No. 39

FINAL REPORT
FOR THE STUDY ON
THE EFFECTIVE USE OF INDUSTRIAL WATER
IN
THE KINGDOM OF THAILAND

PREPARED FOR
INDUSTRIAL WORKS DEPARTMENT
MINISTRY OF INDUSTRY
THE KINGDOM OF THAILAND

SUMMARY

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

MPI
JR
89 - 42

FINAL REPORT
FOR THE STUDY ON
THE EFFECTIVE USE OF INDUSTRIAL WATER
IN
THE KINGDOM OF THAILAND

PREPARED FOR
INDUSTRIAL WORKS DEPARTMENT
MINISTRY OF INDUSTRY
THE KINGDOM OF THAILAND

SUMMARY

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

Table of Contents

Chapter 1 Introduction

1. 1 Background

Faced with the aggravating problems of subsidence of land in the Bangkok Metropolitan Area, the Industrial Works Department (IWD) of the Ministry of Industry in Thailand has launched on the program for reducing the pumping up of groundwater.

For this purpose, IWD requested the Japanese Government to provide technical cooperation in conducting a study on the effective use of industrial water.

Upon the acceptance of this request, the Japanese Government entrusted the Japan International Cooperation Agency (JICA) to carry out the study in Thailand. JICA commenced the study in August 1987 and completed it in March 1989.

1. 2 Purposes of the Study

For the field study, IWD chose Samut Prakarn in the Bangkok Metropolitan Area. The purposes of the study were to grasp the actual situation of industrial water uses, estimate the potential quantity of water saving, and prepare technical guidelines for more effective use of industrial water.

The relationship between this study and other measures against land subsidence is as summed up in Fig. 1. 1.

1. 3 Contents of the Study

The study comprised of eight steps. For the outline of each step, refer to Fig. 1. 2.

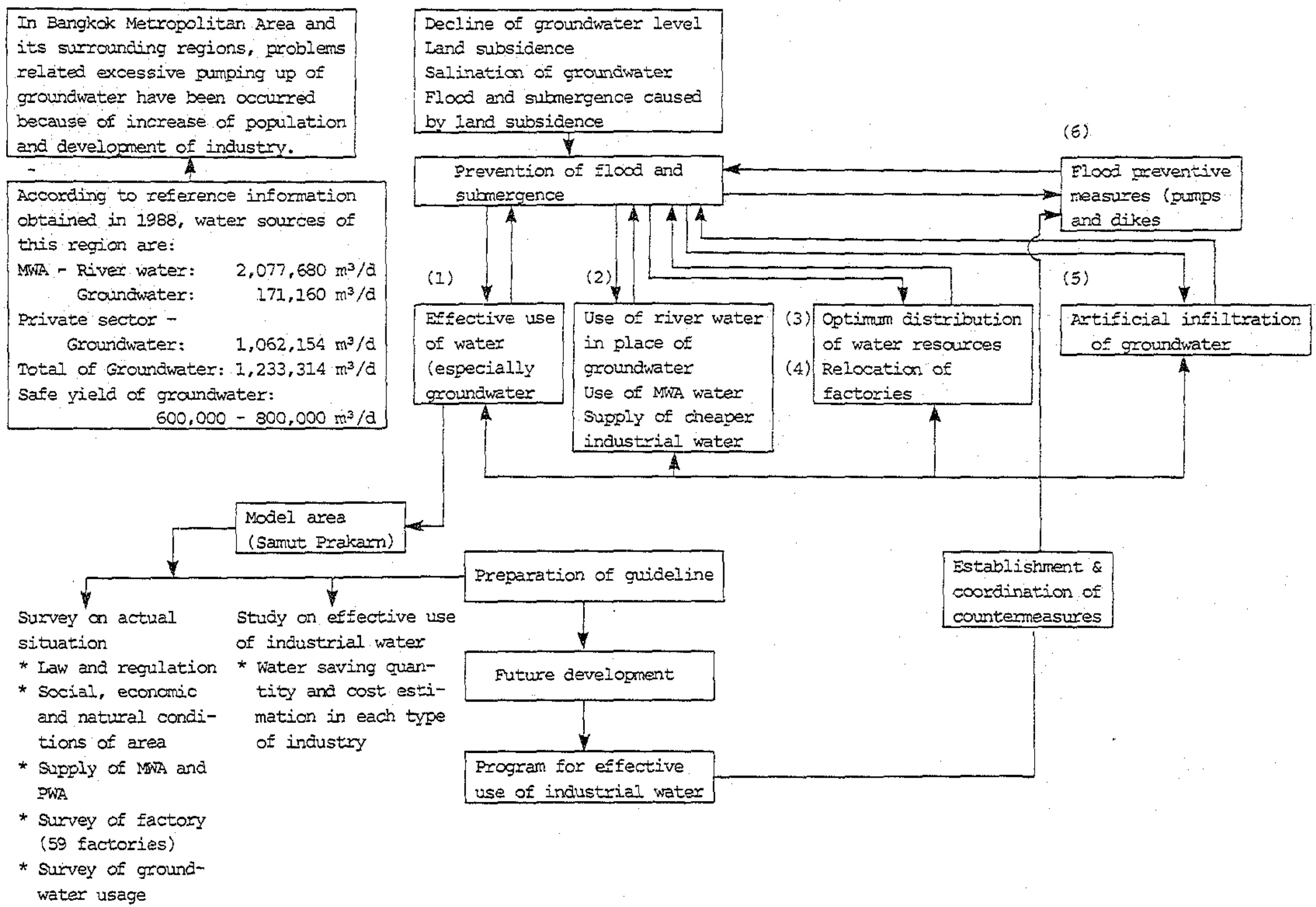


Fig. 1: Study Results and Relations to Plan for Effective Use of Industrial Water

Step 1	Preparatory Office Work	Preparation of questionnaire Preparation of Inception Report
Step 2	Preparation of the Field Work	Selection of factories to be studied Distribution of questionnaire
Step 3	Preparatory Office Work for the Field Work	Collection of answer to questionnaire Analysis of answer
Step 4	Field Work	Visiting survey of 59 factories Technical seminar Preparation of the Progressive Report
Step 5	1st Home Office Work	Clarification of present situation of the use of industrial water Study of effective use of industrial water Estimation of the potential quantity of water saving and reclamation Cost estimation Preparation of the Interim Report
Step 6	Supplementary Field Work	
Step 7	2nd Home Office Work	Preparation of technical guideline for effective use of industrial water classified by water usage Preparation of technical guideline for effective use of industrial water classified by type of industry Preparation of the Draft Final Report
Step 8	Presentation of the Draft Final Report in Thailand Technical seminar Preparation of the Final Report	

Fig. 1.2: Flow Diagram of Study Implementation

Chapter 2 General Conditions in Thailand--From the Viewpoint of Effective Use of Industrial Water

2.1 General Conditions

The population of Thailand, at present 62.65 million, has shown a rapid increase in recent years (refer to Fig. 2.1). Among the nation's total population, about 10 million people are concentrated in Bangkok and its surrounding areas.

Thailand has an area of 513,103 km², which is approximately 1.4 times larger than Japan.

The annual rainfall in Thailand averages 1,550 mm. As shown in Table 2.1, the quantity of rainfall differs from region to region. Generally speaking, the south has greater rainfall precipitation than the north.

Comparatively, Japan has a slightly larger annual rainfall (1,750 mm in 1985) than Thailand. The total volume of rainfall, however, is larger in Thailand (8,000 x 108 m³/Y) than in Japan (6,600 x 108 m³/Y). Thus, both countries are blessed with abundant water.

Nonetheless, as Thailand and Japan differ in geographical features and climates, the conditions of water sources also differs. For example, the run-off ratio of the Chao Phraya, the largest river in Thailand, is much smaller than those of any Japanese rivers.

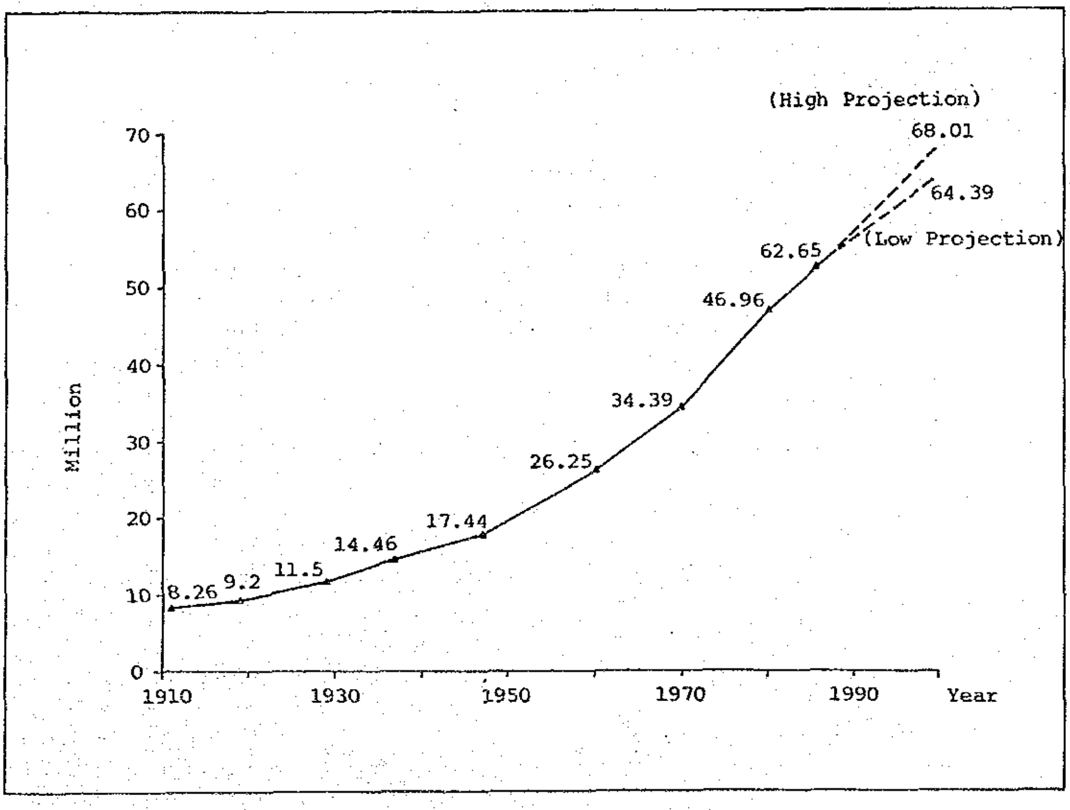


Fig. 2.1: Population of Thailand (1910 - 2000)

Considering the fact that the Chao Phraya River has a large catchment area and flows a considerable distance through hot and tropical regions, this small run-off ratio is understandable. In other words, different conditions produce different effects on the use of water in each country.

Table 2.1: Annual Rainfall in Thailand by Region

Region	Average Annual Precipitation (mm)	Area (km^2)	Rainfall Volumes (Mm^3)
Northeast	1,400	168,854	236,400
North	1,300	169,644	220,500
East	2,100	36,503	76,700
Central	1,350	67,399	91,000
South	2,400	70,715	169,700
Total		503,115	794,300

Note: The categorization of different regions is based on compiled statistics on water resources available in related governmental agencies.

2.2 Conditions in the Bangkok Metropolitan Area and Surrounding Area

2.2.1 Pumping Up of Groundwater and Land Subsidence

According to the Groundwater Act of 1977, 7,923 km^2 of the Bangkok Metropolitan area (including its surrounding area) is designated as "the Bangkok Groundwater Area". Inside this area, a certain portion (2,285 km^2 in total) is designated as "the Groundwater Critical Area".

Pumped up quantity of groundwater and number of wells in this area are shown in Tables 2.2 and 2.3

The present situation of land subsidences in the Bangkok Metropolitan area is as shown in Fig. 2.5. In the worst affected area, the subsidence reaches some 12 cm per year. The Groundwater Critical Area corresponds to those areas which suffer more than 5 cm/Y of land subsidence.

Situated at the mouth of the Chao Phraya River, the Bangkok Metropolitan area is only 0.5 to 1.5 m above sea level. If land subsidence continues at the rate of 10 cm/Y, most of the Bangkok Metropolitan area would sink below the water in ten years' time. Hence, the graveness of the problem in this region is evident.

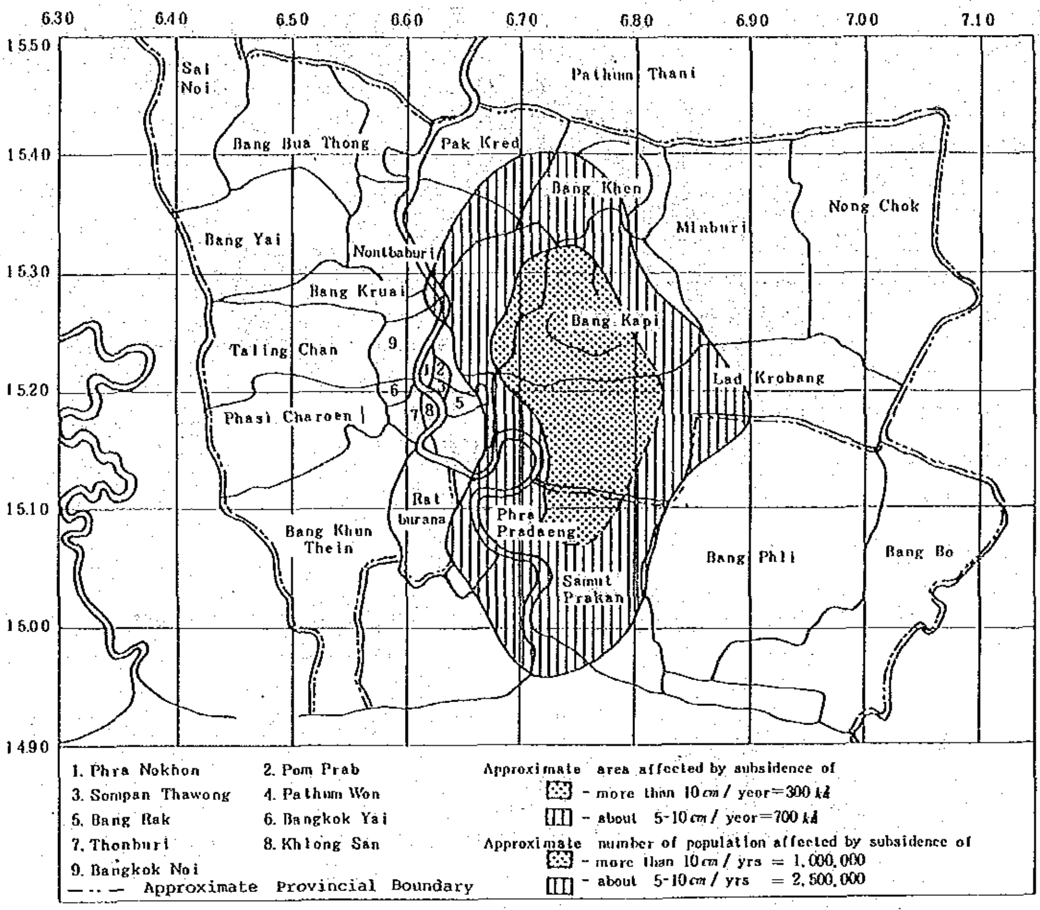


Fig. 2.2: Bangkok, Samut Prakarn and Nonthaburi Administrative Districts and Subsidence Area

Table 2.2: Pumped Up Quantity of Groundwater by Private Sector

Upper: Number of Well
Lower: (m^3/d)
As of January 1986

Use / Area	Domestic	Commercial	Agricultural	Total	%
Bangkok	3,263 (270,589)	1,639 (215,385)	220 (12,543)	5,122 (498,517)	52.5 (46.9)
Samut Prakarn	1,684 (60,402)	1,500 (286,070)	122 (4,284)	3,306 (350,756)	33.9 (33.0)
Samut Sakorn	368 (5,585)	246 (63,519)	91 (1,461)	705 (70,565)	7.2 (6.6)
Nothaburi	181 (3,260)	85 (19,539)	2 (40)	268 (22,839)	2.8 (2.2)
Pathumtai	113 (21,362)	139 (87,792)	22 (1,227)	274 (110,381)	2.8 (10.4)
Ayudhaya	32 (950)	31 (7,782)	9 (364)	72 (9,096)	0.7 (0.9)
Total	5,641 (362,148)	3,640 (680,087)	466 (19,919)	9,747 (1,062,154)	100.0 (100.0)
%	57.9 (34.1)	37.3 (64.0)	4.8 (1.9)	100.0 (100.0)	

Source, IWD, MOI, Thailand

Table 2.3: Pumped Up Quantity of Groundwater in Bangkok Metropolitan Area

(m^3/d)

Year	MWA	Decrease (%)	Private	Change (%)	Total	Decrease (%)
1982	447,000		944,305		1,391,305	
1983	350,000	21.7	993,842	+5.2	1,343,842	4.3
1984	272,365	22.3	1,034,511	+4.1	1,306,876	2.7
1985	269,410	1.0	1,026,032	-0.8	1,295,442	0.9

Note: Record up to May

2.3 Related Laws and Regulations

The following two laws in Thailand have a direct relationship to the study.

(1) Factory Act, B.E. 2512 (1969)

(2) Groundwater Act, B.E. 2520 (1977)

Notifications attached to each of these Acts are as listed in Table 2.4.

Furthermore, the following laws also bear certain relationship to the study.

(1) Public Health Act, B.E. 2484 (1941)

(2) Act for the Cleanliness and Tidiness of the Country, B.E. 2503 (1960)

(3) Building Act, B.E. 2522 (1979)

(4) Act for Metropolitan Waterworks Authority, B.E. 2510 (1967), Revision B.E. 2522 (1979)

(5) Act for Provincial Waterworks Authority, B.E. 2522 (1979)

Among the above, the Act for MWA stipulates that MWA should take charge of the water supply in Samut Prakarn.

Table 2.4: Related Laws and Notification

No.	Law and Notification	Supervising Ministry	Items related to Water Supply and Discharge
1	Factory Act B.E. 2512	Ministry of Industry	1. License is necessary for location and operation of factory. 2. Treatments of solid waste, waste water and waste gas are requested for approval.
2	Industrial Effluent Standard Notification No. 10 and 12 B.E. 2525 (1982)	"	Industrial effluent standard (Refer to Table 2.11)
3	Supervisors for Prevention of Pollution Notification No. 13 B.E. 2525 (1982)	"	Scale and kind of factory that is obliged to employ supervisor and his (her) qualification
4	Environmental Impact Assessment Report Notification No. 15 B.E. 2527 (1984)	"	Scale and kind of factory that is obliged to submit the report and contents of the report
5	Ground Water Act B.E. 2520 (1977)	"	1. Permit is necessary to pump up groundwater 2. Price rate can be imposed on those who use groundwater. But, rate* is under 1 ฿/m³.
6	Technical Measures for Conservative Use of Deep Well Water Notification No. 7 B.E. 2528 (1985)	"	1. Flow meter must be installed to deep well of more than 15 m deep. 2. Technical standard of flow meter.

Note: Price rate* inside service area of MWA is 1 ฿/m³ and that outside area is 0.75 ฿/m³.

Chapter 3 Use of Industrial Water in the Surveyed Factories

3.1 Selection of the Factories for Survey

There are altogether 2,631 factories in Samut Prakarn Province. Among them, IWD selected 59 factories covering five different industries in accordance with the minutes of discussion on the scope of work. The selection was made in accordance with the following principles.

(1) The selected factories should be large enough to represent the industry concerned. (Some small factories, though, may be added.)

(2) The number of factories in each of the five industries should be well balanced.

(3) The selected factories should be those which can cooperate with the survey (questionnaire survey and visiting survey).

The survey was highly detailed, requiring access to the inside of factory premises. Hence, though (3) above may appear odd, cooperative participation of the factories was indispensable.

In accordance with principles (1) and (2) above, IWD first selected about 200 factories, and then, considering (3) on the basis of the preliminary survey, narrowed the number to 59. The outline of these 59 factories is as follows:

Item \ Industry	Food	Paper	Textile	Metal	Chemical	Total
No. of Factories	14	5	7	20	13	59
No. of Employees	4,840	1,870	5,310	5,590	2,240	19,850
Pumping Up Qt. (m^3/d)	6,500	16,900	13,600	8,500	4,700	50,300

The table below shows the relative weight of the selected 59 factories against the active industrial sector in Samut Prakarn Province.

	Samut Prakarn	Selected Factories
No. of Factories	2,631	59 (2.2%)
No. of Employees	130,000-150,000	19,850 (14.2%)
Pumping Up Qt. (m^3/d)	286,000	50,300 (17.6%)

As seen in the table, the pumping up quantity of the selected factories accounts for only 17.6 % of the total pumping up quantity of Samut Prakarn factories. This small ratio may be due to the above-mentioned principles (2) and (3).

Thus the selected factories are not necessarily a mirror-like reflection of the situation in Samut Prakarn area. Nevertheless, considering the following facts, the selection was by and large reasonable.

3.2 Present Situation of Use of Industrial Water

For each of the surveyed factories, the water consumption classified by source is as shown in Table 3.2.

In total, the water consumed in the factories amounts to about 227,000 m^3/d (i.e. 3,847 m^3/d for each factory), of which make-up water accounts for about 53,000 m^3/d (i.e. 896 m^3/d for each factory). Thus, the water recovery rate (the ratio of recovered water to total water consumption) reaches 76.7 % as a whole.

Figs. 3.1 to 3.6 illustrate the surveyed factories' use of industrial water in graphics.

Figs. 3.1 and 3.2 show the water sources. As mentioned above, recovered water occupies the largest percentage, with most (95 %) of the make-up water, on the other hand, coming from wells.

Water consumption in each industry is as shown in Fig. 3.3. The textile and paper industries, though small in the number of factories, use relatively large quantity of water. Considering the fact that both textile and paper production lines require considerable water, this result is understandable. The same can be said of the use of well water (Refer to Fig. 3.5).

The water consumption per factory in each industry is given below.

(Unit: m^3/d)

Item / Industry	Consumption of Water (including Recovered Water)	Consumption of Make-up Water
Food	3,309	502
Paper	5,871	3,769
Textile	9,595	1,947
Metal	1,758	430
Chemical	3,729	368
Average	3,847	896

Table 3.1: Quantity of Consumed Water

Unit: m³/d

Industry	Source / Use	Well Water	MWA	Others	Sub Total	Recovered Water	Total	Recovery Rate (%)
Food Total	Boiler	436	34	0	470	77	547	14.1
	Material	111	2	0	113	0	113	0.0
	Washing	3,508	30	231	3,769	40	3,809	1.1
	Cooling	1,245	9	174	1,428	39,184	40,612	96.5
	Air Cond.	0	0	0	0	0	0	0.0
	Others	1,131	9	15	1,155	0	1,155	0.0
	Outside	90	0	0	90	0	90	0.0
	Total	6,521	84	420	7,025	39,301	46,326	84.8
Paper Total	Boiler	695	0	0	695	377	1,072	35.2
	Material	0	0	0	0	0	0	0.0
	Washing	16,009	0	1,900	17,909	10,572	28,481	37.1
	Cooling	2	0	0	2	60	62	96.8
	Air Cond.	0	0	0	0	0	0	0.0
	Others	209	0	0	209	0	209	0.0
	Outside	30	0	0	30	0	30	0.0
	Total	16,945	0	1,900	18,845	11,009	29,854	36.9
Textile Total	Boiler	858	32	0	890	40	930	43.0
	Material	0	0	0	0	0	0	0.0
	Washing	10,723	6	0	10,729	6	10,735	0.1
	Cooling	164	0	0	164	0	164	0.0
	Air Cond.	830	0	0	830	53,489	54,319	98.5
	Others	983	16	0	999	0	999	0.0
	Outside	20	0	0	20	0	20	0.0
	Total	13,578	54	0	13,632	53,535	67,167	79.7
Metal Total	Boiler	192	0	0	192	50	242	20.7
	Material	0	0	0	0	0	0	0.0
	Washing	3,803	0	0	3,803	4,028	7,831	51.4
	Cooling	2,156	0	0	2,156	22,445	24,601	91.2
	Air Cond.	2	0	0	2	40	42	95.2
	Others	1,542	47	0	1,589	0	1,589	0.0
	Outside	852	0	0	852	0	852	0.0
	Total	8,547	47	0	8,594	26,563	35,157	75.5

Note: Boiler = Boiler feed water
Material = Material water
Washing = Processing and washing water
Cooling = Cooling water
Air Cond. = Air conditioning water
Others = Water for other uses (miscellaneous use)

Table 3.1: Quantity of Consumed Water (Continued, 2/2)

Unit: m³/d

Industry	Source / Use	Well Water	MWA	Others	Sub Total	Reccver-ed Water	Total	Recovery Rate (%)
Chemical Total	Boiler	344	0	5	349	104	453	23.0
	Material	454	0	0	454	0	454	0.0
	Washing	1,187	10	5	1,202	500	1,702	29.3
	Cooling	1,141	0	55	1,196	43,089	44,285	97.3
	Air Cond.	0	0	0	0	0	0	0.0
	Others	1,111	20	0	1,131	0	1,131	0.0
	Outside	467	0	0	467	0	467	0.0
	Total	4,704	30	65	4,799	43,693	48,492	90.1
Gross Total	Boiler	2,525	66	5	2,596	648	3,244	20.0
	Material	565	2	0	567	0	567	0.0
	Washing	35,230	46	2,136	37,412	15,146	52,558	28.7
	Cooling	4,709	9	229	4,947	104,778	109,725	95.5
	Air Cond.	832	0	0	832	53,529	54,361	98.5
	Others	4,975	92	15	5,082	0	5,082	0.0
	Outside	1,459	0	0	1,459	0	1,459	0.0
	Total	50,295	215	2,385	52,895	174,101	226,996	76.7

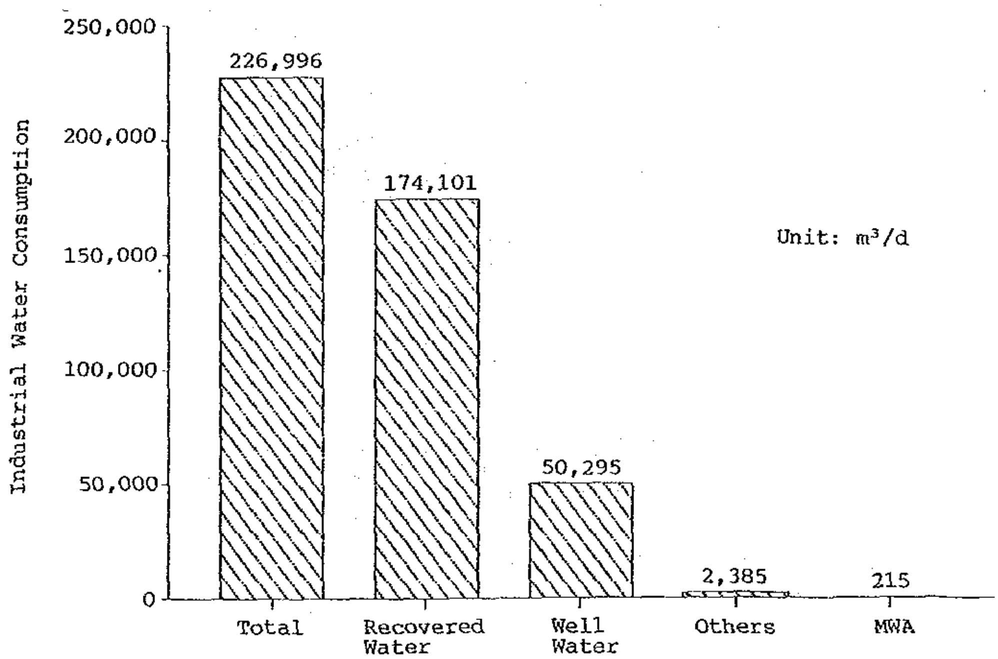


Fig. 3.1: Industrial Water Consumption Classified by Water Source

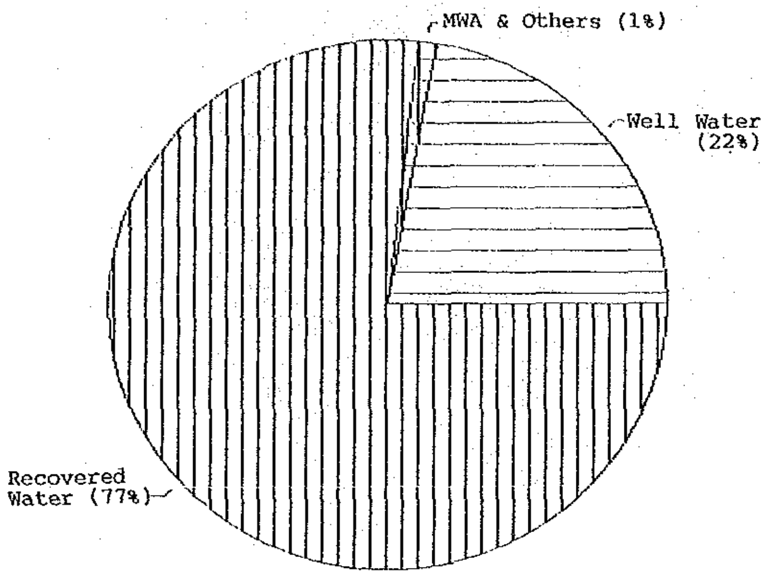


Fig. 3.2: Percentage of Industrial Water Consumption Classified by Water Source

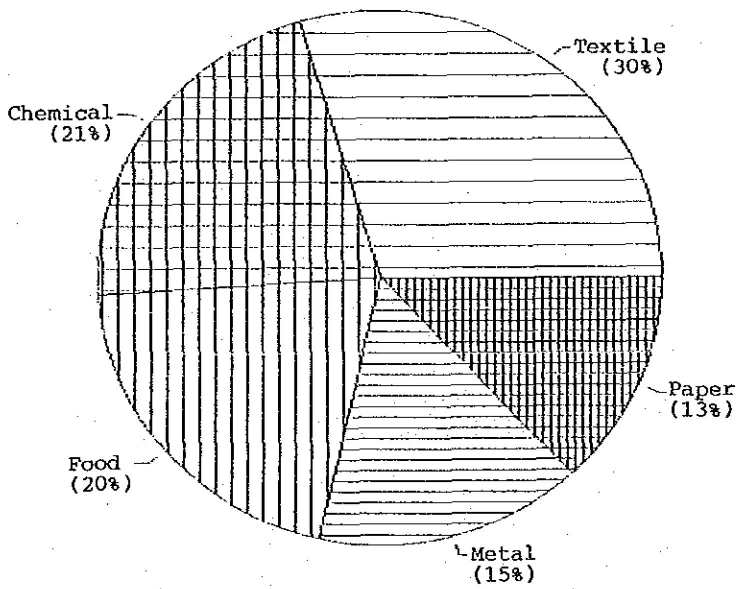


Fig. 3.3: Percentage of Industrial Water Consumption Classified by Industry

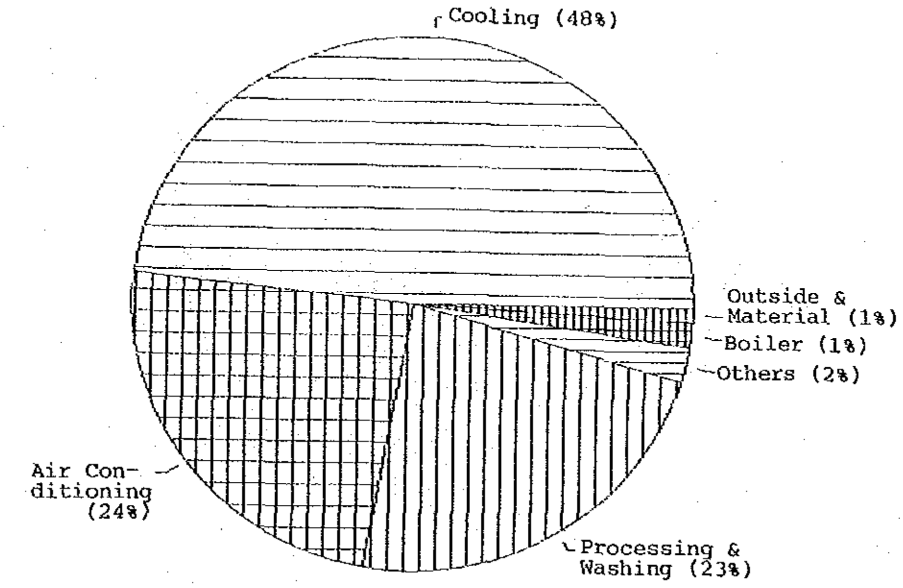


Fig. 3.4: Percentage of Industrial Water Consumption by Use

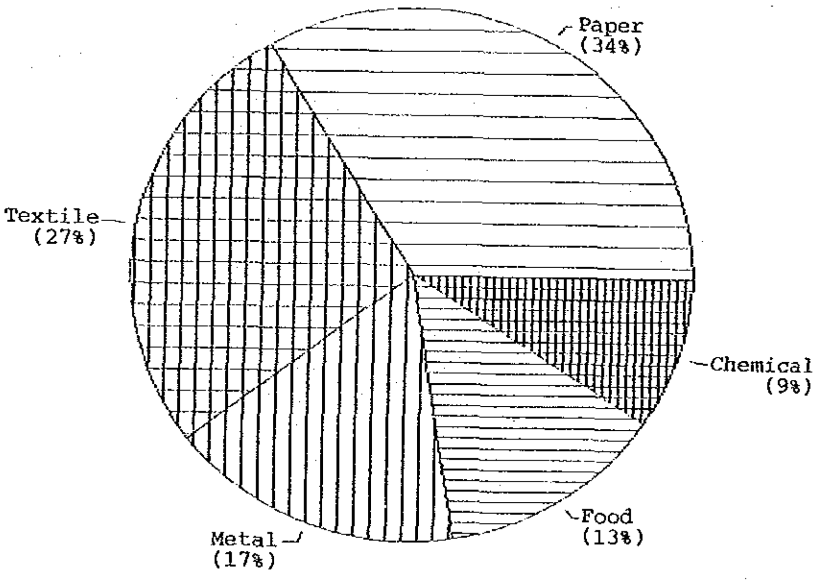


Fig. 3.5: Percentage of Well Water Consumption Classified by Industry

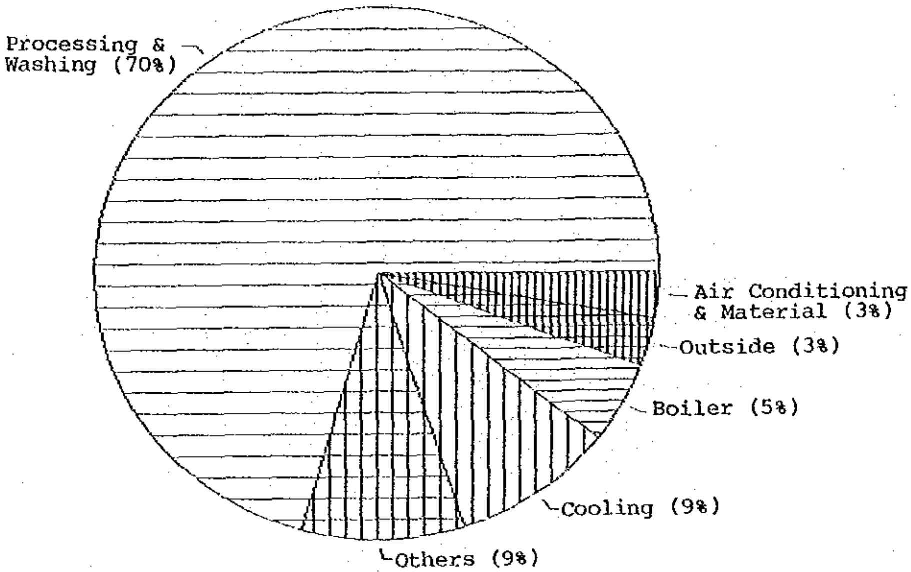


Fig. 3.6: Percentage of Well Water Consumption Classified by Use

Chapter 4 Study of Effective Use of Industrial Water

4.1 Outline

On the basis of the analysis in the previous section, concrete methods for effective use of industrial water were studied for each of the surveyed factories. The improvement methods include:

(1) Thorough control of water use (including the control of domestic water)
(2) Recycle use
(3) Multistage or cascade use of water
(4) Reclamation of waste water
(5) Application of water saving apparatus
(6) Improvement of operation control of cooling tower and other equipment
(7) Others

For each of the above methods, the unit cost was estimated in order to judge the economic feasibility (only those methods whose costs do not exceed reasonable limits should be taken). Table 4.1 shows the potential quantity of water saving/reclamation by each factory.

4.2 Cost Estimation

For each of the surveyed factories, the feasible methods for the effective use of industrial water were studied. Then the costs required for those improvement methods were estimated.

4.2.1 Estimation Procedure

The costs for improvement methods were estimated in the following sequence.

(1) Cost for the construction of required facilities (bahts)
(2) Depreciation cost (฿/Y, ฿/m^3)
(3) Maintenance cost of the facilities (฿/Y, ฿/m^3)
(4) Operating cost of the facilities (฿/m^3)
(5) Unit cost of the improvement (฿/m^3)

4.2.2 Basis for Cost Estimation

(1) Construction cost

The construction cost consists of procurement costs (for materials, main equipment, accessories, electrical and instrumentation equipment, pipings and foundations) and installation costs. The construct cost was estimated on a local cost basis.

(2) Fixed Cost = Depreciation Cost + Maintenance Cost

(a) Depreciation Cost

Life of facilities: 15 years
Interest rate: 12%
Residual value: 0

(b) Maintenance Cost

Except in large-scale plants (thermal power plants, oil refining plants, petrochemical plants and the like), regular maintenance of facilities is not a common practice in light industries.

(3) Operating Cost

The operating cost consists of costs for energy, chemicals, consumables and other relevant items. The required facilities being generally small-scale, the existing personnel would be enough to operate them. So, no personnel cost for operation is included in the estimate.

4.2.3 Estimation of the Unit Cost of Improvement

The unit cost of improvement is defined as follows.

Unit cost = Fixed cost + Operating cost (฿/m^3)

where,

Fixed cost = Annual fixed cost/Annual quantity of water saving (฿/m^3)

Operating cost = Annual operating cost/Annual quantity of water saving (฿/m^3)

The unit cost of improvement indicates how much cost would be required to save one cubic meter of water through the improvement method in question.

It provides an useful criterion to judge whether a particular improvement method is economical or not in comparison with alternative water sources. If the unit cost of improvement is lower than the cost of any alternative water sources (groundwater, MWA water, public industrial water and the like), the improvement method in question makes good economic sense.

4.3 Estimation of Potential Quantity of Water Saving and Water Reclamation

4.3.1 Basic Concepts

As mentioned before, though it is technically possible to construct a complete water recycling system (a "closed" system) for any factory in any industry, its cost would be often prohibitively high. Therefore, in determining the potential quantity of water saving and water reclamation, the unit cost of improvement (refer to 4.2.3 above) should be used.

The economically allowable limit of the unit cost depends on the costs of alternative water sources. The costs of various water sources in Samut Prakarn are:

Rates of MWA water	8 ฿/m^3
Estimated cost of water supplied by public industrial waterworks	4.75 - 7.5 ฿/m^3
(cf. pumping up cost of well water including rate	2 - 2.5 ฿/m^3)

The above costs do not include the costs for water treatments. Since the qualities of water supplied by MWA or the planned public industrial waterworks are not excellent (for instance, high electrical conductivity), some water treatment method will be necessary. (In the case of MWA water, some factories have already implemented water treatments.)

In Japan, the economically allowable limit of the unit cost of improvement is set by the following criterion.

(1) The maximum rates of the public industrial water, or

(2) where the service of public industrial waterworks is not yet available, the expected cost of public industrial water on the assumption that such waterworks were constructed.

If the same criterion is applied, the allowable unit cost of improvement for the surveyed factories is determined by the expected water rates (4.75 to 7.5 ฿/m^3) of the planned industrial waterworks. For the purpose of the study, the standard unit cost of improvement was set at around 8 bahts per cubic meter.

However, the main purpose of the effective use of industrial water is to prevent the subsidence of land, so that economic considerations should give way to the urgency of the problem. Moreover, as mentioned above, the real cost of public industrial water is likely to be increased by the necessity of water treatment.

In the estimation of the potential quantity of water saving/reclamation, therefore, more than 8 ฿/m^3 (i.e. up to 13 ฿/m^3) was allowed as the unit cost of improvement.

In Japan, too, the potential quantity of water saving is calculated on the basis of the unit improvement cost slightly higher than the criterion given above.

4.3.2 Result of Estimation

Table 4.1 shows the estimated quantity of potential water saving/reclamation for each factory.

The aggregate potential quantity of water saving/reclamation of the surveyed factories is as follows.

Total saving/reclamation quantity	11,162 m^3/d
Saving rate of well water	22.2%
Average unit cost of improvement	4.7 ฿/m^3
Maximum unit cost of improvement	13.1 ฿/m^3

Table 4.1: The Potential Quantity of Water Saving by Factory

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
1	F-01	870	330	1,200	540	1,740	31.0	Application of water saving apparatus	Thorough control of water use and use of hand control valve	PW	100	20	0.2	-	0.2
								Others	Use of river water for floor washing and others	PW	150	1,240	3.4	3.7	7.1
		Total									250	1,260			4.3
2	F-02	1,065	-	1,065	4,000	5,065	78.9	Control of water use	Check and control of water requirement for domestic use	D	215	-	-	-	-
3	F-03	178	-	178	672	850	79.1	Application of water saving apparatus	Installation of check valve in cooling tower	C	5	9	0.9	-	0.9
								Recycle use	Recycle use of cooling water of one through system by existing cooling tower	C	8	15	1.0	0.5	1.5
		Total									13	24			1.3
4	F-04	100	-	100	-	100	0		No room for further improvement						
5	F-05	614	40	654	4,797	5,451	88.9		Application of effective use is very difficult						

Note: Use* -- PW = Processing & Washing; D = Domestic; C = Cooling
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 2/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
6	F-06	1,098	-	1,098	4,520	5,618	81.6	Recycle use	Recycle use of cooling water for thermal sterilization by installation of cooling tower	C	350	2,930	3.6	2.4	6.0
7	F-07	163	-	163	5,760	5,923	97.2	Application of water saving apparatus	Use of hand control valve for washing water	PW	10	15	1.5	-	1.5
8	F-08	665	-	665	14,160	14,825	95.5	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concent-ration	C	36	-	-	0.5	0.5
								Application of water saving apparatus	Use of hand control valve for washing water	PW	40	60	1.3	-	1.3
		Total									76	60			0.9
9	F-09	300	-	300	3,565	3,865	92.5	Control of water use	Check and control of water requirement for domestic use	D	25	-	-	-	-
10	F-10	-	54	54	660	714	92.4		Little room for further improvement						
11	F-11	37	-	37	4	41	9.8		As water consumption is very small, application of effective use is difficult.						

Note: Use* -- C = Cooling; PW = Processing & Washing; D = Domestic
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 3/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
12	F-12	323	-	323	23	346	6.6	Improvement of operation control	Improvement of operation and control of deionization system to decrease backwashing water	O	30	-	-	-	-
13	F-13	1,040	80	1,120	600	1,720	34.9		Little room for further improvement						
14	F-14	68	-	68	-	68	0		As water consumption is very small, application of effective use is difficult.						
Food Total		6,521	504	7,025	39,301	46,326	84.8		Water Saving Rate		969 14.9%	4,289			3.4
15	P-01	1,245	-	1,245	600	1,845	32.5	Recycle use	Increase of recovery tank capacity to improve recovery of white water	PW	200	160	0.3	-	0.3
								Recycle use	Recovery of steam condensate	B	90	46	0.5	-	0.5
		Total									290	206			0.4
16	P-02	1,230	-	1,230	2,200	3,430	64.1	Recycle use	Increase of recovery tank capacity to improve recovery of white paper	PW	250	320	0.5	-	0.5
17	P-03	2,958	-	2,958	3,349	6,307	53.1	Reclamation of waste water	Advanced treatment of waste water for re-use in washing process	PW	700	4,200	2.5	1.5	4.0

Note: Use* -- O = Miscellaneous; PW = Processing & Washing; B = Boiler
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 4/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
18	P-04	11,360	1,900	13,260	4,800	18,060	26.6	Recycle use	Increase of recycling capacity of white water to raise recovery ratio	PW	1,000	496	0.2	0.7	0.9
								Reclamation of waste water	Advanced treatment of waste water for re-use in washing process	PW	3,000	37,776	4.5	0.8	5.3
		Total									4,000	38,272			4.2
19	P-05	152	-	152	60	212	33.0	Others	Use of pond water for spraying	O	20	167	3.2	1.2	4.4
Paper Total		16,945	1,900	18,845	11,009	29,854	36.9		Water Saving Rate		5,260 31.0%	43,154			3.3
									Without Reclamation Water Saving Rate		1,560 9.2%	1,178			0.8
20	T-01	10,384	-	10,384	53,489	63,489	83.7	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concentration	A	370		-	0.5	0.5
								Reclamation of waste water process	Advanced treatment of waste water for re-use in washing	PW	2,000	40,000	7.3	5.8	13.1
		Total									2,370	40,000			11.1

Note: Use* -- PW = Processing & Washing; O = Miscellaneous; A = Air Conditioning
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 5/12)

# Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
	Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
21 T-02	113	53	166	-	166	0.0	Recycle use	Recovery of steam condensate	B	6	71	5.0	-	5.0
22 T-03	1,885	-	1,885	40	1,925	2.0	Application of cascade use	Cascade use of cooling water for boiler feed water	B	50	361	3.1	-	3.1
							Application of water saving apparatus	Use of hand control valve for washing water	PW	30	20	0.6	-	0.6
							Control of water use	Thorough control of water use in each process	PW	140	320	1.0	-	1.0
	Total									220	701			1.4
23 T-04	25	1	26	-	26	0.0		As water consumption is very small, application of effective use is difficult						
24 T-05	180	-	180	unknown	180	0.0		As this factory was under test operation, the study on effective use was impossible.						
25 T-06	442	-	442	-	442	0.0	Control of water use	Thorough control of water use	PW	40		-	-	-
26 T-07	549	-	549	6	555	1.1		Little room for further improvement						

Note: Use* -- B = Boiler; PW = Processing & Washing
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 6/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
Textile Total		13,578	54	13,632	53,535	67,167	79.7		Water Saving Rate		2,636 19.4%	40,772			10.1
									Without Reclamation Water Saving Rate		636 4.7%	772			0.8
27	M-01	503	-	503	227	730	31.1	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concent-ration	C	139	-	-	0.5	0.5
28	M-02	1,191	0	1,191	370	1,561	45.6	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concent-ration	C	184	-	-	0.5	0.5
29	M-03	162	-	162	2,442	2,604	93.8	Control of water use	Thorough control of water use to decrease water leakage	O	40	-	-	-	-
30	M-04	6	2	8	960	968	99.2		Little room for further improvement						
31	M-05	620	-	620	812	1,432	56.7	Recycle use	Re-use of treated waste water for washing process	PW	200	1,424	3.0		3.6

Note: Use* -- C = Cooling; O = Miscellaneous; PW = Processing & Washing
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 7/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3 ฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
32	M-06	70	-	70	-	70	0.0	Recycle use	Recovery of steam condensate	B	3	31	4.2	-	4.2
								Recycle use	Re-use of treated waste water for washing process	PW	10	133	5.5	0.6	6.1
		Total									13	164			5.7
33	M-07	58	-	58	95	153	62.1	Recycle use	Recycle use of cooling water by installing receiving tank	C	14	274	8.5	0.5	9.0
34	M-08	40	-	40	10	50	10.0		As water consumption is very small, application of effective use is difficult.						
35	M-09	451	45	496	8,370	8,866	94.4	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concentration	C	105	-	-	0.5	0.5
36	M-10	17	-	17	128	145	88.3		Little room for further improvement						
37	M-11	212	-	212	128	350	39.4	Recycle use	Recycle use of cooling water by existing cooling tower	C	63	318	2.5	1.0	3.5
38	M-12	107	-	107	2,175	2,282	95.3		A semi-closed system has been installed in this factory.						

Note: Use* -- B = Boiler; PW = Processing & Washing; C = Cooling
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 8/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
39	M-13	20	-	20	144	164	87.8		As water consumption is very small, application of effective use is difficult.						
40	M-14	269	-	269	1,100	1,369	80.3		Little room for further improvement						
41	M-15	3,162	-	3,162	4,800	7,962	60.3	Recycle use	Recycle use of cooling water by existing cooling tower	C	110	23	0.1	0.5	0.6
								Application of cascade use	Cascade use of scrubbing water	PW	166	289	0.7	1.3	2.0
								Multistage use	Multistage use of washing water in metal plating process	PW	146	289	0.7	1.3	2.0
								Improvement of operation control	Thorough control of operation and maintenance of water treatment system to decrease backwashing water	PW	63	-	-	-	-
								Control of water use	Check and control of water requirement for domestic use	D	110	-	-	-	-
		Total									595	601			1.2

Note: Use* -- C = Cooling; PW = Processing & Washing; D = Domestic
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 9/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
42	M-16	529	-	529	1,072	1,601	67.0	Control of water use	Check and control of water requirement for domestic use	D	30	-	-	-	-
43	M-17	140	-	140	1,256	1,396	90.0		No room for further improvement						
44	M-18	617	-	617	1,460	2,077	70.3	Recycle use	Recycle use of shower test water	PW	25	140	3.1	1.0	4.1
								Control of water use	Check and control of water requirement for domestic use	D	54	-	-	-	-
		Total									79	140			1.3
45	M-19	350	-	350	600	950	63.2	Recycle use	Recycle use of cooling water by existing cooling tower	C	27	21	0.4	0.5	0.9
								Recycle use	Recovery of steam condensate	B	4	28	3.5	-	3.5
								Control of water use	Check and control of water requirement for domestic use	D	110	-	-	-	-
		Total									141	49			0.3

Note: Use* -- D = Domestic; PW = Processing & Washing; C = Cooling; B = Boiler
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 10/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3B)	Unit Cost (B/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
46	M-20	23	-	23	404	427	94.6		Little room for further improvement						
Metal Total		8,547	47	8,594	26,565	35,159	75.5		Water Saving Rate		1,603 18.8%	2,970			1.4
47	C-01	75	-	75	280	355	78.9		Little room for further improvement						
48	C-02	330	-	330	5,700	6,030	94.8	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concentration	C	40	-	-	0.5	0.5
								Control of water use	Check and control of water requirement for domestic use	D	85	-	-	-	-
		Total									125				0.2
49	C-03	36	-	36	54	90	60.0		Little room for further improvement						
50	C-04	-	40	40	-	40	0.0		Complete effective us has been already done in this factory.						
51	C-05	1,560	-	1,560	14,400	15,960	90.2	Control of water use	Check and control of water requirement for domestic use	D	50	-	-	-	-

Note: Use* -- C = Cooling; D = Domestic
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 11/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
52	C-06	27	-	27	-	27	0.0		Little room for further improvement						
53	C-07	83	55	138	40	178	22.5		Little room for further improvement						
54	C-08	752	-	752	3,770	4,522	83.9	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concentration	C	80	-	-	0.5	0.5
								Control of water use	Check and control of water requirement for domestic use	D	140	-	-	-	-
		Total									220				0.2
55	C-09	226	-	226	790	1,016	78.4		Little room for further improvement						
56	C-10	300	-	300	2,000	2,300	87.0	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concentration	C	26	-	-	0.5	0.5
57	C-11	1,020	-	1,020	14,400	15,420	93.4	Improvement of operation control	Improvement of operation and maintenance of cooling tower to raise degree of concentration	C	246	-	-	0.5	0.5

Note: Use* -- C = Cooling; D = Domestic
Qt.** = Quantity

Table 4.1: The Potential Quantity of Water Saving by Factory (Continued, 12/12)

#	Code No.	Water Consumption (m^3/d)					Recovery Rate (%)	Method of Effective Use		Water Saving		Const. Cost (10^3฿)	Unit Cost (฿/m^3)		
		Well Water	Others	Sub Total	Recovered Water	Total		Method	Item	Use*	Qt.** (m^3/d)		Fixed	Operating	Total
58	C-12	250	-	250	2,227	2,477	89.9	Recycle use	Supply of soft water as make-up water to cooling tower to raise degree of concentration	C	27	4	0.1	1.2	1.3
59	C-13	45	-	45	32	77	41.6		Little room for further improvement						
Chemical Total		4,704	95	4,799	43,693	48,492	90.1		Water Saving Rate		694 14.8%	4			0.3
Gross Total		50,295	2,600	52,895	174,101	226,996	76.7		Water Saving Rate		11,162 22.2%	91,189			4.7
									Without Reclamation Water Saving Rate		5,462 10.8%	9,213			1.4

Note: Use* -- C = Cooling; Qt.** = Quantity

4.4 Potential Quantity of Water Saving Classified by Industry and Use of Water

Table 4.2 summarizes the potential quantity of water saving classified by industry and use of water. Fig. 4.1 and 4.2 illustrate these results in graphics. As mentioned above, the average water saving rate of all the industries is estimated at 22.2%. The saving rate for each industry range from 14.8% (the chemical industry) to 31.0% (the paper industry).

The high rate in the paper industry is owing to the relative easiness of water reclamation (if reclamation were excluded, the potential water saving rate would be mere 9.2%). On the other hand, in the chemical industry, the most part of water (i.e. cooling water) is already recycled, so that there is little room for further water saving.

From the viewpoint of the usage of water, the potential saving quantity of processing and washing water is the largest. This high saving potentiality of processing and washing water is due to the fact that a relatively large quantity of well water is now used for processing and washing (approx. 70% of the total consumption of well water) with a low recovery rate (approx. 29%).

The potential saving rates of cooling water and air conditioning water are fairly high (31% and 45% respectively). Thus, though the recovery rates of cooling water and air conditioning water are already high (69% and 99%), further saving seems to be feasible.

4.5 Potential Quantity of Water Saving Classified by Improvement Method and Use of Water

Table 4.3 summarizes the potential quantity of water saving classified by improvement method and use of water. Fig. 4.3 illustrates these results in graphics.

From the viewpoint of the improvement method, reclamation takes up the largest share (approx. 51%) of potential water saving. However, as explained later (4.8.1), the cost of water reclamation is high. If reclamation is excluded, recycling quantity for about 46% of the total water saving. Hence recycling seems to be the most common way of water saving.

The potential water saving through the improvement of operation control and water use control reaches almost the same quantity as the saving through recycling. This fact implies that water saving depends on training and awareness of employees as well as on effective facilities.

Table 4.2: Potential Quantity of Water Saving Classified by Industry and Use

Use / Industry	Category	Consumption of Well Water (m^3/d)						
		Boiler	Material	Proc. & Washing	Cooling	Air Cond.	Others	Total
Food	Present Q.	436	111	3,508	1,245	0	1,221	6,521
	Potential Q.			300	399		270	969
(14)	Water Saving Rate (%)			8.6	31.3		22.2	14.9
Paper	Present Q.	695	0	16,009	2	0	209	16,945
	Potential Q.	90		5,150			20	5,260
(5)	Water Saving Rate (%)	12.9		32.2			9.6	31.0
Textile	Present Q.	858	0	10,723	164	830	1,003	13,578
	Potential Q.	56		2,210		370		2,636
(7)	Water Saving Rate (%)	6.5		20.6		44.6		19.4
Metal	Present Q.	192	0	3,803	2,156	2	2,394	8,547
	Potential Q.	7		610	642		344	1,603
(20)	Water Saving Rate (%)	3.7		16.0	29.8		14.4	18.8
Chemical	Present Q.	344	454	1,187	1,141	0	1,578	4,704
	Potential Q.				419		275	694
(13)	Water Saving Rate (%)				36.7		17.4	14.8
Total	Present Q.	2,525	565	35,230	4,709	832	6,434	50,295
	Potential Q.	153		8,270	1,460	370	909	11,162
(59)	Water Saving Rate (%)	6.1		23.5	31.0	44.5	14.1	22.2

Remarks: Boiler = Boiler Feed Water
Material = Material Water
Proc. & Washing = Processing & Washing Water
Cooling = Cooling Water
Air Cond. = Air Conditioning Water
Others = Water for Other Uses (Miscellaneous Use)
Present Q. = Present Quantity
Potential Q. = Potential Quantity of Water Saving

Figures in ( ) show number of factories.

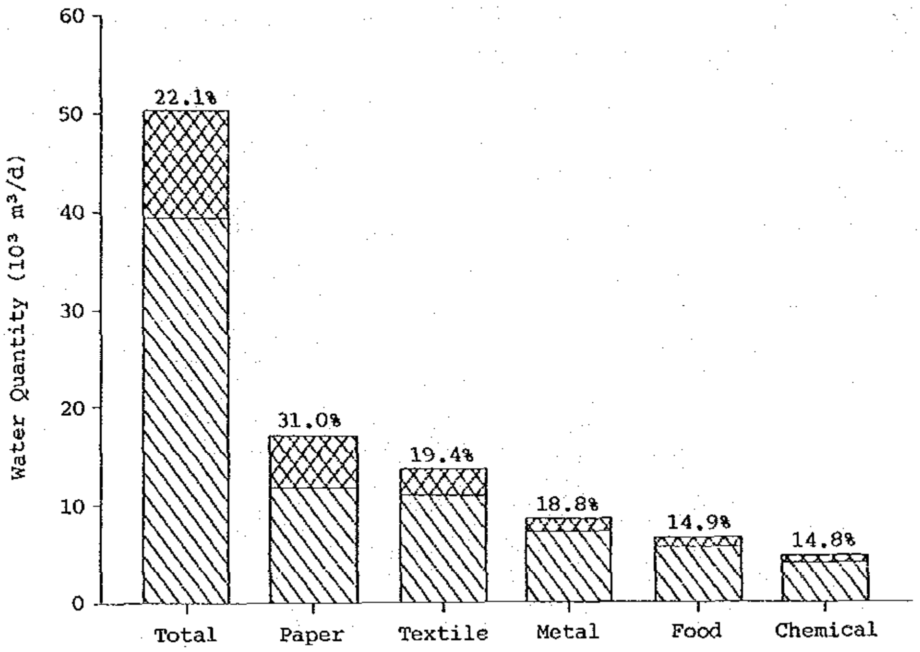


Fig. 4.1: Potential Quantity of Water Saving and Saving Rate Classified by Industry

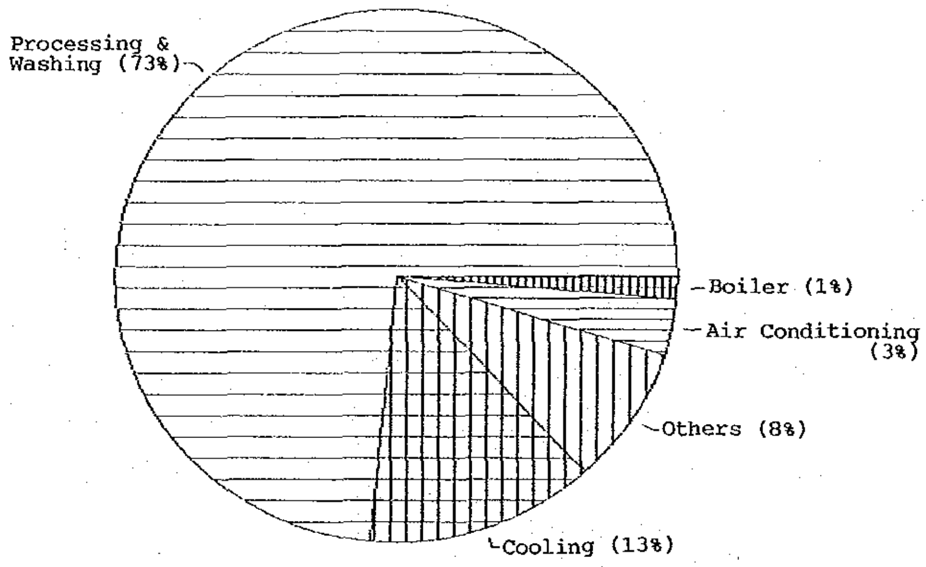


Fig. 4.2: Percentage of Potential Quantity of Water Saving Classified by Use

Table 4.3: Potential Quantity of Water Saving Classified by Method for Effective Use and Use

Use / Method of Effective Use	Items	Consumption of Well Water (m^3/d)					
		Boiler	Proc. & Washing	Cooling	Air Cond.	Others	Total
Recycle Use	Number Qt. (m^3/d) Ratio (%)	4 103 67.3	6 1,685 20.4	7 599 41.0			17 2,387 21.3
Multistage Use	Number Qt. (m^3/d) Ratio (%)	1 50 32.7	2 312 3.8				3 362 3.2
Reclamation	Number Qt. (m^3/d) Ratio (%)		3 5,700 68.9				3 5,700 51.1
Water Saving Appratus	Number Qt. (m^3/d) Ratio (%)		4 180 2.2	1 5 0.3			5 185 1.7
Operation Control	Number Qt. (m^3/d) Ratio (%)		1 63 0.8	8 856 58.7	1 370 100.0	1 30 3.3	11 1,319 11.8
Control of Water Use	Number Qt. (m^3/d) Ratio (%)		2 180 2.2			10 859 94.5	12 1,039 9.3
Others	Number Qt. (m^3/d) Ratio (%)		1 150 1.8			1 20 2.2	2 170 1.5
Total	Number Qt. (m^3/d) Ratio (%)	5 153 100	19 8,270 100	16 1,460 100	1 370 100	12 909 100	53 11,162 100

Remarks: Boiler = Boiler Feed Water
Proc. & Washing = Processing & Washing Water
Cooling = Cooling Water
Air Cond. = Air Conditioning Water
Others = Water for Other Uses (Miscellaneous Use)
Qt. = Water Quantity

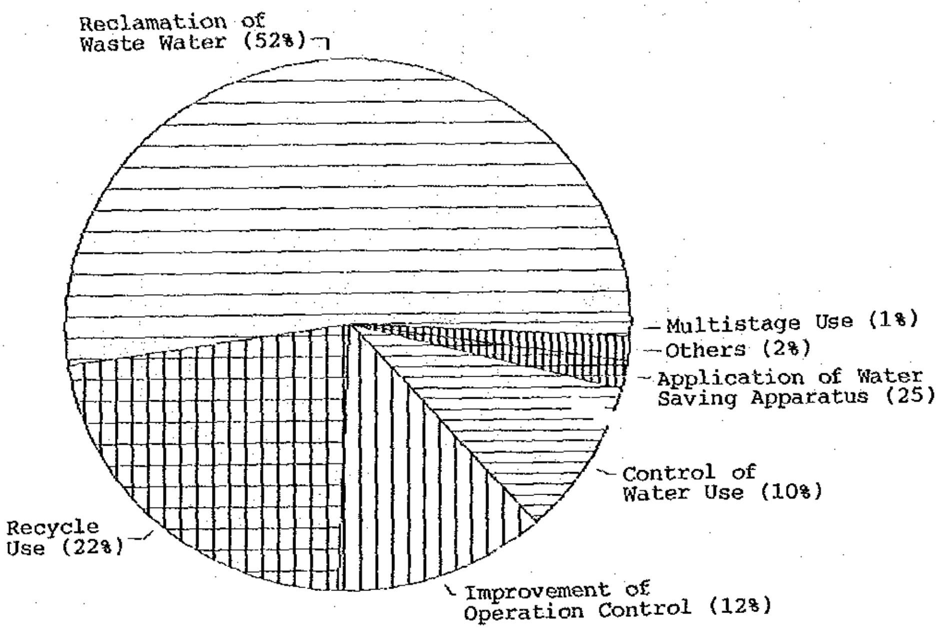


Fig. 4.3: Percentage of Potential Quantity of Water Saving Classified by Method for Effective Use

4.6 Potential Quantity of Water Saving Classified by Industry and Improvement Method

Table 4.4 summarizes the potential quantity of water saving classified by industry and improvement method. As mentioned above, since water reclamation is relatively easy in the paper and textile industries, it accounts for the large part of water saving in these industries. Next to water reclamation, recycling plays a fairly big role in the water saving of the food, paper and metal industries.

The percentage of recycling is small in the textile and chemical industries. This can be explained by the fact that the textile industry uses plenty of processing and washing water which is hard to recycle, and that the most part of water (i.e. cooling water) in the chemical industry is already recycled.

In the metal and chemical industries, a great deal of water can be saved through the improvement of operation control (i.e. through the raising of the degree of concentration in cooling water).

The improvement of water use control mainly concerns domestic water, so that the differences between industries do not matter much.

Table 4.4: Potential Quantity of Water Saving Classified by Method for Effective Use and Industry

Use / Method of Effective Use	Items	Consumption of Well Water (m^3/d)					
		Food	Paper	Textile	Metal	Chemical	Total
Recycle Use	Number Qt. (m^3/d) Ratio (%)	2 358 36.9	4 1,540 29.3	1 6 0.2	9 456 28.4	1 27 3.9	17 2,387 21.3
Multistage Use	Number Qt. (m^3/d) Ratio (%)			1 50 1.9	2 312 19.5		3 362 3.2
Reclamation	Number Qt. (m^3/d) Ratio (%)		2 3,700 70.3	1 2,000 75.9			3 5,700 51.1
Water Saving Apparatus	Number Qt. (m^3/d) Ratio (%)	4 155 16.0		1 30 1.1			5 185 1.7
Operation Control	Number Qt. (m^3/d) Ratio (%)	2 66 6.8		1 370 14.0	4 491 30.6	4 392 56.5	11 1,319 11.8
Control of Water Use	Number Qt. (m^3/d) Ratio (%)	2 240 24.8		2 180 6.8	5 344 21.5	3 275 39.6	12 1,039 9.3
Others	Number Qt. (m^3/d) Ratio (%)	1 150 15.5	1 20 0.4				2 170 1.5
Total	Number Qt. (m^3/d) Ratio (%)	11 969 100	7 5,260 100	7 2,636 100	20 1,603 100	8 694 100	53 11,162 100

Remark: Qt. = Water Quantity

4.7 Unit Cost of Improvement

4.7.1 Unit Cost of Improvement Classified by Industry

As shown in Table 4.1, the average unit cost of improvement is 4.7 ฿/m^3, which is much lower than the cost of MWA water or (expected) public industrial water. If the relatively high cost of reclamation is excluded, the average unit cost of improvement goes down to 1.4 ฿/m^3, the value equal to the pumping up cost of well water.

Except the textile industry where the high cost of reclamation (13.1 ฿/m^3) increases the unit cost up to 10 ฿/m^3, the unit cost of improvement is more or less the same as the cost of the pumping up of well water. It is low especially in the metal and chemical industries, since the percentages of inexpensive methods (operation control and control of water use) are high in these industries (refer to Table 4.4).

4.7.2 Unit Cost of Improvement Classified by Method

Table 4.5 shows the unit cost for each improvement method. As stated above, even with the high cost of reclamation included, the average unit cost of improvement does not exceed the cost of water form the alternative source.

If the cost of reclamation is excluded, the average unit cost becomes no more than the pumping up cost of well water. This inexpensiveness of the improvement is owing to the fact that the operation control and the control of water use account for 21% of the whole methods (43%, if reclamation is excluded). Making the use of industrial water more effective does not necessarily require a huge quantity of money.

Table 4.5: Potential Quantity of Water Saving Classified by Method for Effective Use and Unit Cost

Method of Effective Use \ Use	Items	Rank of Unit Cost (฿/m³)				
		Less than 1	1 to 5	5 to 10	More than 10	Total
Recycle Use	Number Qt. (m^3/d) Av. U/Cost	6 1,677 0.7	7 330 3.4	4 380 6.1		17 2,387 2.0
Multistage Use	Number Qt. (m^3/d) Av. U/Cost		3 362 2.2			3 362 2.2
Reclamation	Number Qt. (m^3/d) Av. U/Cost		1 700 4.0	1 3,000 5.3	1 2,000 13.1	3 5,700 7.9
Water Saving Appratus	Number Qt. (m^3/d) Av. U/Cost	3 135 0.3	2 50 1.3			5 185 0.6
Operation Control	Number Qt. (m^3/d) Av. U/Cost	11 1,319 0.5				11 1,319 0.5
Control of Water Use	Number Qt. (m^3/d) Av. U/Cost	11 899 0.0	1 140 1.0			12 1,039 0.1
Others	Number Qt. (m^3/d) Av. U/Cost		1 20 4.4	1 150 7.1		2 170 6.8
Total	Number Qt. (m^3/d) Av. U/Cost	31 4,030 0.5	15 1,020 3.1	6 3,530 5.5	1 2,000 13.1	53 11,162 4.7
	Ratio (%)	36.1	14.4	36.1	17.9	100.0

Remarks: Qt. = Water Quantity; Av. U/Cost = Average Unit Cost

4.7.3 Unit Cost of Improvement and Potential Quantity of Water Saving

As mentioned in 4.3, the potential quantity of water saving is closely related with the unit cost of improvement. When the latter is set high the former increases, and vice versa.

In the study, the allowable unit cost of improvement was set at 8 ฿/m³. In estimating the potential quantity of water saving, however, the unit cost up to about 13 ฿/m³ (1.5 time larger than the allowable cost) was allowed to be taken into account.

Some examples are given below.

Upper Limit of Unit Cost (฿/m³)	Water Saving Quantity (%)
2 (equivalent to the pumping up cost)	39
5	52
8 (equivalent to the cost of public industrial water)	82
10	82

Average Unit Cost (฿/m³)	Water Saving Quantity (%)
2 (equivalent to the pumping up cost)	77
4	82
4.7 (Still much lower than the cost of public industrial water)	100

The above figures may be summed up as follows:

(1) If the upper limit of the unit cost of improvement is set at the present cost of pumping up, the water saving is reduced to 39% (i.e. 4,350 m³/d, 8.7% of saving rate) of the total potential quantity.

(2) If the average unit cost of improvement is set at the present cost of pumping up, the water saving is reduced to 77% (i.e. 8,595 m³/d, 17.1% of saving rate) of the total potential quantity.

(3) If the upper limit of the unit cost is set at the cost of the alternative water sources, 82% (i.e. 9,150 m³/d, 18.2% of saving rate) of the total potential quantity is saved.

(4) Even if the average unit cost of improvement is much lower than the cost of alternative water, 100% of the total potential quantity is saved.

As shown in 4.2, the estimation of the unit cost of improvement is based on certain assumptions. Hence, in some cases, the real costs of improvement may differ from those indicated here.

Chapter 5. Improvment Methods for Each Factory

Improvement methods for effective use of industrial water are described in details for each of the surveyed 59 factories. The description of each factory includes:

(1.) Outline of Factory

(2.) Present Situation of the Use of Industrial Water

(2.1) Water Consumption

(2.2) Process Diagram of Production Line

(2.3) Flow Diagram of Water Supply and Waste Water Discharge

(2.4) Explanation of Present Situation

(2.4.1) Sources and Uses

(2.4.2) Water Treatment

(2.4.3) Waste Water Treatment

(3.) Plans of Effective Use of Industrial Water

(3.1) General

(3.2) Details

(4.) Cost Estimation

6. Guideline for Effective Use of Industrial Water Classified by Use

6.1 Outline

In this Chapter, general methods for effective use of industrial water are explained being classified by the purpose of use, in addition to those for each factory which have been described in the previous Chapter 4.

Purpose of industrial water use are as follows:

(1) Boiler water
(2) Product processing and washing water
(3) Cooling and air conditioning water
(4) Others

To clarify the effective use of water, the method for each purpose of water use are detailed as follows:

(1) Characteristics of feed water and drainage,

(2) Standard methods for effective use of water,

(3) Cost estimation, and

(4) Notes and problems in effective use of water.

In addition to the above, a theoretical explanation are partly given.

The conditions for cost estimation are as follows, unless otherwise specified:

Depreciation period:	10 years
Average interest:	10% per year
Annual operating days:	300 days
Water cost:	10 ¥/m^3

6.2 Industrial Water for Processing and Washing of Products

6.2.1 Characteristics of Supply Water and Drainage Water

Industrial water for processing and washing of products should usually be comparatively good in quality, corresponding to the quality of material water as much as possible, because it often contacts directly with the products.

And a large quantity of water is often consumed in all industries, though the quantity used at each production process depends on the type of processing line. As for the quality of waste water discharged from the washing process, on the other hand, the concentration of pollutant is relatively high and it determines in many cases the characteristics of waste water for a factory.

6.2.2 Standard Methods for Effective Use of Water

The following standard methods have been applied for effective use of product processing and washing water:

(1) Counter-current and multistage washing system
(2) Cascade system
(3) Water saving apparatus

The principle, water saving rate and etc. for each method are as follows:

(1) Counter-current and multistage washing system

(a) General concept

In this system, materials to be washed and washing water flow counter-currently to each other. With a single washing tank system, the washing of product is not effective. Thus a multistage washing system should be selected. An outline drawing of this counter-current and multistage system is shown in Fig. 6. 1.

This system is widely applied. For examples, metal-plated products washing in the metal industry and cans and bottles washing for canned foods and refreshing drinks in the food industry.

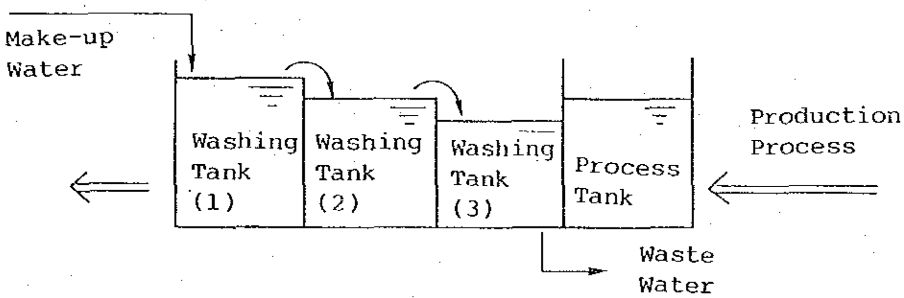


Fig. 6. 1: Example of Counter-Current Multistage Washing System

(b) Water consumption for counter-current washing system

In the washing process for metal-plated products, washing water is used to wash out residual chemicals on the surface of products delivered from a plating bath. In this case, any chemicals are not required to be absolutely removed, however, they should be diluted to an acceptable concentration.

The relationship between the number of stages and the water consumption is shown in Fig. 6. 2. As seen in this figure, the increasing of the washing stage over the third is not so effective for water saving.

In the counter-current and multistage washing with a bottle washing machine, bottles are dipped in a caustic soda solution and washed by means of water jet for five to six times as shown in Fig. 6.3.

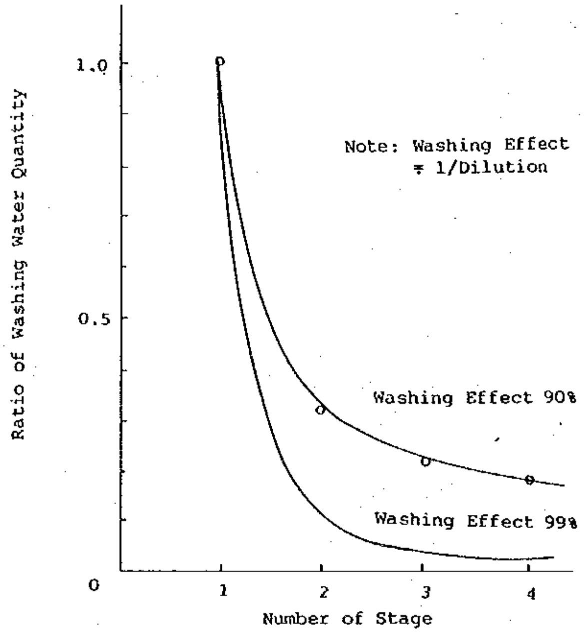


Fig. 6.2: Number of Stage and Ratio of Washing Water Quantity in Counter-Current Washing System

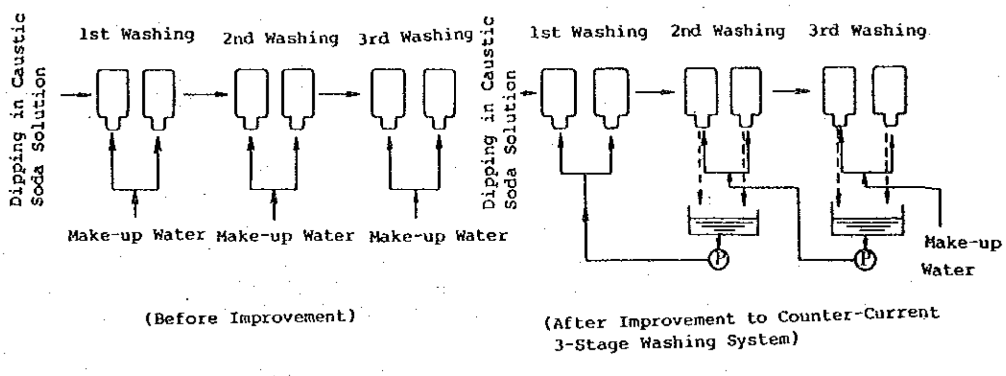


Fig. 6.3: Counter-Current Multistage Type Bottle Washing Machine

For example, make-up fresh water is used only at the third washing stage as shown in Fig. 6. 3. Its waste is used at the second stage washing then the waste water from this stage is re-used at the first stage washing. This system assures the almost same washing effect as that to be obtained under any stage washing systems.

The water consumption, different from that for the washing of plated products as described above, is inversely proportional to the number of washing stages. With a three-stage washing system, for example, the total quantity of water use is one third of that by supplying fresh water to all washing stages.

(2) Cascade system

With a cascade system, waste water used for a certain process is re-used for another process without treatment. Because it does not require any expensive facilities flow re-use and the operation cost is small, this cascade system can be a highly effective method of washing if it is practically available.

In most cases, indirect cooling water is re-used as a cascade in a washing process. To introduce this system, however, there are a lot of restrictions as described below.

(a) The quality and the temperature of waste water from the preceding process should be kept a level acceptable for the succeeding process.

(b) The quantity of waste water from the preceding process and the water consumption at the succeeding process should be nearly balanced.

(c) Operating conditions such as operating time and so on of both preceding and succeeding processes should be similar to each other.

In the effective use of water with a cascade system, water consumption can be saved by 50% at most even if all the requirements as stated above have been satisfied.

(3) Use of water saving apparatus

The following washing equipment and devices are available to save the water consumption.

(a) Hand control valve
(b) Flow control valve
(c) Automatic water supply system for washing tank
(d) High pressure jet washer
(e) Hot water jet washer

6.2.3 Cost Estimation

The methods for effective use of water explained in the previous section are as follows:

(1) Counter-current multistage washing system

(2) Cascade system

(3) Use of water saving apparatus

Among these methods, (1) and (2) require only a very small cost of equipment and the water saving rate directly corresponds to the cost saving rate of water.

As for (3), there is a certain variation of both cost of equipment and water saving rate, so it is difficult to exactly calculate the required cost.

Table 6.1 shows the water saving cost for each system or apparatus calculated on the basis of appropriate assumptions. Judging from this Table, it is clear that the application of water saving apparatus should save the washing cost by 9 to 40%.

6.2.4 Notes and Problems in Effective Use of Water

Since each factory is using industrial water for processing and washing of products in various ways, appropriate methods may be found by thinking out the ideas to satisfy the effective use of water.

Therefore each factory is expected to make its own effort for the effective use of water not sticking to any method proposed here.

It is important to avoid wasting water, however, excessive water savings should also be avoided in order not to give any bad influence to products, because the use of industrial water for processing and washing of products is closely related to the quality of products.

Table 6.1: Cost Saving Rate when Water Saving Apparatus is Adopted

Apparatus / Item	Hand Control Valve	Flow Control Valve	Automatic Water Supply System for Washing Tank	High Pressure Washer	Hot Water Washer
Condition					
Initial Cost (¥)	30,000	50,000	150,000	400,000	500,000
Amount of Water Saving (m^3/d)	10 30% saving of 50 m^3/d consumption	50 10% saving of 500 m^3/d consumption	50 50% saving of 100 m^3/d consumption	150 30% saving of 500 m^3/d consumption	150 30% saving of 500 m^3/d consumption
Present Water Cost (¥/d)*	500	5,000	1,000	5,000	5,000
Cost Estimation					
Depreciation of Apparatus (¥/d) (including Interest)	20	33	100	267	333
Water Cost after Adoption of Water Saving Apparatus (¥/d)	400	4,500	500	3,500	3,500
Total Water Cost after Improvement of System (¥/d)	420	4,533	600	3,767	3,833
Cost Saving Rate (%)	16	9	40	25	23

Note: * Water cost is 10 ¥/m^3 in this cost estimation.

Remarks: Water saving rates after installations of these apparatuses vary in large extent in accordance to conditions of water use before installations, and standard rates are difficult to set up. Saving rates which are deemed to be attained are assumed here in order to figure out cost saving rates.

6.3 Industrial Water for Cooling and for Air Conditioning

6.3.1 Characteristics of Water

Industrial water for cooling ("Cooling water") can be classified into the following three categories:

(1) Indirect cooling water
(2) Direct cooling water
(3) Indirect cooling water to be used at a low temperature

In general, cooling water means indirect cooling water which is the most part of cooling water . However in some industrial fields such as food industry, machine and apparatus manufacturing industry, direct cooling water is often used and also indirect cooling water at a low temperature is used in food and chemical industries.

Indirect cooling water is scarcely polluted while its temperature may rise (usually 5 to 10 C) during the use, so that it can be easily recycled for re-use through cooling towers as brought into practice in industrial fields generally.

Direct cooling water is similar to washing water in utilization and all methods for effective use of washing water (counter-current multistage washing system, cascade washing system and utilization of water saving apparatus) are applicable.

A detecting system of the water temperature can also be employed as a detecting section of an automatic water supply system for washing tank.

For indirect cooling water to be used at a low temperature, a refrigerator is required. However, costs of both equipment and operation is high in this system, and for this reason, the application of this system should be studied taking such conditions into account.

6.3.2 Standard Methods for Effective Use of Water by Cooling Tower

Cooling tower is the popular equipment used for the effective use of indirect cooling water. However, the cooling tower system is effective only under the conditions where the inlet water temperature is below 50 °C and the maximum allowable temperature of outlet water is more than 30 °C, and a refrigerator should be used as stated below if cooling water of lower temperature is required.

Cooling tower is used in order to lower the water temperature by latent heat of water evaporation obtained after the contact of warm water with cold air (exactly, air with lower wet bulb temperature than temperature of water to be cooled).

Fig. 6.4 shows a model flow for recycling use of water through a cooling tower. If effective use of water could be realized as shown in this figure by using a cooling tower, the water consumption is reduced from 100 to 5.

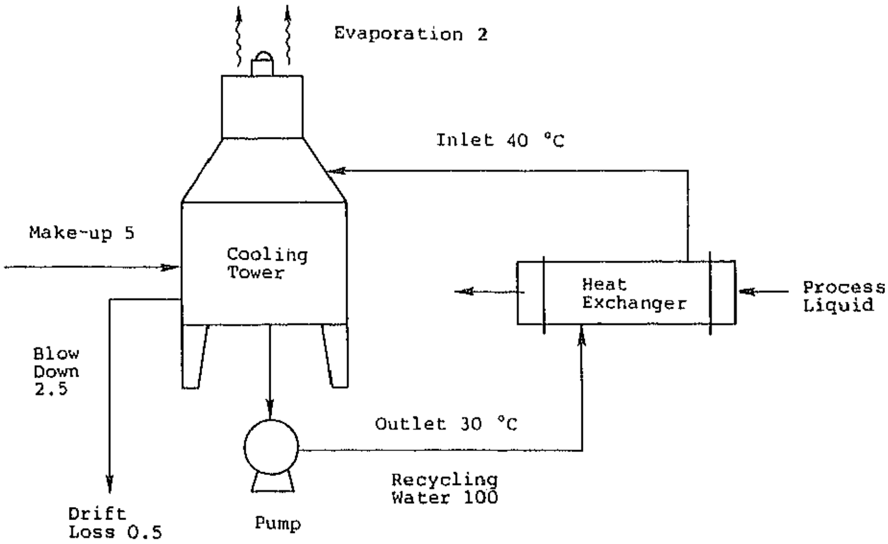


Fig. 6.4: Recycling System of Cooling Tower

Make-up water (M) is equal to the total quantity of water lost due to evaporation (E), drift loss (W) and blow down (B). Then, the following equation is obtained.

$M = E + B + W$ .... (1)

Degree of concentration is an index to show the ratio of dissolved solids concentration in the circuiting water to that of the make-up water, and is defined by the following equation:

$N = C_R/C_M$ .... (2)

C_R/C_R : Dissolved solids concentration in circulating water
C_R/C_M : Dissolved solids concentration in make-up water

$$N = \frac{E + B + W}{B + W} = 1 + \frac{E}{B + W} \quad \text{....(3)}$$

Since both the evaporation loss (E) and the drift loss (W) are constant if the operating conditions of a cooling tower are constant, the dissolved solids concentration in the cooling water can be controlled by adjusting of the blow down rate (B).

Assuming E = 2% and W = 0% (both are percentages to the flow rate of circulating cooling water) in the equation (3), the relationship between N and B can be illustrated as in Fig. 6.5.

As seen in this figure, the reduction of blow down is large when the degree of concentration increase within 5 or so, however, it becomes considerably smaller when degree of concentration exceeds such a level.

That is, since M = 2 + B + 0 is found from the equation (1), it is understood that a considerable saving of make-up water (M) is possible until the degree of concentration reaches 5.

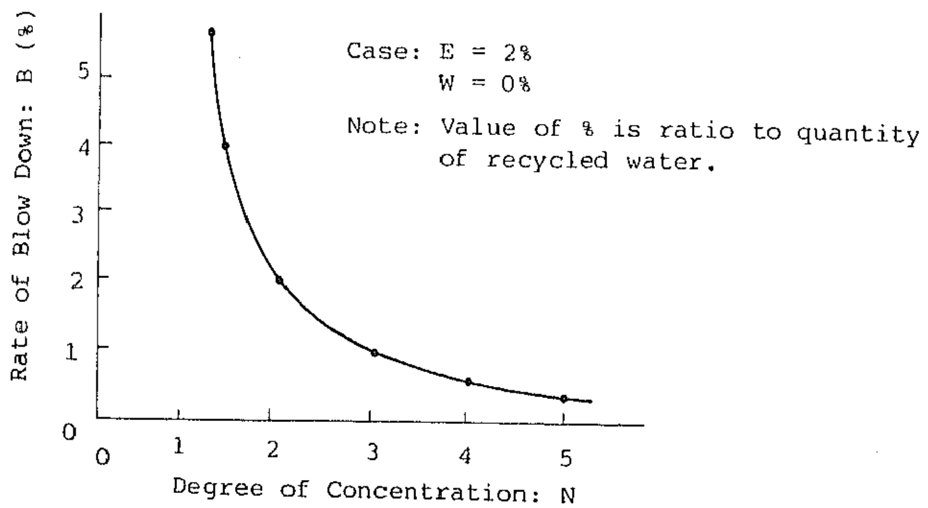


Fig. 6.5: Degree of Concentration and Rate of Blow Down

6.3.3 Cost Estimation for Cooling Tower

The price for a 50 RT cooling tower is about 0.9 million yen and about 7 million yen for a 500 RT cooling tower.

In addition to the above, the installation of pumps, reservoirs, pipings and other equipment is also required in the actual cooling water facilities, thus about double of the unit cost of a cooling tower system is required as a whole construction cost.

The followings are comparison of running costs of cooling system before and after the installation of a cooling tower.

(a) Before the installation of cooling tower

Cooling water consumption : 312 m^3/d
Cost of make-up water : 3,120 ¥/d

(b) After the installation of cooling tower

Capacity of cooling water	: 50 RT
Quantity of circulating water	: 312 m^3/d (39 m^3/h x 8 h)
Quantity of make-up water	: 6.2 m^3/d (2% of circulating water)
Cost of make-up water (A)	: 62 ¥/d
Price of cooling tower	: 0.9 million yen
Total construction cost	: 1.8 million yen (Double of cooling tower's price)
Depreciation (including interests) (B)	: 1,200 ¥/d
Cost of electricity and chemicals (C)	: 624 ¥/d (2 ¥/m^3)

Total cost (A) + (B) + (C) : 1,886 Y/d

(c) Cost saving rate

Consequently, the cost saving rate attained by the installation of a cooling tower is 40%.

Chapter 7 Guideline for Effective Use of Industrial Water Classified by Industry

7.1 Outline

Following on Chapter 6 which describes common methods for effective use of water classified by use, methods for effective use of water classified by industry are described in this Chapter. The industries have been divided into the following six:

(1) Food industry
(2) Paper industry
(3) Textile industry (Dyeing)
(4) Metal manufacturing industry
(5) Machine industry
(6) Chemical industry

The metal industry has been divided into the metal manufacturing industry and machine industry due to the difference in the product and the processing stages.

As stated at the beginning of Chapter 6, differences in water usage are especially apparent in the areas of processing and washing water when divided by the type of industry. Therefore, the methods of effective use will be mainly focused on those uses.

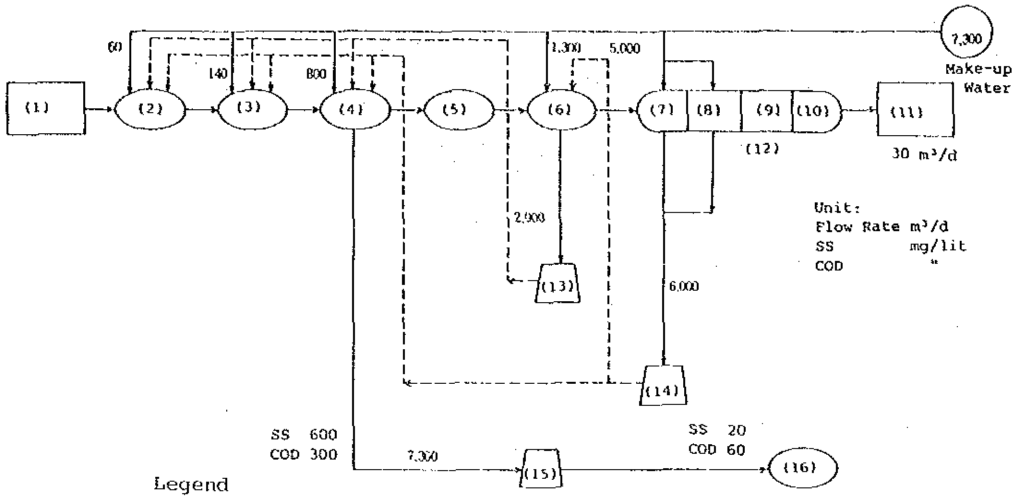
7.2 Paper Industry

7.2.1 Outline of Process and Water Use

On the whole, it is only the large companies which have production processes for manufacturing virgin pulp, and this restricts the number of companies dealing with this process.

Therefore, the processing stages and water use described below relate mainly to used paper pulp which is more common and they have been based on companies which possess process for manufacturing used paper pulp through to those for paper manufacture.

A flow chart of the processing stages is provided in Fig. 7.1.



Legend

(1) Used Paper	(9) Dry Part
(2) Pulping	(10) Winding
(3) Screening	(11) Product (Toilet Paper)
(4) Washing	(12) Paper Machine
(5) Bleaching	(13) White Water Recovery Tank
(6) Washing	(14) White Water Recovery Tank
(7) Wire Part	(15) Coagulation/Sedimentation Tank
(8) Press Part	(16) Discharge Gate

Fig. 7.1: Production Process of Toilet Paper

7.2.2 Standard Methods for Effective Use of Water

The following procedures can be achieved in the paper industry;

a. Recycle use of white water

b. Reclamation of waste water

7.2.3 Reclamation of Waste Water

(1) Outline

Although in pulp and paper manufacturing factories it is usual for waste water to be discharged after coagulation and sedimentation, the method for effective use shown here consists of waste water reclamation after slight additional treatment, and reclaimed water is used as a substitute for fresh water in process.

This method is also used in Japan in regions which are liable to suffer from water shortages. While the method has not yet been adopted widely, it will be shown here because it was included as a method for effective use in some factories.

The reclamation treatment system composes of the biological treatment and sand filtration, and it is presumed that the reclaimed water is used in the wire part and press part of the paper machine.

(2) Conditions for cost estimation

1) Types of raw water

Water from waste water discharged from pulp and paper factories which has been treated by a coagulator

2) Quality of raw water and treated water

	Raw Water	Treated Water
SS (mg/lit)	20	5
COD (mg/lit)	100	25
Electrical Conductivity (μS/cm)	500	500

3) Reclamation system

Biological treatment - Sand filtration

4) Quantity of treated water

1,000 m^3/d

5) Processes for re-use

Wire part and press part

(3) Cost estimation

Table 7.1: Cost Comparison of Re-Use of Reclaimed Water (Pulp and Paper Industry)

Item \ Stage	Before Installation	After Installation	Remarks
Quantity of Make-up Water (m^3/d)	10	1	
Quantity of Paint (kg/d)	20	2	
Cost of Water & Paint (¥/d): (a)	70,100	7,010	Water Cost = 10 ¥/m^3 Paint Cost = 3,500 ¥/kg
Quantity of Ultrafiltrated Water	-	10	20 lit/min x 60 min x 8 h
Cost of Ultrafiltration System (¥)	-	40,000	Including installation
Depreciation including Interest (¥/d): (b)	-	26,700	
Operating Cost (¥/d): (c)	-	200	
Total Cost (¥/d): (a)+(b)+(c)	-	33,910	
Cost Saving Rate (%)	-	52	

(4) Notes and problems related to effective use of water

This system has of the disadvantage of the high cost of water in comparison to water normally used for industrial purposes. This system is a final option which can be used after it has been ascertained that there are no prospects for finding new water sources.

7.3 Machine Industry

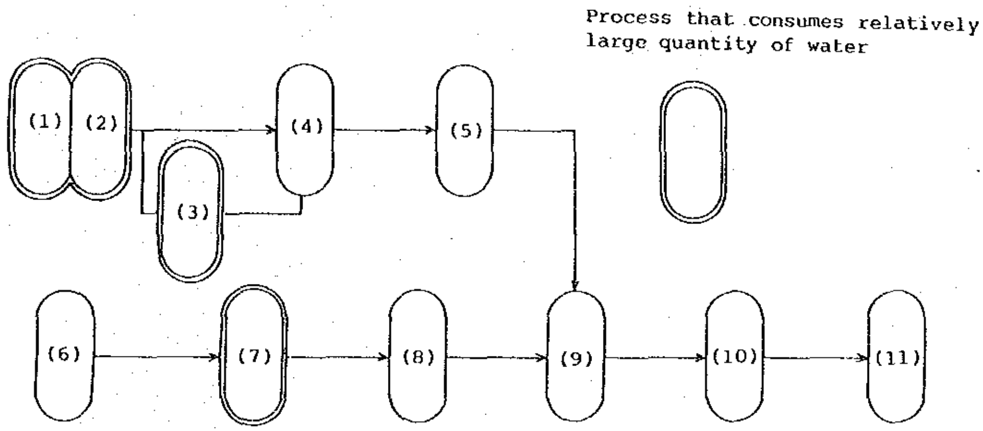
7.3.1 Outline of Process and Water Use

The machine industry involves the manufacture of automobiles and their parts, electrical machinery and machinery for other industries, and water consumption varies considerably according to the different processing stages adopted by the various kinds of manufacturing plants.

Some typical examples of processes used within the industry are the painting, plating, degreasing, pickling, and casting slag cooling processes. These processes mainly use cooling water, washing water and processing water. The machine industry uses a small quantity of water and is therefore unlike industries such as the chemical, steel, and pulp and paper industries which consume large quantities of water.

Nevertheless, automobile manufacturing plants have a high level of water consumption. For this reason and also because they incorporate a range of different processing stages the automobile manufacturing industry will be used as an example here for explaining the various processes involved.

Fig. 7.2 shows an outline of the general manufacturing process of the automobile industry. The process which consumes the largest volume of water is the painting process, and here water is used mainly in the pretreatment process which takes place before painting and in the electro-static coating process. This is followed by the casting process where water is used for cooling the furnaces and also for cooling welding machines used during the body assembly process.



Legend

(1) Casting
(2) Forging
(3) Heat Treating
(4) Mechanical Treating
(5) Unit Assembling
(6) Pressing
(7) Body Assembling
(8) Painting
(9) Final Assembling
(10) Inspecting
(11) Shipping

Fig. 7.2: Production Process of Automobiles

7.3.2 Standard Methods for Effective Use of Water

As has been shown above, much water is used in product treatment and for washing during the manufacturing processes. However, the recovery of used water is carried out in the automobile industry to a much greater extent than in other industries. The following provides some details on methods which have been widely adopted for the effective use of water.

(1) Water for processing and washing

(a) Counter-current multistage washing system

- the adoption of the water washing process and spraying between the tanks as part of in the pretreatment process

- washing using water in the electro-static coating process

(b) Cascade system

- use of waste water discharged from degreasing process in the preparatory degreasing and then in the hot water washing process

- use of waste water discharged from pure water spraying in the pretreatment process in processes which use industrial water for washing

- use of waste water discharged from pure water used in the electro-static coating process, for industrial washing water

(c) Reclamation of waste water

- re-use of waste water discharged from electro-static coating and recovered by ultra filtration in washing processes (recovered paint is also re-used)

- circulation of waste water discharged from the water polishing stage after the separation of solid matter

(d) Recycle use

- recycle of washing water in the painting booth

(e) Use of water saving apparatus

- automatic water supply system (setting to an appropriate level the volume of fresh water to be sprayed during the painting pretreatment process)

(2) Cooling water

Recycle of indirect cooling water by using a cooling tower.

As most of the methods described above have already been explained in Chapter 6, only the following one method is to be outlined here: re-use of waste water reclaimed from electro-static coating by using ultra filtration.

Most of the substances contained in the waste water resulting from electro-static coating are paint chemicals. Therefore, it is possible to re-use the water and the paint chemicals by using ultra filtration to separate the paint chemicals. By doing this it is possible to decrease a significant load for waste water treatment. The quantity of water re-used in this process ranges from 0.01 to 0.1 m^3/unit of vehicle.

7.3.3 Cost Estimation

Of some methods for effective use of water which have been outlined above, the re-use of water by using ultra filtration to treat waste water discharged from the electro-static coating process will be used here for the purpose of cost estimation.

An ultra filtration device which can filter 20 liters of water per minute costs around 20 million yen. Fig. 7.3 is a flow diagram showing a process which incorporates ultra filtration.

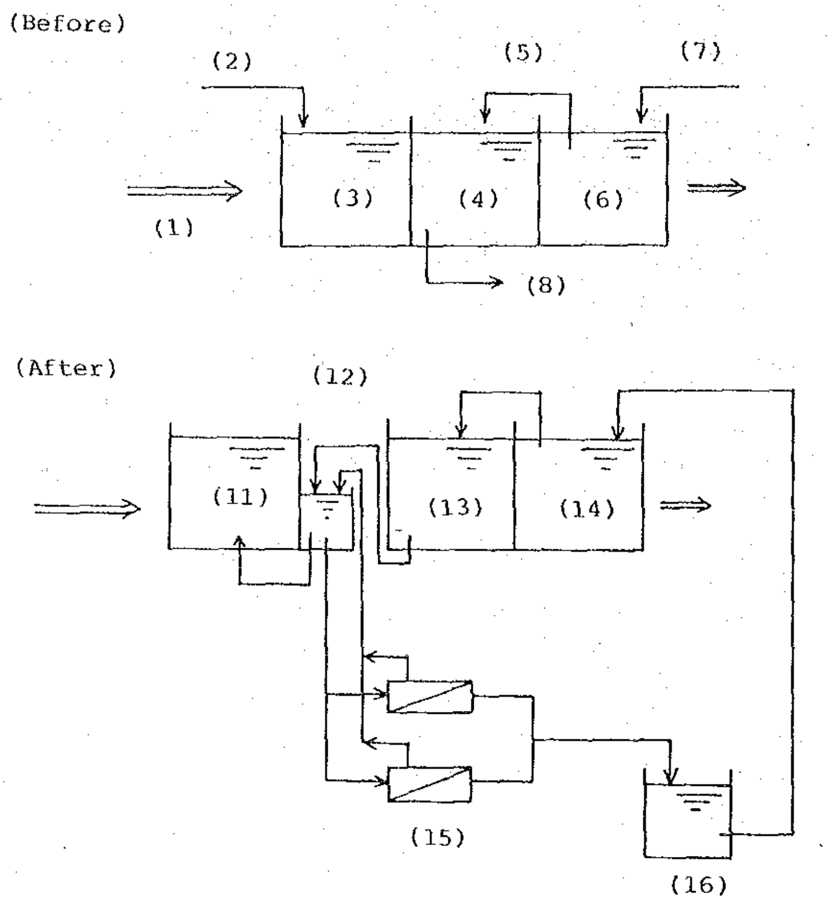
According to Table 7.2, by using reclaimed water the saving rate for costs is estimated at 52%, and this shows that the method is a fairly effective one.

7.3.4 Notes and Problems Related to Effective Use of Water

The automobile industry is ahead of other industries in the effective use of water. There is no particular problem related to this.

But it should be noted that due to the relationship between water quantity and the number of stages in counter-current multistage washing system the effectiveness decrease if system is carried out in more than 3 stages. (Refer to Chapter 6)

Also, as for the use of recycled cooling water, in the case of water used for cooling spot welding machines care should be taken to prevent blockages from occurring in the cooling coils and small tubes of the spot chips as a means of preventing the cooling water from becoming dirty and the formation of scale and slime.



Legend

(1) Production Process
(2) Supply of Paint
(3) Electro Coating Tank
(4) No.1 Washing Tank
(5) Cascade
(6) No.2 Washing Tank
(7) Make-up Water
(8) Discharge

(11) Electro Dipping Tank
(12) Sub Tank
(13) No.1 Washing Tank
(14) No.2 Washing Tank
(15) Ultrafiltration Apparatus
(16) Treated Water Tank

Fig. 7.3: Flow Diagram of Before and After Installation of Ultrafiltration Apparatus

Table 7.2: Comparison of Water Cost Before and After Installation of Ultrafiltration System

Item \ Stage	Before Installation	After Installation	Remarks
Quantity of Make-up Water (m^3/d)	10	1	
Quantity of Paint (kg/d)	20	2	
Cost of Water & Paint (¥/d): (a)	70,100	7,010	Water Cost = 10 ¥/m^3 Paint Cost = 3,500 ¥/kg
Quantity of Ultrafiltrated Water	-	10	20 lit/min x 60 min x 8 h
Cost of Ultrafiltration System (¥)	-	40,000	Including installation
Depreciation including Interest (¥/d): (b)	-	26,700	
Operating Cost (¥/d): (c)	-	200	
Total Cost (¥/d): (a)+(b)+(c)	-	33,910	
Cost Saving Rate (%)	-	52	

Chapter 8 Problems in Implementing Water Saving Measures

8.1 Outline of Countermeasures Against Land Subsidence

In the previous sections of this report, the results of field study were summed up, and analyzed from various points of view, with some suggestions made.

In this Chapter, the study will be reviewed again. Also, some of the problems encountered in implementing the measures against land subsidence in Thailand will be discussed.

As both the nation's population and industrial activities grow sharply, the Bangkok Metropolitan area (including its surrounding areas) has recently seen various problems caused by excessive pumping up of groundwater.

In addition to lowering of the water level and the intrusion of saline water to groundwater, the subsidence of land has become so serious that it often triggers floods during the rainy season.

Though the excessive pumping up of groundwater may not be the sole cause of land subsidence, it is undoubtedly the main one. Thus, effective measures are urgently called for.

The Government of Thailand has been making strenuous efforts to prevent the subsidence of land by implementing various laws (i.e. the Groundwater Act, the Factory Act and the Metropolitan Waterworks

Authority Act). The Government's objective is to switch water sources in the area--from wells to rivers.

However, even today a large quantity of water is daily pumped up in the Bangkok Metropolitan area. For example, the pumping up quantity in 1986 reached more than 1,200,000 m^3/d (Fig. 8.1).

According to a study made by the Thai Government, the safe yield (i.e. limit of pumping up quantity that does not cause land subsidence) in the Bangkok Metropolitan area amounts to between 600,000 and 800,000 m^3/d. Thus, the present pumping up amount is nearly twice as much as the safe yield.

In order to stop the subsidence of land, it is necessary to reduce the pumping up quantity by more than 400,000 to 600,000 m^3/d. However, the reduction of groundwater consumption by this quantity cannot be done at one stroke as this would halt all industrial activities in the area.

Rather, measures for the prevention of land subsidence should be coordinated with the area's economic/industrial development plans. Moreover, future increases in the demand for industrial water must also be taken into account.

On the basis of the above considerations, the measures listed in Fig. 8.1 will be reviewed one by one.

8.2 Problems in Implementing Water Saving Measures

As explained above, the reduction of water consumption alone may not be enough to prevent the subsidence of land. Other countermeasures against land subsidence should be taken together with water saving measures.

Table 8.1 sums up the various countermeasures against land subsidence to be taken in the public and private sectors.

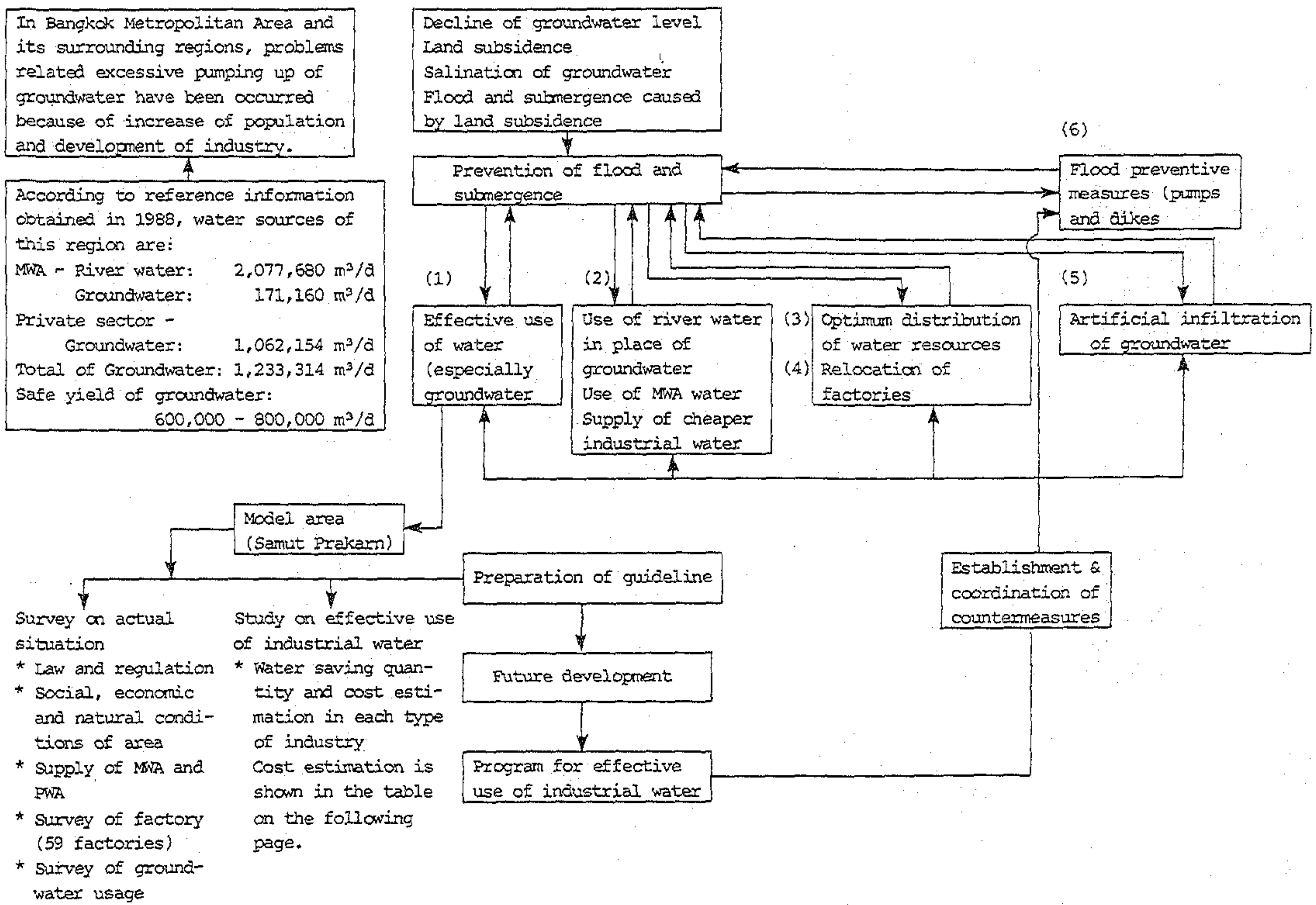


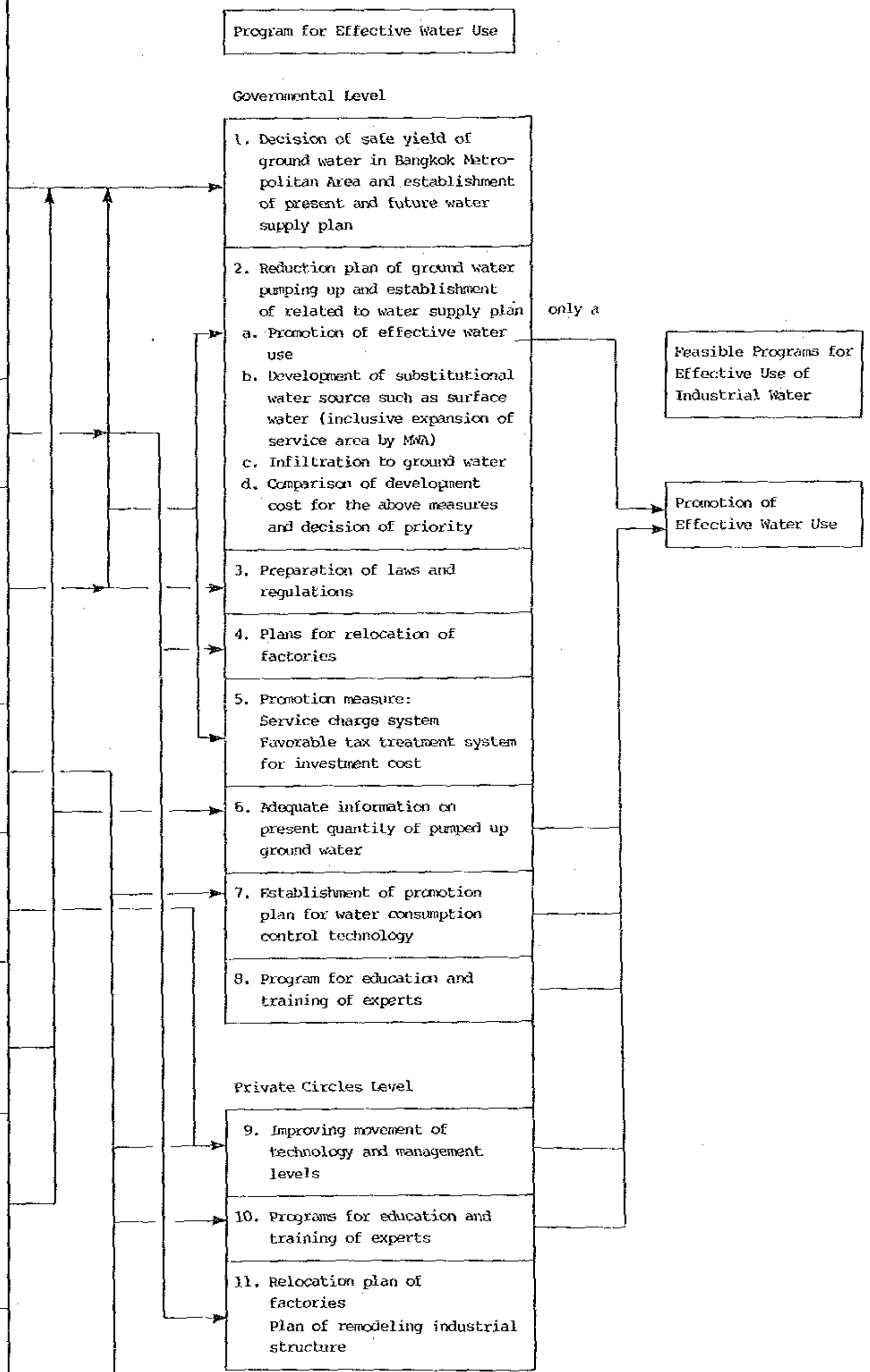
Fig. 8.1: Study Results and Relations to Plan for Effective Use of Industrial Water

Industry	No. of Surveyed Factory	Make-up Water (m^3/d)	Recycled Water (m^3/d)	Total (m^3/d)	Possible Saving Amount of Water (m^3/d)	Unit Cost for Effective Use (฿/m^3)
Food	14	7,025	39,301	46,326	969	3.4
Paper	5	18,845	11,009	29,854	1,560 5,260	0.8 3.3
Textile	7	13,632	53,535	67,167	636 2,636	0.8 10.1
Metal	20	8,594	26,565	35,159	1,603	1.4
Chemical	13	4,799	43,693	48,492	694	0.3
Total	59	52,895	174,103	266,998	5,462 11,162	1.4 4.7

Fig. 8.1: Continued, Part 2

Table 8.1: Problems and Measures related to Effective Use of Industrial Water

Present Situation/Problems	Measures	Promoter
A. System and Policy		
1. Water act, especially adjustment of plan for water utilization, preparation of laws and regulations, and intensification of enforcement regulations are necessary.	Quantity of pumped up groundwater in Bangkok Metropolitan Area is over 1,200,000 m^3/day, and allowable quantity for prevention of land subsidence is said to be 600,000 to 800,000 m^3/d. Therefore, pumping up of 400,000 to 600,000 m^3/d groundwater must be reduced. In order to promote this reduction program in each industrial area, safe yield in each area must be estimated and reduction plan must be prepared to attain the object. MWA is reducing quantity of pumped up groundwater, but quantity of pumped up groundwater by industries is rather increasing. Thus, quantity of pumped up groundwater is not reduced as a whole. Reducible quantity of industrial water by adoption of water saving and effective water use is not sufficient, and developments of substitutional water source (surface water and others) are necessary. Use of surface water requires quantity adjustment with agricultural water and public water works. Plan for independent public industrial water works would necessitate adjustment with MWA Act and consideration of service charge. (Some factories would not like to pay high service charge.)	Government
2. Review of plans for factory location and factory relocation	By relocation of factories in industrial zone for modernization and expansion of factories, effective water use and waste water treatment shall be promoted. In this modernization plan of factory, change to new production process that does not use much water shall be included.	Government Private Sector
3. Measure for effective use of industrial water is not fully established.	As an incentive of effective water use, introduction of service charge system, especially gradual increase system by which user of much quantity of water has to pay higher service charge, is most effective. But, for those factories which depend on groundwater, service charge of public industrial water works would be operating burden. To solve the problems, laws and regulations should be enacted to enforce the promotion of effective use of industrial water, and public industrial water works should be constructed to supply substituted water of reasonable price by developing river water and other water sources.	Government
4. Personnel engaged in industrial water supply and discharge is shorthanded and system for authorizing process is not established.	Education and training system shall be expanded. At the same time, authorizing system such as "water control engineer" and "environmental preservation engineer" shall be newly established, so that control capabilities shall be intensified.	Government
5. Test and inspection institutions, evaluation body of test process and services related to industrial water supply and discharge are not established.	Confirmation of water quantity and quality data by establishment of flow meter repair center and authorizing system for material standardizing, for example. Establishment and operation of technology development center for promotion of water treatment technology.	Government
B. Technology		
6. Designation of safe yield of pumped up groundwater in area of land subsidence is not clear.	This figure is basis for restriction of pumping up quantity of groundwater. It is necessary to clarify target quantity of reduction of pumping up groundwater. The data are also used for future plans of factory relocation in various areas.	Government
7. Factory staff does not grasp exact quantity and quality of consumed water.	These data must be fundamentally grasped for effective use of industrial water. Quantity of process water and water for living including leakage must be clearly grasped. Recycled quantity from cooling tower for recycling use of water, quantity of flow, quantity of discharged water and quality of discharge water must be firmly grasped. Overall situation must be grasped by further investigation of those on these items.	Government Private Sector
8. Intermediate managing staff and engineers specializing in water treatment are shorthanded, and training institute of engineers is lacked.	Promotion for establishing guidance organization initiated by central government. Promotion of improvement activities of managing and technological levels by private circles. Establishment of engineering firms capable of acting as coordinator of these matters.	Government Private Sector



Chapter 9 Suggestions for Effective Use of Industrial Water

9.1 Programs for Effective Use of Industrial Water

In Table 8.1, various measures are summarized as the programs for the effective use of industrial water. The programs are divided into some for the public sector and others for the private sector.

Among the programs, 2-a, 3, 5, 6, 8 (in the public sector) and 9 (in the private sector) are closely related to the study. In the following, these program items are explained one by one.

9.1.1 Promotion of Effective Water Use (Item 2-a)

The water saving measures suggested in this study should be applied not only in Samut Prakarn but also in the whole Bangkok Metropolitan area (including its surrounding areas). The following projects may be useful for this purpose.

a. To promote the technical guidelines for effective use of industrial water to all persons concerned (by holding seminars, for example)

b. To conduct the survey on an enlarged number of factories

c. To operate a model plant to demonstrate effective use of industrial water

d. To visit industrial factories in order to help them implement the technical guidelines for effective use of industrial water

e. To send experts to industrial factories in order to implement the technical guidelines for effective use of industrial water

These projects are relatively easy to implement, and hence are explained in detail later in this section (9.2).

9.1.2 Preparation of Laws and Regulations (Item 3)

In carrying out the water saving programs, certain legal measures which confirm the land subsidence as a public hazard and control the pumping up of groundwater will be required to make factories invest in water saving equipment or employ expert personnel.

Such legal measures may be taken at both the central and local government levels. (In case of local governments, the training of supervising staff may be necessary.)

9.1.3 Promotion Measures for Effective Use of Industrial Water (Item 5)

The voluntary cooperation on the part of factories is indispensable for the implementation of the water saving programs. Financing help or favorable tax treatment systems (e.g. low interest financing and reduced tax for investment of effective use) are effective incentives to bring out such cooperation.

In addition the shift of the water source from well to river (e.g. MWA water) may be encouraged by the raising of the groundwater rate from the present level (1 ฿/m³) and/or the installation of new public industrial waterworks that will supply water at reasonable prices.

The final goal is to reduce the pumping up quantity of groundwater. To achieve this goal, any and every creative measures should be employed.

9.1.4 Adequate Information on Present Quantity of Pumped Up Groundwater (Item 6)

The accurate data on the quantity of groundwater consumption is a prerequisite for any the water saving programs. As mentioned in 8.3, although the Groundwater Act makes it compulsory to furnish a flow meter for each well, the study revealed that some flow meters were out of order. Such irregularities should be promptly corrected.

9.1.5 Programs for Education and Training of Experts (Item 8)

It is vital for a national economy to secure stable water supply. In Thailand, if things are left untouched, some areas are likely to face the storage of water. So, some long-term program should be established to train experts on the control of water.

9.1.6 Improving Movement of Technology and Management Levels (Item 9)

Although some of the surveyed factories have already achieved remarkable levels of effective use of water, none have flow waters installed at inlet/outlet sides of the cooling towers. Also, the data on water qualities are often inadequate. Further efforts seem necessary to improve water control techniques on more accurate data.

For the technical improvement, the exchange of experience and know-how between factories concerned will be of great help. Needless to say, governmental backups (e.g. section of model factories or the invention of some incentive systems) may be required for this purpose.

Among the above programs, "9.1.1 Promotion of Effective Water Use" is the easiest to implement. The other programs, though important, cannot take immediate effects for the following reasons:

(1) As Japanese experience indicates, it takes a long time to establish or revise the water-related laws and regulations, though it should be done some day.

(2) At present, Thailand has no financing or favorable tax treatment systems for effective use of industrial water, and the like. Establishing such systems from scratch may not be easy.

(3) Although it is highly advisable to raise the groundwater rate, various vested interests make it difficult to implement.

(4) The enlargement of MWA's supply area or the construction of public industrial waterworks takes a lot of time and money.

(5) The gathering of accurate data should be included in the program 9.1.1, Promotion of Effective Water Use.

(6) The training of experts is the most difficult of all the programs.

Among the above, (1), (2) and (3) need not huge amount of money. Implementation of improving movement by the Thai government in near future is highly expected.

9.2 Feasible Programs

9.2.1 Promotion of the Technical Guidelines by Holding Seminars

In order to promote technical guideline for effective use of industrial water, two seminars (one on November 11, 1987 and the other on December 12, 1988) have been held.

The first one was attended by people from public organizations and universities, while the second was held for factory engineers.

The important point in holding such seminars is to set a clear target and define the participants. The lecturers may be found not only in governmental organizations or universities but also in private companies.

9.2.2 Survey on the Enlarged Number of Factories

As mentioned in 8.2, the survey covered only 2.2% of the whole factories in Samut Prakarn (or 17.6% in term of pumping up quantity). To generalize the result of the survey may be misleading.

In Japan, the Ministry of International Trade and Industry (MITI) has been conducting the similar kind of survey for over ten years, covering altogether more than 1,000 factories.

As has been practiced in Japan, the plan for the effective use of groundwater should be established on the basis of the survey of the area in question. The result of the survey in one area cannot be simply extended to another area. That is why the survey should be conducted on the enlarged number of factories.

The following are some practical hints for effective surveys.

(1) Selection of factories to be surveyed

Selection should be made among the leading factories that represent the area concerned (in the case of Samut Prakarn, approximately 200 factories belong to this category). The pumping up quantity of the selected factory should reach over 80% (preferably 90%) of the total pumping up quantity in the area.

However, with a limited staff and time, it may be difficult to survey a large number of factories. For Samut Prakarn, a practical way is to survey 40 to 50 (preferably in the same industry or in the same area) each year, thus completing the whole survey in 4 or 5 years.

(2) Procedure of the survey

As is the case in the study, the survey generally proceeds as follows:

Selection of factories ----> Questionnairing --->
Visiting survey ----> Analysis of results ----->
Preparation of technical guidelines

(3) Period and staff for the survey

The survey should be conducted in concentrated schedule. In addition to the staff members of IWD, the survey team may include the member(s) of regional bureau of MOI and expert(s) recruited from the outside. For example, the survey team may be organized as follows.

Period & Members / Item	Period (Month)	Leader	Outside Expert	Survey Member	Assist-ant	Member from Regional Bureau
(1) Preparation (Selection and Questionnairing)	2	1	1	1		
(2) Visiting Survey	2	1	1	2	1	1
(3) Data Analysis	4	1	1	2		
(4) Preparation of Guidelines	2	1	1	2		
Total	10					

Each member of the survey team takes the following responsibility.

a. Leader :	To plan and control the whole process of the survey
b. Outside expert :	To give advice and help on the basis of expert knowledge
c. Survey member :	To conduct the survey
d. Survey assistant :	To take measurements in the field survey
e. Member from the regional bureau of MOI :	To assist the survey and to act as an intermediary for technical transfer

(4) Cost of the survey

Besides personnel expenses, the survey needs the costs for questionnairing (i.e. the printing and sending of questionnaires), technical seminars, reports and the like, which may not amount to a large sum.

As for expert(s) from the outside, it would require considerable cost.

(5) Qualifications required for the outside expert

Expert(s) provided from the outside should meet the following requirements.

(a) To have highly specialized experience and knowledge about the use and discharge of industrial water

(b) To have sufficient experience and knowledge about the treatment of supply/waste water.

(c) To have general knowledge about the use of water for various production lines

(d) To have general knowledge about various production lines

(e) To be able to attend the field survey and give appropriate advice

Although it is of great help if expert(s) from the outside have detailed knowledge about, say, the food or textile industry, such expert(s) are hard to find. So, for the purpose of the survey, general knowledge of production lines should be regarded as satisfactory.

9.2.3 Operation of a Model Plant to Demonstrate the Effective Use of Industrial Water

To encourage the effective use of industrial water, one of the surveyed factories may be selected as a model plant.

With appropriate water saving equipment (for example, cooling towers) installed, this model plant will demonstrate actual process and result of the effective use of industrial water.

To put the technical guidelines into practice in this way will greatly encourage other factories to do the same. However, the establishment of a model plant is expected to face the following problems.

(1) Difficulty of selecting a model plant

In a model plant, water saving equipment must be installed in the production line, the maximum cooperation of the selected factory is required.

(2) Installation cost

The factory selected as a model plant is not expected to bear the installation cost of water saving equipment. It is, however, difficult for IWD to put public money to install the equipment for a private enterprise.

(3) Operation and control

It is doubtful whether the selected factory pays due attention to the operation/control of water saving equipment which does not bring in visible profit. Insufficient operation/control of equipment in a model plant may turn out to be counterproductive.

Taking the above problems into account, the operation of a model plant, though very effective if realized, seems to be difficult to implement.

9.2.4 Visit to Factories to Help Them Implement the Technical Guidelines

As is practiced in Japan, the guidance through visiting each factory may be effective to implement the measures specified in the technical guidelines. Fig. 9.1 shows the simplified procedure of such guidance adjusted to the conditions in Thailand. The outline of the visiting guidance is as follows.

(1) Organizations in charge

IWD and regional bureaus of MOI take charge of the visiting guidance. The staff of the other central/local government organizations may join whenever necessary.

(2) Cooperation from private sector

To obtain cooperation from the private sector, an advisory committee for the effective use of industrial water is to be organized. This committee will consist of members of private companies and experts from universities and research centers.

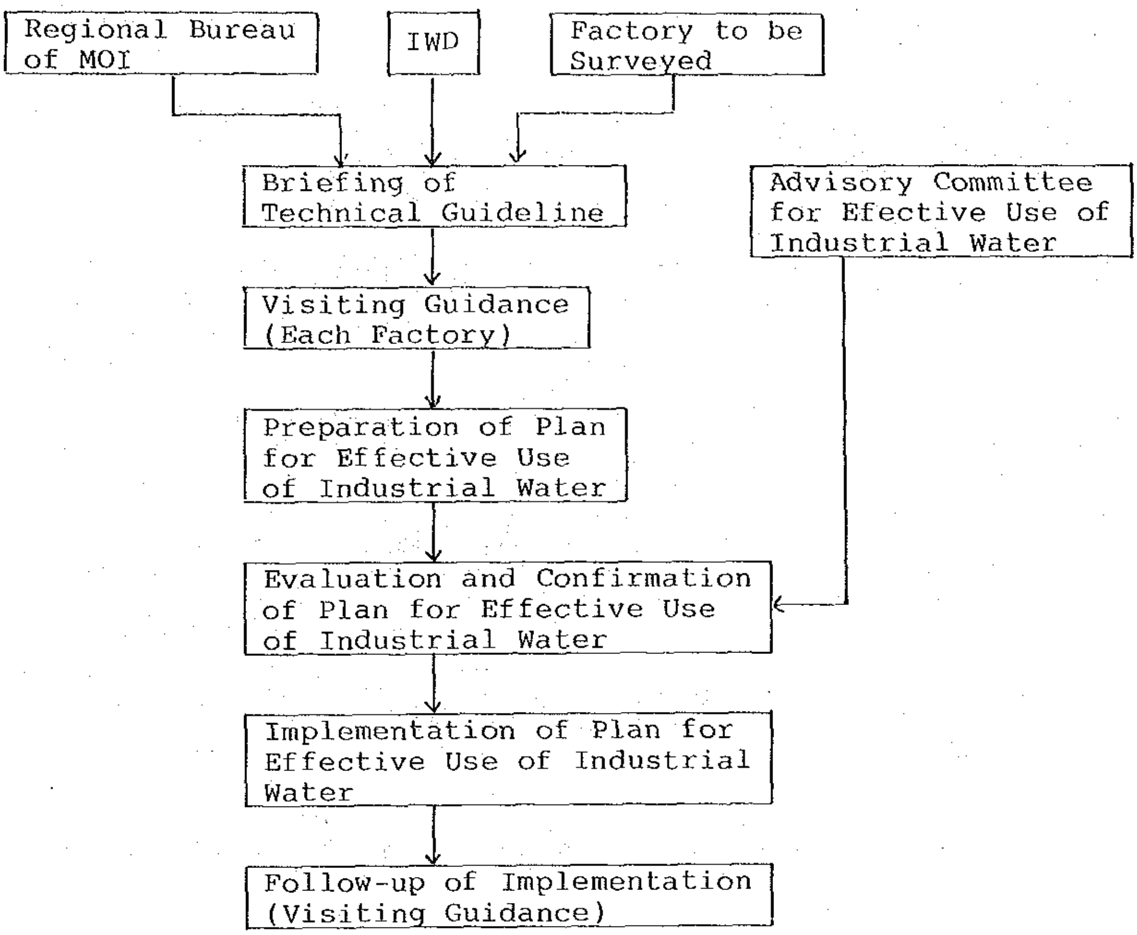


Fig. 9.1: Example of Implementation of Visiting Guidance

(3) Plan for visiting guidance

A team consisting of three or four members (two or three members from IWD and one expert from the outside) visits one or two factories per day. The team should visit the same factory at least twice.

The first visit is to set up the plan for effective use of industrial water of the factory, and the second is to check the implementation of the plan. Besides these two visits, the team may call on the factory from time to time to follow up the guidance.

(4) Plans for the effective use of industrial Water of individual factories

The technical guidelines prepared by the study team do not reflect the particular conditions of each individual factory. Therefore, the best way to implement the guidelines is not to impose them on factories but to encourage each factory to establish its own plan, which is the main aim of visiting guidance.

(5) Review of factories' plan for the effective use

The plan for the effective use set up by each factory is reviewed by IWD members and outside experts. The approved plan is reported to the above-mentioned committee in order to obtain its cooperation. The plan for the effective use of factory is a kind of informal agreement between the factory and the organization. Such voluntary cooperation on the factory's side is indispensable.

(6) Follow-up of factories' plan for the effective use

As mentioned above, at least one follow-up visit is necessary for each factory. The follow-up visit may be repeated whenever necessary. If the plan for the effective use is not implemented properly, the guidance team should investigate the reason and give appropriate advice.

In some areas in Japan, such guidance by visiting has been proved very effective. According to the experience in Japan, the following conditions are helpful in bringing out factories' efforts to reduce groundwater consumption.

(1) By virtue of the Public Pollution Control Law, the central and local governments assume responsibility to take the measures for the prevention of land subsidences and private companies are obliged to be cooperative.

(2) Some local governments have established their own regulations to control the pumping up of groundwater.

(3) Factory managers and engineers in general know the importance of the saving of groundwater

(4) Knowledge level of inhabitants for land subsidence is fairly high, so behavior of factories which pump up groundwater are watched by these inhabitants.

(5) Financial and tax incentives are provided for the effective use of groundwater.

Thailand at present lacks such conditions. Also, the technical staff for visiting guidance appears to be in short supply. Hence it is too early to expect much effect from visiting guidance. The visits to factories, however, may, serve to make them more conscious of the use of water as well as to promote good relationships between IWD and each factory.

9.2.5 Sending Experts to Factories in Order to Implement the Technical Guidelines

Upon the establishment of the plan for the effective use of a factory, IWD may send technical experts on particular water usages (cooling water, washing water, etc.) or production processes (in the paper, textile or other industries) to the factory to help it implement the plan.

This project, however, presupposes the positive attitude on the factory's side, which for the time being cannot be expected. The sending of experts may be effective if it is carried out after the visiting guidance stated in 9.2.4.

9.2.6 Examination of Programs and Summary of Suggestions

The detailed examination in the above paragraphs has made it clear that each program has various practical problems. the underlying reason for these problems is the lack of basic conditions (laws, regulations, tax and financing systems, awareness, and the like) for the effective use of industrial water.

The following basic conditions are very important for the implementation of these programs in Thailand.

(1) Preparation of Laws and Regulations

(a) Confirmation of land subsidence as a public hazard

(b) Obligations of government and private companies for prevention of land subsidence

(c) Preparation of laws and regulations to control pumping up of groundwater

(2) Encouragement of incentives for effective use of water

(a) Raising of groundwater rate

(b) Low interest financing and favorable tax on investment for effective water use

(3) Education and training of experts

(4) Level up of knowledge for land subsidence and groundwater saving

(a) Staff and engineers of related governments and private companies

(b) Inhabitants who live in land subsidence areas

Chapter 10 Conclusion

The land subsidence in the Bangkok Metropolitan Area is serious. To curb further subsidence, a wide range of measures (refer to 8.1) should be urgently taken. Although the saving of water consumption alone cannot cope with the situation, the study on effective use of industrial water would contributes to the solution of the problem.

The study covered only around 2% of the factories in Samut Prakarn Area. As suggested in this report, the study should be extended to cover a wider area.

Taking measures for effective use of industrial water implies that certain conditions (refer to the programs in Table 8.1) should be satisfied. Moreover, those measures should be harmonized with other measures.

JICA