgetary allocations	:	Jan. '93	–	June '93
(5)	Executive estimate and contract	:	July '93	–	Dec. '93
(6)	Basic design	:	Jan. '94	–	Apr. '94
(7)	Detailed design	:	Apr. '94	–	Sept. '94
(8)	Procurement of machines and equipment	:	July '94	–	Mar. '95
(9)	Civil engineering & construction work	:	July '94	–	June '95
(10)	Machine installation & piping work	:	Feb. '95	–	Sept. '95
(11)	Instrumentation and electric work	:	July '95	–	Nov. '95
(12)	Test operation	:	Dec. '95	–	Dec. '95
(13)	Commercial operation	:	Jan. '96	–	

Table 21 Schedule of Waste Water Treatment and Recovery Project



VOLUME VI FINANCIAL/ECONOMIC ANALYSIS AND OVERALL EVALUATION

1. Total Capital Requirement

Total capital requirement is the total of construction cost, pre-operating expense, leasehold fee, and interest during construction.

(1) Total capital requirement for the Yanshan district is shown in Table 22 and that of each case is as follows.

Case 1 : 416,080,000 yuan

Case 2 : 465,470,000 yuan

(2) Total capital requirement for the Taiyuan district is shown in Table 23 and that of each case is as follows.

Case 1A : 748,290,000 yuan

Case 1B : 808,490,000 yuan

Case 2A : 875,100,000 yuan

Case 2B : 943,870,000 yuan

Outline of individual expense is shown below.

1.1 Construction cost

Construction cost was calculated based on the result of conceptual design according to the preconditions and method as follows.

(1) Calculation base : Prices in Japan in October 1990

(2) Conversion to prices in China

1) Machines and equipment : Japanese prices × 1.0

2) Field construction : Japanese prices × 0.6

3) Exchange rate : 25 yen/yuan (5.2221 yuan/US dollars)

(3) Construction period : 24 months (Jan. 1994- Dec. 1995)

Table 22 Total Capital Requirement (Yanshan)

(Unit: 10,000 yuan)

Item		Case 1	Case 2
Oil refinery	1. Construction cost	9,731.3	10,050.7
	2. Pre-operating expense	(1,112.0)	(1,137.6)
	(1) Personnel training expense	28.2	23.4
	(2) Test operation expense	51.5	51.5
	(3) Official work cost, etc.	12.6	11.5
	(4) Leasehold fee	33.5	33.8
	(5) Interest during construction	986.1	1,017.4
	Total	10,843.3	11,188.3
Petrochemical	1. Construction cost	27,714.7	31,843.9
	2. Pre-operating expense	(3,049.8)	(3,515.1)
	(1) Personnel training expense	41.8	36.2
	(2) Test operation expense	116.3	156.6
	(3) Official work cost, etc.	22.3	22.4
	(4) Leasehold fee	71.8	84.4
	(5) Interest during construction	2,797.6	3,215.5
	Total	30,764.5	35,359.0
Total of Yanshan district	1. Construction cost	37,446	41,894.6
	2. Pre-operating expense	(4,161.8)	(4,652.7)
	(1) Personnel training expense	70	59.6
	(2) Test operation expense	167.8	208.1
	(3) Official work cost, etc.	34.9	33.9
	(4) Leasehold fee	105.3	118.2
	(5) Interest during construction	3,783.7	4,232.9
	Total	41,607.8	46,547.3

Table 23 Total Capital Requirement (Taiyuan)

(Unit: 10,000 yuan)

	Item	Case 1A	Case 1B	Case 2A	Case 2B
Northern district	1. Construction cost	27,408.8	27,408.8	22,939.7	33,611.2
	2. Pre-operating expense	(3,218.1)	(3,218.1)	(2,704.9)	(3,898.4)
	(1) Personnel training expense	57.1	57.1	62.7	69.5
	(2) Test operation expense	278.3	278.3	233.7	332.9
	(3) Official work cost, etc.	38.9	38.9	38.7	46.9
	(4) Leasehold fee	58.8	58.8	37.8	38.1
	(5) Interest during construction	2,785.1	2,785.1	2,332.1	3,411.0
	Total	30,626.9	30,626.9	25,644.6	37,509.6
Southern district	1. Construction cost	39,540.7	44,961.2	55,415.3	50,928.8
	2. Pre-operating expense	(4,661.2)	(5,261.2)	(6,449.8)	(5,948.3)
	(1) Personnel training expense	75.1	76.3	75.6	75.2
	(2) Test operation expense	416.1	456.4	561.9	520.4
	(3) Official work cost, etc.	53.4	56.6	61.0	58.4
	(4) Leasehold fee	97.0	104.9	125.5	122.0
	(5) Interest during construction	4,019.6	4,567.1	5,625.9	5,172.3
	Total	44,201.9	50,222.4	61,865.1	58,877.1
Total of Taiyuan district	1. Construction cost	66,949.5	72,370	78,355	84,540
	2. Pre-operating expense	(7,879.3)	(8,479.3)	(9,154.7)	(9,846.7)
	(1) Personnel training expense	132.2	133.4	138.3	144.7
	(2) Test operation expense	694.4	734.7	795.6	853.3
	(3) Official work cost, etc.	92.3	95.5	99.7	105.3
	(4) Leasehold fee	155.8	163.7	163.3	160.1
	(5) Interest during construction	6,804.7	7,352.2	7,958	8,583.3
	Total	74,828.8	80,849.3	87,509.7	94,386.7

(4) Calculation result

1) Construction cost for the Yanshan district is shown in Table 24 and that of each case is shown below.

Case 1 : 374,460,000 yuan

Case 2 : 418,950,000 yuan

2) Construction cost for the Taiyuan district is shown in Table 25 and that of each case is as follows.

Case 1A : 669,500,000 yuan

Case 1B : 723,700,000 yuan

Case 2A : 783,550,000 yuan

Case 2B : 845,400,000 yuan

1.2 Personnel training expense

(1) Training of core personnel in Japan

① Applicable personnel : core technical personnel in charge of operation (one/50 personnel)

② Period : 1 month

③ Expense required : 40,000 yuan/head

(2) Training of all personnel

It was assumed that all personnel are trained for 2 months before the start of test operation and labor, official work and administration expenses required for it were calculated.

Table 24 Construction Cost (Yanshan)

(Unit: 10,000 yuan)

Facility		Case 1	Case 2
Oil refinery	1. Preparatory treatment	118.8	118.8
	2. Primary treatment/recovery	265.6	0
	3. Recovery system	5,654.6	6,137.2
	4. Additional treatment in waste water treatment plant	3,692.4	3,794.7
	Total	9,731.3	10,050.7
Petrochemical	1. Preparatory treatment	10,010.5	10,010.5
	2. Primary treatment/recovery	5,469.6	0
	3. Recovery system	7,050.5	14,836.8
	4. Additional treatment in waste water treatment plant	5,184.0	6,996.6
	Total	27,714.7	31,843.9
Total of Yanshan district	1. Preparatory treatment	10,129.3	10,129.3
	2. Primary treatment/recovery	5,735.2	0
	3. Recovery system	12,705.1	20,974
	4. Additional treatment in waste water treatment plant	8,876.4	10,791.3
	Total	37,446	41,894.6

Table 25 Construction Cost (Taiyuan)

(Unit: 10,000 yuan)

Facility		Case 1A	Case 1B	Case2A	Case2B
Northern district	1. Preparatory treatment	8,458.2	8,458.2	8,458.2	8,458.2
	2. Primary treatment/recovery	7,120.9	7,120.9	0	0
	3. Recovery system	0	0	9,154.5	19,826.1
	4. Recovery for agriculture (1)	9,013.6	9,013.6	2,077.7	2,077.7
	5. Recovery for agriculture (2)	0	0	433.2	433.2
	6. Sludge burning	2,816.0	2,816.0	2,816.0	2,816.0
	Total	27,408.8	27,408.8	22,939.7	33,611.2
Southern district	1. Preparatory treatment	18,928.6	18,928.6	18,928.6	18,928.6
	2. Primary treatment/recovery	4,747.6	4,747.6	0	0
	3. Luocheng waste water treatment plant	3,306.8	3,544.4	4,507.0	4,233.0
	4. Recovery system	6,767.2	6,767.2	26,189.3	16,794.0
	5. Recovery for agriculture (1)	5,790.4	10,973.2	5,790.4	10,973.2
	Total	39,540.7	44,961.2	55,415.3	50,928.8
Total of Taiyuan district	1. Preparatory treatment	27,386.8	27,386.8	27,386.8	27,386.8
	2. Primary treatment/recovery	11,868.5	11,868.5	0	0
	3. Luocheng waste water treatment plant	3,306.8	3,544.4	4,507.0	4,233.0
	4. Recovery system	6,767.2	6,767.2	35,343.8	36,620.1
	5. Recovery for agriculture (1)	14,804	19,986.8	7,868.1	13,050.9
	6. Recovery for agriculture (2)	0	0	433.2	433.2
	7. Sludge burning	2,816.0	2,816.0	2,816.0	2,816.0
	Total	66,949.5	72,370	78,355	84,540

Notes: Untreated water of the recovery for agriculture (1) is water flowing out of the waste water treatment plant.
Untreated water of the recovery for agriculture (2) is W3, W4, and W12 waste water.

1.3 Test operation expense

Period of test operation was assumed to be 1 month and labor, chemical and utility expenses for that period were calculated.

1.4 Official work cost and others

Ten percent of the overall labor expense was appropriated for the term from the initial stage of construction to start of training of all personnel, and 5% of personnel training and test operation expenses were added as overhead expense.

1.5 Leasehold fee

Leasehold fee was assumed to be 50 yuan/m^2 and required area was estimated and calculated from the result of conceptual design.

1.6 Interest during construction

Interest during construction was calculated by establishing financing plan and payment schedule as follows.

(1) Payment schedule

① Machine-related payment schedule : Payment in installments of 30% at the time of order, 25% and 25% midway, and 20% on completion of test operation

② Field construction related payment schedule : Payment in installments of 10%, 20%, 20%, 20%, 20%, and 10% during construction.

(2) Financing plan

① Funds on hands : 25%

② Aid from official agencies : 25%

③ Debt : 50%

(3) Interest

① Rate of interest : 15% per year

② Repayment conditions : Repayment after start of operation corresponding to depreciation

2. Operating Cost

Operating cost is roughly classified into variable cost and fixed cost. Variable cost includes chemical expense, utility expense, membrane and activated carbon expenses, etc. The fixed cost covers labor expense, maintenance expense, land toll, depreciation expense, plant overhead, etc.

Operating cost for the Yanshan and Taiyuan districts is shown in Tables 26, 27.

Table 26 Operating Cost (Yanshan)

(Unit: 10,000 yuan/year)

Item		Case 1	Case 2
Oil refinery	1. Chemical expense	17.6	18.1
	2. Utility expense	512.8	516.0
	3. Labor expense	49.3	44.5
	4. Maintenance expense	430.2	445.0
	5. Land toll	0.1	0.1
	6. Depreciation expense	954.7	985.2
	7. Plant overhead	98.2	100.4
	Total	2,063.1	2,109.4
Petrochemical	1. Chemical expense	45.4	52.0
	2. Utility expense	1,178.0	1,631.1
	3. Labor expense	82.5	73.3
	4. Maintenance expense	1,267.0	1,449.2
	5. Land toll	0.8	0.8
	6. Depreciation expense	2,748.2	3,146.5
	7. Plant overhead	266.1	317.6
	Total	5,588.0	6,670.5
Total of Yanshan district	1. Chemical expense	63.0	70.1
	2. Utility expense	1,690.8	2,147.1
	3. Labor expense	131.8	117.8
	4. Maintenance expense	1,697.2	1,894.2
	5. Land toll	0.9	0.9
	6. Depreciation expense	3,702.9	4,131.7
	7. Plant overhead	364.3	418.0
	Total	7,651.1	8,779.9

Table 27 Operating Cost (Taiyuan)

(Unit: 10,000 yuan/year)

Item		Case A1	Case A2	Case2A	Case2B
Northern district	1. Chemical expense	1,148.3	1,148.3	1,101.1	1,269.1
	2. Utility expense	1,895.3	1,895.3	1,670.0	2,595.4
	3. Labor expense	166.3	166.3	176.3	193.1
	4. Maintenance expense	1,455.8	1455.8	1,243.9	1,736.4
	5. Land toll	0.6	0.6	0.4	0.4
	6. Depreciation expense	2,906.6	2,906.6	2,450.7	3,507.6
	7. Plant overhead	339.6	339.6	293.1	426.1
	Total	7,912.5	7,912.5	6,935.4	9,728.1
Southern district	1. Chemical expense	2,954.2	2,964.0	2,977.2	2,953.8
	2. Utility expense	1,386.4	1,658.6	2,991.3	2,391.2
	3. Labor expense	162.5	169.7	165.3	163.3
	4. Maintenance expense	1,840.8	2,093.4	2,578.1	2,371.7
	5. Land toll	1.0	1.0	1.3	1.2
	6. Depreciation expense	3,962.6	4,500.8	5,532.8	5,089.4
	7. Plant overhead	515.4	569.4	712.3	648.5
	Total	10,822.7	11,956.9	14,958.3	13,619.2
Total of Taiyuan district	1. Chemical expense	4,102.5	4,112.3	4,078.3	4,222.9
	2. Utility expense	3,281.7	3,553.9	4,661.2	4,986.6
	3. Labor expense	328.8	336.0	341.6	356.4
	4. Maintenance expense	3,296.5	3,549.2	3,822.0	4,108.2
	5. Land toll	1.5	1.6	1.6	1.6
	6. Depreciation expense	6,869.2	7,407.4	7,983.6	8,596.9
	7. Plant overhead	855.0	909.0	1,005.4	1,074.6
	Total	18,735.2	19,869.4	21,893.7	23,347.2

3. Financial Analysis

3.1 Major premises for financial analysis

① Project period

Construction period : 2 years

Operation period : 15 years

② Base price

The prices are based on those as of 1990 with no escalation considered.

③ Depreciation

Straight line depreciation is applied and depreciation is made in 10 to 20 years depending on the type of facilities.

3.2 Water volume recovered

(1) Yanshan district

26,400 m^3/day for each case (8,857,000 m^3/year)

(2) Taiyuan district

① Industrial water : 50,000 m^3/day for each case (16,775,000 m^3/year)

② Agricultural water

Cases 1A and 2A : 24,118 m^3/day (5,149,000 m^3/year)

Cases 1B and 2B : 34,118 m^3/day (7,284,000 m^3/year)

3.3 Economic benefit

(1) Yanshan district

① Production profit by increase in production : 187,800,000 yuan/year

(Including cost born for new production facilities for increase in production)

② Reduction of excess waste water fee : 1,940,000 yuan/year

(2) Taiyuan district

① Production profit by increase in production : 66,840,000 yuan/year

(Including cost born for new production facilities for increase in production)

② Loss avoidance of production reduction for agricultural water

Case 1A, 2A : 56,640,000 yuan/year

Case 1B, 2B : 80,130,000 yuan/year

③ Reduction of excess water fee : 20,000 yuan/year

④ Reduction of excess waste water fee : 4,090,000 yuan/year

⑤ Evaluation of by-product ammonium chloride : 38,840,000 yuan/year

3.4 Financial analysis method

Financial Internal Rate of Return (F.IRR) is used to analyze profitability.

F. IRR is a method to obtain the profit rate of capital invested to capital recovery amount and is an index showing a substantial profitability of the project with no regard to effects due to change in loan terms or equity ratio. Construction cost to be born for new production facilities to increase production in both Yanshan and Taiyuan districts was assumed to be 0.

(1) Yanshan district

F.IRR for each case is shown in Table 28.

Table 28 F. IRR for cases

Case	F.IRR (%)
1	56.4
2	44.2

According to the above table, investment efficiency is higher in the case 1, presenting better conditions.

(2) Taiyuan district

F.IRR for each case is shown in Table 29.

Table 29 F.IRR for cases

Case	F.IRR (%)
1A	-2.0
1B	1.6
2A	-10.5
2B	-6.2

According to the above table, profitability of each case is very low. Investment efficiency is higher in the cases 1A and 1B.

3.5 Sensitivity analysis

Sensitivity analysis is conducted about F.IRR by fluctuating the following factors in the case.

① Change on construction cost (±10%, ±20%)

② Change on economic benefit (±10%, ±20%)

③ Change on variable cost (±10%, ±20%)

(1) Yanshan district

Result of sensitivity analysis about the case 1 of higher profitability is shown in Table 30.

Table 30 Sensitivity Analysis of Case 1 (F.IRR : %)

Item	-20%	-10%	Base	+10%	+20%
Construction cost	85.9	68.3	56.4	47.8	41.2
Economic benefit	36.5	45.9	56.4	68.5	82.6
Variable cost	58.7	57.6	56.4	55.3	54.2

In the above table, among F.IRR factors, influence of the economic benefit is largest and construction cost also exerts influence of approximately same extent.

However, the variable cost has very insignificant influence.

(2) Taiyuan district

Profitability is extremely low for all cases. Among them, result of sensitivity analysis for the case 1B, which is most profitable, is shown in Table 31.

Table 31 Sensitivity Analysis of Case 1B (F.IRR : %)

Item	-20%	-10%	Base	+10%	+20%
Construction cost	6.9	4.1	1.6	-0.6	-2.7
Economic benefit	-4.2	-1.2	1.6	4.1	6.5
Variable cost	5.1	3.4	1.6	-0.3	-2.4

From the above table, influence of each factor makes no great difference.

3.6 Comment on result of financial analysis

(1) Yanshan district

Though F.IRR including no construction cost of new production facilities, which are a source of profits, is high, calculation result of changes in F.IRR when the construction cost of the new production facilities is included is shown in Table 32.

Table 32 Correlation between Construction Cost of New Production Facility and F.IRR

Construction cost of new production facility (100 mil. yuan)	0	1	2	3	4	5	6	7	8	9
Case 1 F.IRR (%)	56.4	39.0	28.9	22.2	17.2	13.4	10.2	7.6	5.3	3.2
Case 2 F.IRR (%)	44.2	32.1	24.0	18.6	14.3	10.9	8.0	5.7	3.5	1.6

As the loan accounts for 50% and the rate of interest is 15%, F.IRR higher than 7.5% including the construction cost of new production facilities is required. Investment of about 700 million yuan is possible for new production facilities in the case 1 and about 600 million yuan in the case 2.

(2) Taiyuan district

As F.IRR including no construction cost of new production facilities is very low, economic benefit was assumed to be constant. It was calculated to what extent the construction cost and variable cost should be reduced to improve it to the same level as in the Yanshan district (F.IRR: 40%), the result of which is shown in Table 33.

Table 33 Rate of Reduction of Expenses to Improve F.IRR to 40%

(Unit: %)

Item	Case1A	Case1B	Case2A	Case2B
Construction cost	56	53	63	60
Variable cost	56	53	63	60

According to the above table, more than 55% of construction cost and variable cost should be reduced in order to obtain economic efficiency including the construction cost of new production facilities.

4. Economic Analysis

4.1 Economic internal rate of return

The Economic Internal Rate of Return (E.IRR) was calculated based on the economic benefit and economic expenses. Values close to F.IRR were obtained for all cases of the Yanshan and Taiyuan districts.

4.2 Indirect benefit

(1) Increase of employment opportunities

About 400 direct personnel in the Yanshan district and 900 in the Taiyuan district will be newly employed. In addition, construction and maintenance of facilities, operation of utility facilities, and other peripheral industries are expected to become active.

(2) Utilization of resources and improvement of environment

Production of water resources now in short supply and removal of adverse influence of waste water are very significant socially.

(3) Contribution to development of regional economy

Eliminating environmental pollution, developing industries (including agriculture), and contributing to improvement of health of inhabitants are very important.

5. Overall Evaluation

Result of overall evaluation of the waste water treatment and recovery project based on the financial and economic analysis is described below.

5.1 Yanshan district

(1) F.IRR of the waste water treatment and recovery project in the Yanshan district is 44.2 - 56.4%, excluding the construction cost of new production facilities to increase the production, presenting relatively favorable values. In this case, however, allowable limit of the construction cost to reinforce the production plant, which is the source of benefit, is 600-700 million yuan. As the construction cost of a waste water treatment and recovery system is about 400 million yuan, reduction of the construction cost and other expenses of this system will be necessary.

(2) In order to improve the economic efficiency and heighten the feasibility of this project, reduction of expenses is necessary. Measures for that purpose are described below.

① Construction cost for primary treatment and recovery in the case 1 (volume recovered: 11,426 m^3/day) is 57,352,000 yuan, which is more economical in comparison with the construction cost of 127,051,000 yuan for recovery system with reverse osmosis film (volume recovered: 14,974 m^3/day). Therefore, method of increasing the volume of primary treatment and recovery will have to be studied. Searching for waste water with good quality now discharged without treatment, and modification of the standard for recovered water quality will be also necessary.

② Construction cost of preparatory treatment is 101,293,000 yuan, accounting for 24.2 - 27.1% of the overall construction cost. It should be studied to restrict flow out of pollutant by taking measures for origin in production processes and meet the discharge standard fundamentally only by final treatment in the oil refinery and petrochemical waste water treatment plants.

③ Construction cost of additional treatment by the contact oxidation method in both waste water treatment plants is 88,764,000 - 107,913,000 yuan, accounting for 23.7 - 25.8% of the overall construction cost. It should be studied to eliminate the necessity of the additional treatment by confirming the performance of both waste water treatment plants, rationalizing the operation and facilities, and modifying them.

5.2 Taiyuan district

(1) F.IRR of the waste water treatment and recovery project in the Taiyuan district is as low as 1.6 ~ -10.5% even though the construction cost to reinforce the production plant for production increase is not included. Economic efficiency cannot be attained by the current premises.

(2) Therefore, in order to improve the economic efficiency, drastical expense reduction and other improvements are necessary. Measures for that purpose are described below.

① The construction cost for primary treatment and recovery in the cases 1A and 1B (volume recovered: 41,085 m^3/day) is 118,685,000 yuan, which is more economical in comparison with the construction cost of 67,672,000 yuan for the recovery system with reverse osmosis film (volume recovered: 8,915 m^3/day).

On the other hand, the construction cost of the cases 2A and 2B to recover the waste water (50,000 m^3/day) entirely by the reverse osmosis film method is 353,438,000 ~ 366,201,000 yuan, very high in comparison with the primary treatment and recovery method.

Therefore, it is necessary to limit the recovery method to primary treatment and recovery, and, in addition, methods of increasing the recoverable volume should be studied, and standard for recovered water quality should be modified for that purpose. Shut down of production facilities with low profitability corresponding recovery volume will be also required.

② The construction cost of preparatory treatment are 84,582,000 yuan in the northern district and 189,286,000 yuan in the southern district, amounting to as high as 273,868,000 yuan in total, accounting for 32.4 - 40.9% of the overall construction cost.

It should be studied to restrict flow out of pollutant by taking measures for the origin in the production processes and meet the discharge standard fundamentally only by final treatment in the Nanyan and Luocheng waste water treatment plants.

③ Regarding to recovery for agriculture (24,118 - 34,118 m^3/day), $C\ell^-$ and TDS do not satisfy the standard for agricultural water quality. It requires reverse osmosis film and the construction cost is 83,013,000 - 199,868,000 yuan, accounting for 10.6 - 27.6% of the overall construction cost.

It should be studied to restrict flow out of pollutant by taking measures for the origin in the production processes and utilize waste water with relatively good quality following the waste water primary treated and recovered, and for that purpose standard for quality of agricultural water should be also modified.

Securing agricultural water is a problem of the entire region and it can be considered that the government aids it.

5.3 Considerations common to Yanshan and Taiyuan districts

The construction cost is calculated on the assumption that the machine and equipment expenses are the same as that in Japan and field construction expenses are 60%.

Excluding for special machines and equipment, those manufactured in China should be employed as far as possible to reduce the construction cost.

The construction cost including filled construction expenses should be calculated according to actual situation in China.

6. Additional Case Study for Improvement of Feasibility

6.1 Yanshan district

Financial analysis for the industrial waste water treatment and recovery project in Yanshan district, has been studied for 2 cases in previous chapter. As a result, fairy good feasibility has been obtained for both cases.

However, these results are not including the construction cost of new production facilities to increase production capacity.

Thus, it will be better to reduce construction cost of waste water treatment and recovery system, which is auxiliary facilities of production, in order to make allowance for investment of new production facilities.

Therefore, additional case study for improvement of feasibility has been done as follows.

Strictly speaking, this case study is out of 'Scope of Work' and requires internal study of processes, then we made some assumption based on Japanese experience in this field.

(1) Additional case

Case 1 is modified as following variations described in (2) and financial analysis has been studied.

(2) Contents of variations

1) Additional treatment in waste water treatment plant could be omitted by means of rationalization and reinforcement of existing waste water treatment plant. This means 70% reduction for construction cost, operating cost and employees, when compared with those of additional treatment system.

- Oil refinery

Construction cost	;	36,920,000	→	11,080,000 yuan
Operating cost	;	5,610,000	→	1,680,000 yuan/year
Employees	;	0	→	0

- Petrochemical factory

Construction cost	;	51,840,000	→	15,550,000 yuan
Operating cost	;	7,890,000	→	2,370,000 yuan/year
Employees	;	0	→	0

2) Recovery system (reverse osmosis film method) could be omitted by means of increase of recovered volume from primary treatment/recovery system and reduction of industrial water.

ⓐ Construction cost, operating cost and employees for recovery system are changed to zero.

- Oil refinery

Construction cost	;	56,550,000	→	0 yuan
Operating cost	;	13,460,000	→	0 yuan/year
Employees	;	137	→	0

- Petrochemical factory

Construction cost	;	70,510,000	→	0 yuan
Operating cost	;	17,260,000	→	0 yuan/year
Employees	;	141	→	0

ⓑ Increase of recovered volume from primary treatment/recovery system

Construction cost, operating cost and employees are increased proportionally to increased volume of recovered water. This means 2.311 times than those of primary treatemnt/recovery system in case 1.

Recovered volueme ; 11,426 m^3/D → 26,400 m^3/D

- Primary treatment/recovery system in oil refinery

Construction cost	; 2,660,000	→	6,150,000 yuan
Operating cost	; 1,370,000	→	3,170,000 yuan/year
Employees	; 16	→	37

- Primary treatment/recovery system in petrochemical factory

Construction cost	; 54,700,000	→	126,400,000 yuan
Operating cost	; 12,060,000	→	27,860,000 yuan/year
Employees	; 60	→	138

3) Reduction of overall construction cost by means of full utilization of Chinese machines and equipment

Construction cost ; 260,460,000 → 236,780,000 yuan

(10% reduction)

(3) Result of case study

Total capital investment is reduced from 416,000,000 yuan to 263,000,000 yuan, that is 37% reduction (153,000,000 yuan in total), reflecting above variation.

Financial Internal Rate of Return (F. IRR) is also improved drastically from 56% to 163%.

Simulation result of changes in F. IRR when the construction cost of the new production facilities is included is shown in Table 34.

Table 34 Correlation between Construction Cost of New Production Facility and F. IRR (Yanshan District)

Construction cost of new production facility (100 mil. yuan)	0	1	2	3	4	5	6	7	8	9	10
F. IRR (%)	163	78	50	36	27	21	16	13	10	7.2	5.0

Required F. IRR is little more than 7% and investment of about 900 million yuan is possible for new production facilities.

6.2 Taiyuan district

Financial analysis for the industrial waste water treatment and recovery project in Taiyuan district, has been studied for 4 cases in previous chapter.

As a result, all cases are not feasible on the basis of given conditions reflecting basic concept of Chinese counterpart.

Therefore, additional case study for improvement of feasibility has been done as follows.

Strictly speaking, this case study is out of 'Scope of Work' and requires internal study of processes, then we made some assumption based on Japanese experience in this field.

(1) Additional case

Case 1A is modified as following variations described in (2) and financial analysis has been studied.

(2) Contents of variations

1) Recovery system (reverse osmosis film method) could be omitted by means of increase of recovered volume from primary treatment/recovery system and reduction of industrial water.

ⓐ Construction cost, operating cost and employees for recovery system in southern district are changed to zero.

Construction cost ; 67,670,000 → 0 yuan

Operating cost ; 16,100,000 → 0 yuan/year

Employees ; 62 → 0

ⓑ Increase of recovered volume from primary treatment/recovery system

Construction cost, operating cost and employees are increased proportionally to increased volume of recovered water. This means 1.217 times than those of primary treatment/recovery system in case 1A.

Recovered volume ; 41,085 m^3/D → 50,000 m^3/D

- Primary treatment/recovery system in northern district

Construction cost	;	71,210,000	→	86,660,000 yuan
Operating cost	;	17,610,000	→	21,430,000 yuan/year
Employees	;	80	→	97

- Primary treatment/recovery system in southern district

Construction cost	;	47,480,000	→	57,780,000 yuan
Operating cost	;	8,520,000	→	10,360,000 yuan/year
Employees	;	84	→	103

2) Pre-treatment system in southern district could be omitted by means of taking measures for the origin in the production processes.

Revamping (modification) cost, operating cost and employees of taking measures for the origin in the production processes are estimated 30% of those figures for pre-treatment system in southern district, which are ammonium stripping and liquid oxidation facilities.

Construction cost	;	189,280,000	→	56,790,000 yuan
Operating cost	;	59,400,000	→	17,820,000 yuan/year
Employees	;	180	→	54

Evaluation of by-product ammonium chloride

; 38,840,000 → 0 yuan/year

Evaluation of recovered ammonium

; 0 → 9,920,000 yuan/year

3) Among the pre-treatment facilities in northern district, deep aeration system for W10 waste water could be omitted by means of rationalization and reinforcement of existing deep aeration facility. This means 70% reduction for construction cost, operating cost and employees, when compared with those of a new deep aeration facility.

Construction cost	;	31,460,000	→	9,440,000 yuan
Operating cost	;	166,000	→	50,000 yuan/year
Employees	;	48	→	14

4) Reduction of overall construction cost by means of full utilization of Chinese machines and equipment.

Construction cost	;	473,050,000	→	430,050,000 yuan
				(10% reduction)

5) Construction and operating cost of recovery system for agricultural water are born by public sector.

Facilities for agricultural water are classified as social infrastructure, and governmental agency will construct and manage the system. Construction cost, operating cost and employees are changed as follows.

Construction cost	;	148,040,000	→	0 yuan
Operating cost	;	31,670,000	→	0 yuan/year
Employees	;	202	→	0

6) Construction cost of Nanyan waste water treatment plant can be omitted.

Construction cost	;	45,000,000	→	0 yuan

(3) Result of case study

Financial Internal Rate of Return (F. IRR) is calculated as 26%. This figure means some possibility for the project.

Simulation result of changes in F. IRR when the construction cost of new production facilities is included is shown in Table 35.

As a result, F. IRR is not enough when considering construction cost of new production facilities. Thus, improvement of feasibility should be made by means of taking measures for the origin in the production processes.

Table 35 Correlation between Construction Cost of New Production Facility and F. IRR (Taiyuan District)

Construction cost of new production facility (100 mil. yuan)	0	1	2	2.5	3	4
F. IRR (%)	26.3	16.0	9.5	7.0	3.6	1.1

Required F. IRR is little more than 7% and investment of about 2.5 million yuan is possible for new production facilities.

VOLUME VII CONCLUSION AND RECOMMENDATION

In this volume, our conclusion and recommendation will be described at the final stage of the study for this project.

1. Evaluation of Waste Water Treatment and Recovery System

1.1 Yanshan district

(1) Preparatory treatment facilities

1) Oil refinery factory

① Switching the A15 waste water to the A21 system making use of the surplus capacity of the desulfurization process of this factory is rational.

② Quality of A8 waste water (COD, oil content) varies remarkably but such fluctuation can be settled by simple oil separation.

2) Petrochemical factory

① Since waste water of high organic concentration should be treated by the liquid oxidation method, great construction cost is required. However, it is inevitable as other simple treating method is unavailable.

(2) Primary treatment/recovery facilities

This facility offers no specific problem because of the simple process. Construction cost is expensive as an activated carbon regeneration furnace is installed to treat a large volume of D46 and D47 waste water of the petrochemical factory. However, the running cost is economical in comparison with the regeneration method entrusted to the outside.

(3) Waste water treatment plant facilities

Waste water in the existing waste water treatment plant is treated by the rotary disc method to remove COD. Though the construction expense increased, the running cost is low because of the biological treatment.

(4) Recovery system facilities

The reverse osmosis film method produces stable water quality but both the construction cost and running cost are expensive.

1.2 Taiyuan district

(1) Preparatory treatment facilities

1) Northern district

① F^-, Hg, oil content, and COD removal processes are satisfactory. However, PH of the treated water is very low and requires a large volume of neutralizing alkali, which accounts for the greater part of the chemical expense in the northern district.

② The waste liquid burning process requires high fuel expense to evaporate the water content in the waste liquid, which accounts for the greater part of the utility expense in preparatory treatment.

2) Northern district

Construction cost for the facilities to recover ammonium chloride after air stripping of NH_3-N is high and enormous amount of chloric acid is required.

(2) Primary treatment/recovery facilities

There are no specific problems because of simple processes. However, since W1•W4 waste water and Lf48 waste water are extensive in volume, an activated carbon regeneration furnace is provided. Though the construction cost is high, the running cost is economical in comparison with regeneration methods entrusted to the outside.

(3) Waste water treatment plant facilities

1) Northern district

There are no problems if preparatory treatment is applied.

It was determined to provide an organic dehydrated sludge burning system.

2) Southern district

Construction cost can be reduced due to the coagulative sedimentation method in comparison with the biological treatment method.

However, NH_3-N cannot be removed by this method and preparatory treatment by ammonia stripping will be applicable.

(4) Recovery system facilities

The reverse osmosis film methods produces stable water quality but both the construction cost and running cost are high.

(5) Recovery for agriculture facilities

The reverse osmosis film method is adopted to meet the agricultural water standard for TDS and $C\ell^-$. Both the construction and running costs are high for the applications.

2. Conclusion for Waste Water Treatment and Recovery Systems

In order to improve the overall economic efficiency, facility and construction cost should be reduced (In the Taiyuan district, in particular, a drastic reduction is required). Importance should be attached to the following points in the study.

2.1 Yanshan district

(1) Preparatory treatment facilities

Principally, pollutant should be removed close the origin in a waste water treatment system. However, since COD, telephthalic acid, etc. are very high in concentration, the origin itself and processes should be reviewed, and rationalization and other measures should be adopted to reduce their values so that biological treatment by the existing waste water treatment plant is enough without providing a liquid oxidation process.

(2) Primary treatment/recovery facilities

Simple facilities will be able to recover water. However, only part of the water reused can be recovered according to the study. Waste water with good quality which is now discharged without treatment should be searched for, and efforts should be made to reduce pollutant so as to recover the water entirely by primary treatment.

(3) Waste water treatment facilities

The contact oxidation process for the oil refinery factory is required in order to treat the waste water containing residential water. Separate treatment of residential water should be studied. Efforts should be made to reduce COD to the level requiring no additional treatment by contact oxidation, by improving and reinforcing the existing biological treatment facilities in both waste water treatment plants.

(4) Recovery system facilities

Efforts should be exerted so that water to be reused can be recovered entirely by primary treatment. Even when the reverse osmosis film system should be provided, it should be studied to minimize the volume of water to be treated.

2.2 Taiyuan district

(1) Preparatory treatment facilities

1) Northern district

Principally, pollutant should be removed close to the origin in a waste water treatment system.

However, since PH, oil content and COD are very high in concentration, the origin itself and process should be reviewed and measures for rationalization should be taken.

2) Southern district

Much importance should be attached to reduction of NH_3-N by improvement and rationalization of the origin and process. Recovery of ammonium chloride is unprofitable, comparing with construction cost and running cost.

For the Lf47 waste water, treatment by the biological treatment method should be adopted instead of a liquid oxidation system by decreasing COD taking measures for the origin.

(2) Primary treatment/recovery facilities

Water to be reused can be recovered with simple facilities. However, only part of the water reused can be recovered according to the study. Efforts should be made to reduce the pollutant to recover the water entirely by primary treatment.

(3) Recovery system facilities

Efforts should be made to recover the water to be reused entirely by primary treatment. It should be studied so that water to be treated is minimized even when a reverse osmosis film system should be provided.

(4) Recovery for agriculture facilities

It should be studied to avoid application of the reverse osmosis film method. Efforts should be made to reduce pollutant, and reuse of waste water with relatively good quality, following to the waste water recovered by primary treatment, by simple treatment should be studied. The standard for agricultural water quality should be also modified for that purpose.

3. Considerations and Recommendation

3.1 Recommendation

We recommend the following points in conclusion of the industrial waste water treatment and recovery project. This recommendation is applicable both to the Yanshan and Taiyuan districts.

(1) The construction cost of each case is calculated on the Japanese basis and converted to the Chinese basis incorporating the results of the field survey. Before executing the project, conditions peculiar to China and utmost possible utilization of machines and equipment which can be domestically manufactured should be considered and the construction cost should be reviewed comprehensively on the part of China.

(2) Reduction of pollutant at each outlet

Pollutant concentration is very high at some outlets. Waste water treatment systems applicable to them are expensive and, in addition, useful substances are discharged wastefully. Measures should be taken for the origin to reduce the pollutant.

(3) Modification of standards for recovered water (common to Yanshan and Taiyuan districts) and agricultural water (Taiyuan district)

It is important to improve the quality of cooling water and improve the agricultural water to ensure environmental protection. On the other hand, in order to reduce facility and operating expenses, usage of recovered water and agricultural water should be also studied and the standards of water quality should be modified.

(4) Reduction of water

By reducing the current water volume through improvement of the recovery rate of boiler water, process water and cooling water, the waste water volume will be reduced and water shortage improved very effectively. Reduction of water volume should be studied.

3.2 Considerations for implementation

Considerations should be given to the following points when executing the project, after studying the above-described points sufficiently.

(1) Promotion of project with project system

Well-qualified men with the right of decision to executing the plan should be selected from each factory and relevant section and promote the project from the stage of preparation for implemental plan to completion of test operation with the project team system.

(2) When preparing for implemental plan, overall investigation to decide priority of each facility should be made, and it will make easier to afford the budget for construction expense.

It will be also effective to improve efficiency of investment. As a result, construction shall be made step by step.

(3) Establishment of design standard

Before starting design and construction, design standard should be established to coordinate design conception of treatment facilities and for efficient construction.

(4) Reconfirmation of waste water quality

Waste water quality at each outlet should be analyzed again to confirm the design conditions.

(5) Treatment test using actual waste water

In order to obtain basic values for design, simple test of actual waste water should be carried out. Checks on actual waste water as follows are necessary for instance.

① Preparation of neutralization curves

② Preparation of sedimentation curves for coagulative sedimentation process

③ Preparation of adsorption curves of activated carbon

④ Grasping of basic values of liquid oxidation process

(6) Confirmation with pilot plants or demonstration facilities

Following treatment methods should be tested with pilot plants, etc.

① Pilot plant of reverse osmosis film facilities for recovery and agricultural water (including attached facilities)

② Pilot plant of ammonium chloride recovery system by the ammonia stripping method

③ Primary treatment/recovery demonstration facilities

For instance, exact scale facilities for the following waste water:

- Yanshan district : sand filtration of A7 or E50 waste water
- Taiyuan district : sand filtration of W8 waste water or oil adsorption of W17 waste water

(7) Overseas technical investigation

Overseas technical investigation should be carried out to get the information of the technical details for the following treatment methods. When executing the project, possibility of new technical cooperation from Japan should be also studied.

① Reverse osmosis film equipment

② Activated carbon regeneration equipment

③ Liquid oxidation equipment

(8) Training of technical personnel

It is desirable to train core technical personnel related with operation for about 1 month in Japan before starting operation of the facilities.

(9) Cooperation with Chinese national research institutions

Close cooperation should be kept with The State Science and Technology Commission and The Ecological and Environmental Research Center to promote the project.

JICA