7.2

RE-USE OF MUNICIPAL WASTE WATER

[DOCUMENT NO. 5511]

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WATER RE-USE PROMOTION CENTER

TOKYO, JAPAN

CONTENTS

# # #

1. Introduction

To cope with the water shortage now foreseen for the future in Japan, efforts are now being exerted toward the development of new water sources. As the promising sources, desalination of sea water and re-use of municipal waste water are considered.

Above all, the re-use of municipal waste water can be utilized as a source of the industrial and/or nonpotable water with relative ease in terms of quantity and quality.

For the purpose of promotion the pracitical application of re-using municipal waste water, technological developments have been advanced in recent years and a number of excellent results have been obtained.

2. Types of Water Re-Use

In water re-use, the following methods are aveilable: direct use of secondary effluent, and indirect use of secondary effluent, in which the secondary effluent is discharged into the upstream of a river and then drawn form the downstream together with river water.

(1) Direct Re-Use

This type and system are employed in Tokyo Metropolis Nagoya and Kita Kyushu Cities for producing Industrial water.

In the future, it is expected to be adopted more extensively. In Tokyo and Nagoya, secondary effluent has been supplied to various industries after treatment by coagulation and sedimentation, rapid sand fitration, and chlorination. The amount of water supplied respectively has stood at as much as about 80,000 m^3/day and about 30,000 m^3/day. In particular, the case of Tokyo is regarded as typical in scale and performance, and the quality of supplied water is shown in Table 1. Type of industry and use are shown in Tables 2 and 3 respectively.

Table 1: Quality of Reclaimed Water Supplied by Tokyo Metropolis

Turbidity	1.6
Color	17
pH	6.8
Alkalinity	63 mg/ℓ
$C\ell^-$	64 mg/ℓ
Elec. Cond.	551 μs/cm
T. Hardness	101 mg/ℓ
Fe	0.12 mg/ℓ
MBAS	0.30 mg/ℓ

Table 2: Type of Industry using Reclaimed Water Supplied by Tokyo Metropolis

Type	%
Chemical	25.2
Iron and Steel	6.8
Metal	8.5
Foods	9.4
Leather	11.7
Paper and Pulp	15.1
Textile and Dyeing	3.6
Gas	1.8
Rubber	0.8
Others	17.1

Table 3: Use of Reclaimed Water Supplied by Tokyo Metropolis

Use	%
Cooling	49.8
Washing	29.4
Process	13.7
Material	1.7
Boiler	0.1
Others	5.3

Kita Kyushu City has supplied secondary effluent directly to the Kurosaki plant of Mitsubishi Chemical Industries Co., Ltd. Last year, then the area suffered severe shortage of water, the City supplied secondary effluent mixed with water of the existing industrial water works. In the case of Nagoya City, reclaimed water is supplied after being mixed with other industrial water through its piping connected to industrial water with river water as its source.

Water re-use for nonpotable water, the center of attention recently in various fields, is also a case of direct water re-use. In this case, roughly, the following three systems are available:

1) Wide area circulating system: This is applied to the use of industrial water and/or nonpotable water (toilet flusing and car washing) with secondary effluent as its source. Easy to carry out, it has been established as a basic concepts of water re-use for nonpotable water.

2) Regional circulating system: This is applied to selected areas. It is designed so that the sewage produced in the area is treated for re-use within it, so far covering housing complexes or reclaimed areas.

3) Individual circulating system: This is applied to buildings and the like. It is designed so that sewage discharged from such constructions is treated for re-use within themselves. Implementation of the system if very difficult for existing buildings, but as it is easy for those to be newly constructed, big cities in Japan have tended to require this system in buildings to be newly constructed.

Table 4 shows three examples of the individual circulating system that are practically installed in Japan.

In view of the use for nonpotable water, none of these three systems is necessarily immune to cost and sanitation problems involved in required water reclamation and dual system. Judging from cost, the wide area system is advantageous in using industrial water supply system. There is no established definition of nonpotable water as yet. Generally, this refers to water for flush toilets, car washing, water sprinkling, cleaning and cooling air conditioner. In some concepts, water for bath rooms and washing clothes are added to these.

Table 4: Examples of Re-Use System of Building Drainage

Example	Quantity [m^3/day]	Use	Process
Bldg. "A"	480	Toilet Flushing	Aeration Sedimentation Rapid Sand Filtration Disingection
Bldg. "B"	1,700	Toilet Flushing	Coagulation NaClO Rapid Sand Filtration
Bldg. "C"	100	Toilet Flushing and Cooling	Oil Separation Aeration Sedimentation Biofiltration Sedimentation Rapid Sand Filtration Adsorption

(2) Indirect Re-Use

As mentioned above, in this method of water re-use, secondary effluent is discharged into the upstream of a river and then drawn from the downstream together with river water. (Only for a case that river flows in nearby area.)

If the proportion of the secondary effluent in the river water is very small and water is collected at the point where both waters are mixed throughly, this makes no difference with the use of river water. Hence, in terms of quality, this cannot be called water re-use. It has been said that secondary effluent should be primarily discharged into rivers. However in recent years, the increase in its proportion in the river water has posed a threat of water pollution.

Under the circumstances, the discharge of secondary effluent alone is no longer permitted and tertiary treatment is required. Indirect water re-use can achieve its intrinsic significance only by bringing the quality of the treated water close to that of the river water when it is discharged into a river, even if the self-purification effect of the river can be taken into account to a certain extent.

However, this method has the following advantages: the burden involved in the required reclamation can be lessened as compared with the direct type due to dilution and self-purification effect of the river, though the condition varies from the dry to rainy season, and river water flow rate is not so reduced. On this account, this type is considered primary for effective water re-use.

However, depending on the ratio of reclaimed water to river water and the concept of advanced waste water treatment, there is a possibility that the load from pollution of river may increase. Though it is not seen in the case of water re-use, some water purification plants in the Kansai District have conducted activated sludge treatment of water as a pretreatment to cope with worsened pollution of river water.

Thus, due caution must be used where the river serving as the source of water supply is intended to be used for water re-use of this type.

Sewage treatment is generally aimed at preventing pollution for an improved environment, not at water re-use. Any attempt to achieve the two purposes by the same facilities may raise such tough problems as how to share the expense. To solve these problems, top priority should be given to the profit of local community.

Additional methods of the indirect water re-use are availably by utilization of secondary effluent that has permeated to the underground and doing so after recharged into the underground. But both of them are now in the experimental stage.

The former which requires only equipment for permeation and pumping water, is advantageous from an economical point of view, only if good quality of water is available.

The latter is an underground injection and is an interesting method though coagulation, sedimentation and sand filtration is needed prior to recharging into the underground. Whether employign permeation underground or groundwater recharge, a number of problems appear to remain to be studied, including possible effects on the quality of underground water surrounding the intended area.

The method of recharging secondary effluent into the underground is also applied to prevention of land subsidence and salt water permeation.

Figs. A, B and C show 3 systems of water re-use

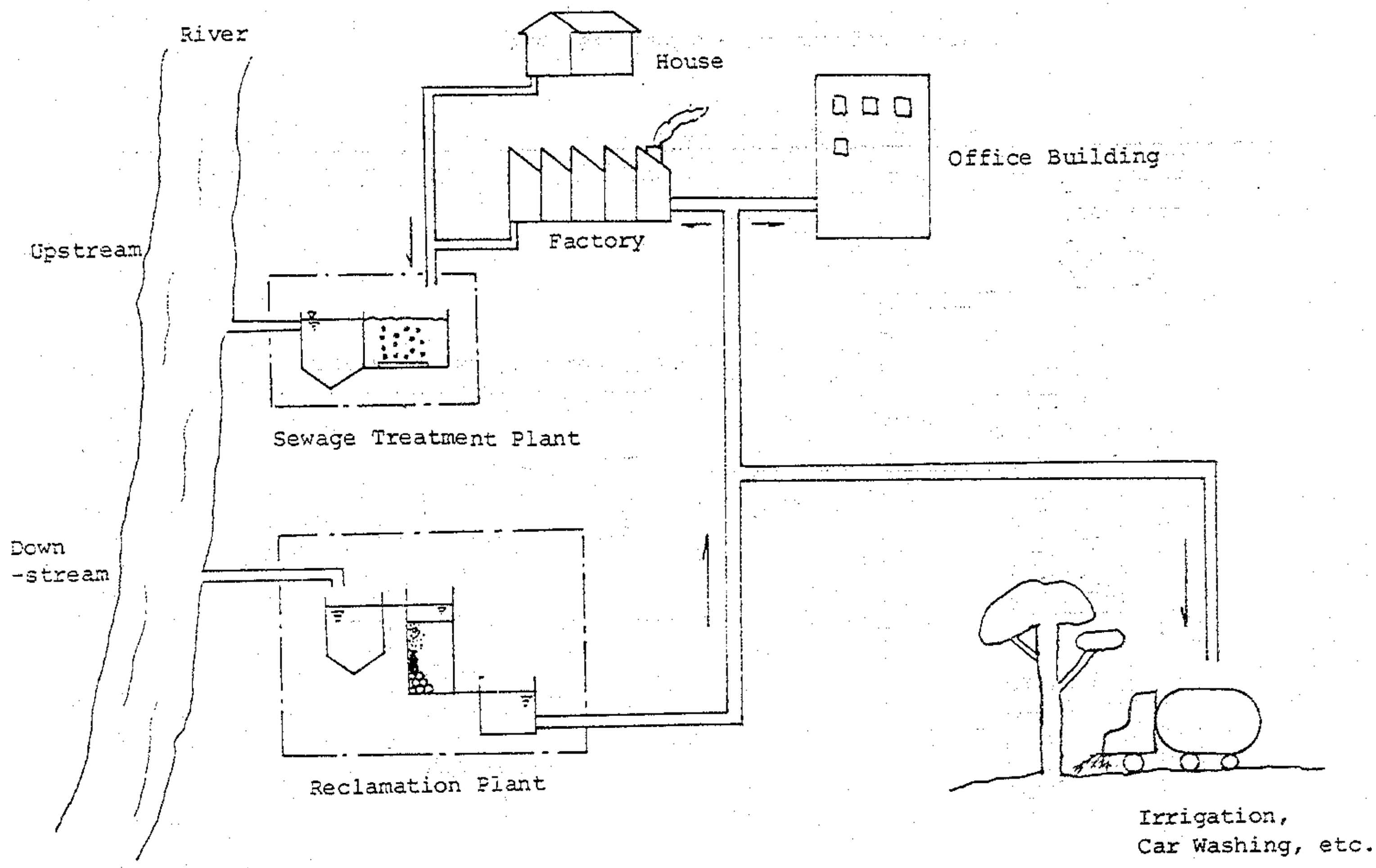


Fig. A: Wide Area Circulating System

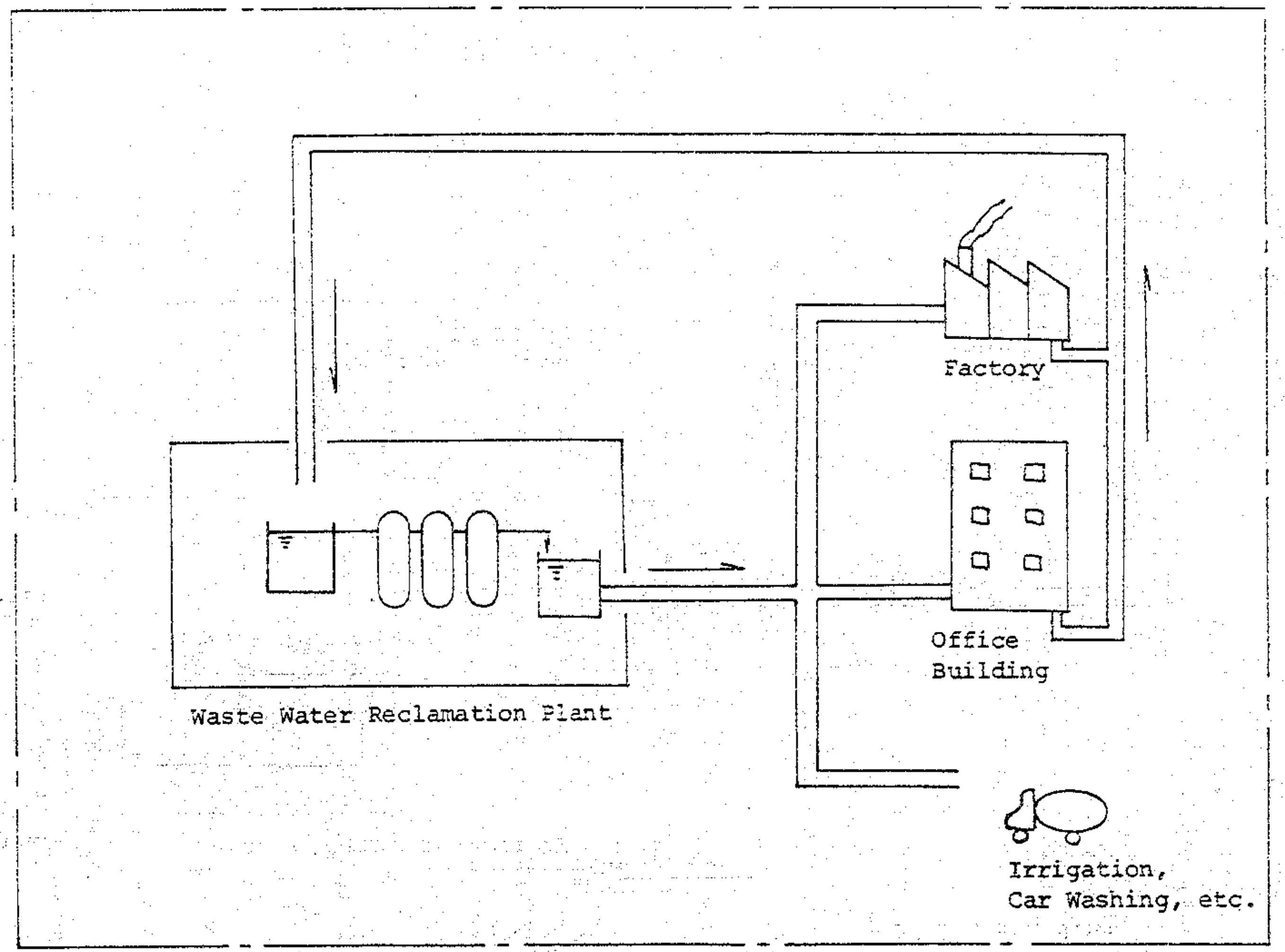


Fig. B: Regional Circulating System

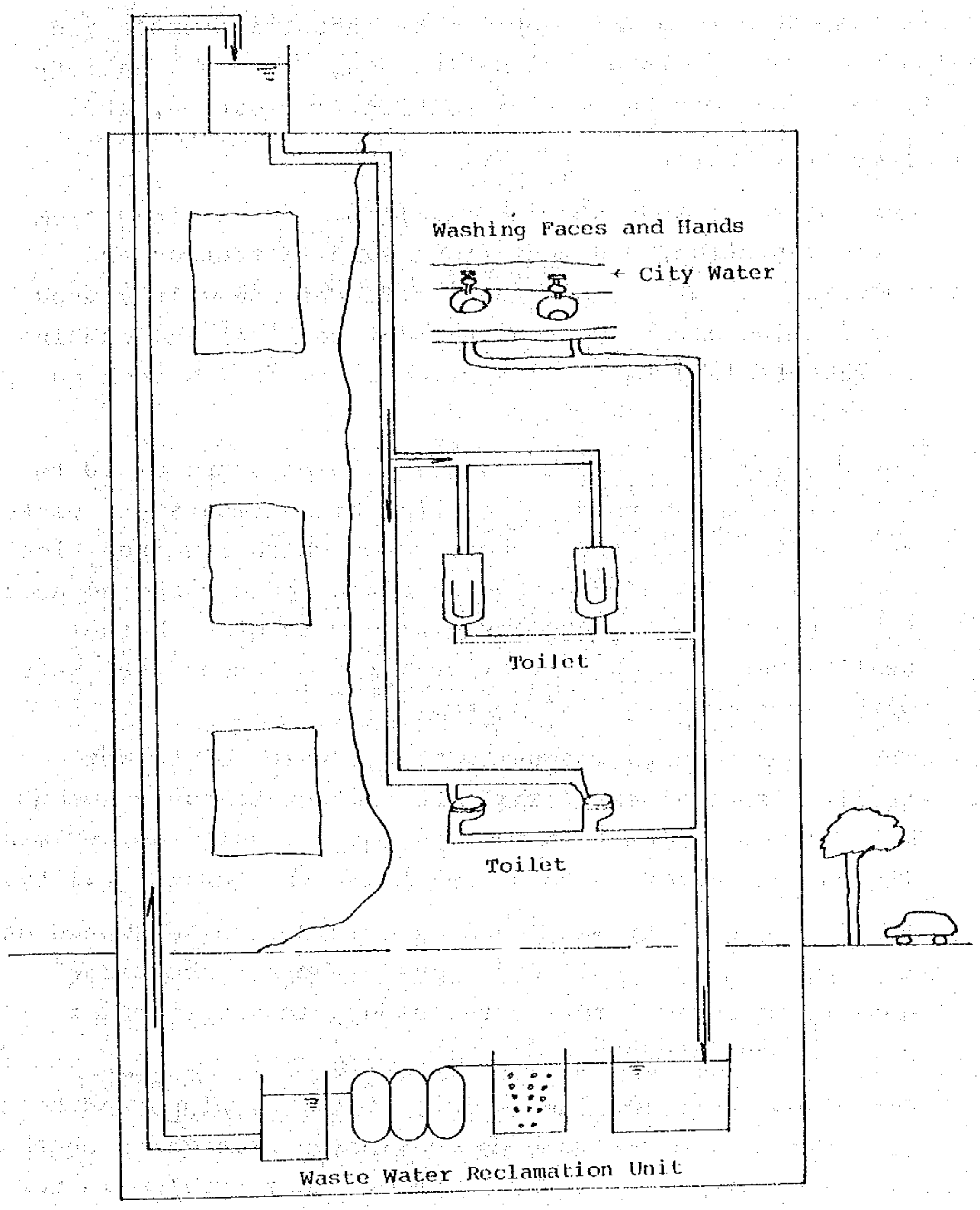


Fig. C: Individual Circulating System

3. Application of Reclamation and Re-Use

Reclaimed water is mainly applied to industrial water and nonpotable water. In addition, its usage covers a variety of fields such as water for recreation, irrigation, etc.

(1) Industrial Water

Most of reclaimed water now available is obtained from the coagulation, sedimentation, sand filtration and chlorination of the secondary effluent and mainly used for cooling water (mostly indirect cooling) and washing water. Process water is applicable to fields such as regeneration of waste paper.

For cooling water which reaches a temperature of 40 to 50°C after being used for cooling high temperature parts, and washing water and process water which requires high quality, recommended method is either conducting advanced treatment of waste water or mixing with other higher quality water, such as service water or industrial water with river water as its source.

The former requires higher cost but water of target quality is obtainable, while the latter is advantageous in terms of cost but it remains questionable whether mixing can be performed so as to attain the target quality.

The target quality mentioned here is determined based on experience and actual conditions. Whether the target quality is optimal for actual usages leaves room for experimental study.

Corrosion and slime damage impairing feed pipes and heat exchangers have so far been considered critical problems in water re-use. However, in fact, this problem is not so severe as generally thought. If measures are confined to solving this problem, selection of material for pipes or equipment or partial use of chemical agents should be applied rather than advanced waste water treatment.

When used for industrial water, reclaimed water is engulfed into the water supply system of the plant and thus, isolated use of the water is not always possible. Therefore, depending on cases, the use of reclaimed water must be considered in connection with recovery of waste water from plants.

(2) Nonpotable water

Today, reclaimed water has been partially used for water for flush toilets, car washing, water sprinkling and fire fighting utilizing the industrial water supply system. Additional cases of water re-use for nonpotable water include washing cars of the Shinkansen (super express railway in Japan) or cleaning slaughterhouses using a special piping system arranged from sewage treatment plants. In the case of washing cars of the Shinkansen, secondary effluent is supplied from sewage treatment plants to the Tokyo Depot of Shinkansen where it is subjected to chlorination and sand filtration. Subsequently, water thus treated is used for washing cars (excluding final washing). Water used for this purpose has reached a relatively large volume of about 400 m^3/day, and it is desirable to expand the use of reclaimed water in this field.

In the housing plan, utilization of nonpotable water has been adopted in newly developed housing complex on an experimental basis.

According to an estimate of the Japan Housing Corporation, the average and maximum amount of required water per person in the housing complexes will respectively reach 250ℓ and 330ℓ per day in 1985. By usage, those for bathroom and washing clothes are respectively estimated at 110ℓ and 145ℓ, those for washing faces, hands and kitchens 80ℓ and 106ℓ, those for toilet 40ℓ and 53ℓ for cleaning ~~53ℓ~~, car washing and water sprinkling 20ℓ and 26ℓ.

Thus, those for nonpotable water are respectively considered to reach 170ℓ (60ℓ excluding water for bathrooms and washing clothes) and 224ℓ (79ℓ excluding water for bathrooms and washing clothes). If the usage of reclaimed water is extended to cover water for bathrooms and washing clothes, further advanced water treatment will be needed and public sanitation must be studied.

No law providing for nonpotable water has been established and quality standards (several tentative plans are available) as well as fee, etc. have not been definitive yet.

However, the Government of Japan is taking positive measures, such as financing of governmental fund and reducing of tax, to promote the use of nonpotable water.

Originally, the use of nonpotable water initiated based on the idea that service water should be limited to drinking use as it is too precious to be used for water for flushing toilets, cooling air conditioners, washing cars, etc.

With studies now underway aimed at establishing its proper system as early as possible, it is expected to be enforced in the near future.

4. Water Reclamation and Water Quality

It is generally recognized that the reclamation process for secondary effluent using coagulation, sedimentation, rapid sand filtration and chlorination have long achieved substantial results and can be applied to a wide range of usages. Corrosion, a typical problem, can be prevented to a considerable extent by controlling the residual chlorine to 0.5 mg/ℓ and the generation of slime also can be checked by chemical agents with relative ease. It has been made clear that simply using high quality secondary effluent can reduce damage due to corrosion and slime to minimum.

The quality of secondary effluent is governed by the quality of sewage and the efficiency of its treatment. Quality of secondary effluent that the Tokyo Metropolis uses as a source of industrial water is shown in Table 5.

Table 5: Quality of Secondary Effluent used by Tokyo Metropolis

pH	6.9∿7.0
BOD	10∿25 mg/ℓ
COD	11∿18 mg/ℓ
SS	7∿15 mg/ℓ

For that reason, the quality of reclaimed water can be improved substantially if sewage that is not containing industrial waste water and not mixed with sea water is used as an influent, and this is practically possible.

To further expand the usage of reclaimed water, removal of residual color, organic substance, etc. is essential. (In some cases, removal of non-organic and pathogenic substances is required.)

In addition to the conventional methods, there are several others including activated carbon adsorption, reverse osmosis, electrodialysis, ion exchange and biological denitrification. Operational technologies on some of those have been established and those on others are now being advanced.

As mentioned above, various ways of reclamation systems are feasible by combination of unit operations. Decisive factors for the selection are water quality necessary for respective usages and cost of reclamation. As to necessary water quality, quality criteria are now established only for service water. Concerning other water, only provided are desirable standard quality for industrial water and tentative standards for nonpotable water.

There are difficult problems in connection with the standard of water quality for the re-use of municipal and industrial waste water, serious studies to determine quality criteria are now being exerted.

5. Water Re-Use and Water Re-Use Promotion Center [WRPC]

Harmomious development of technologies on advanced water treatment and water re-use is essential for effective promotion of water re-use programs. From this point of view, WRPC has proceeded with the following projects and experiments:

(1) Demonstration Plant for Industrial Re-Use of Municipal Sewage

Construction of demonstration plant for industrial re-use in Japan has reached a stage where coagulation, sedimentation, filtration and chlorination of secondary effluent is put to practical use as previously mentioned and water thus produced has already been supplied as industrial water and/or nonpotable water.

However, since its quality has restricted its usage in one way or another, further improvement of quality is required to utilize reclaimed water extensively as a new water source.

To achieve this, WRPC decided to construct a practical-scale demonstration plant employing activated carbon in cooperation with Tokyo Metropolis from fiscal 1973 through fiscal 1978. This plant had started formal operation in May, 1979, and its outlines are as follows:

1) Capacity: 52,500 m^3/day
2) Influent: Secondary effluent treated by coagulation, sedimentation, sand filtration & chlorination
3) Process: Activated carbon adsorption
4) Target quality of effluent
   Color: Less than 5°
   MBAS: Less than 0.1 mg/ℓ
   COD (Mn): Less than 5 mg/ℓ
5) Activated carbon contactor:
   Steel-made prossure type, two-column, 9 series, SV2

6) Activated carbon to be used:
   Qualified carbon above the selection standard
7) Washing:
   Surface washing and back washing
   Back washing velocity: 25∿35 cm/min
   Back washing duraction: 35 min
   Washing frequency: 1 time/3 days
   Expansion rate: 25∿30%
8) Regeneration facility of activated carbon:
   External heat rotary kiln

The influent of this demonstration plant is supplied from the Minami Senju Tertiary Treatment Plant of the Tokyo Metropolitan Government and the effluent is supplied to the factories in the nearby area for industrial use.

The layout and flow diagram are shown in Figs. 1 and 2 respectively.

The selection standard of activated carbon to be used in this plant is as follows:

1) Hardness by Japan Industrial Standard (JIS) K1474:
   More than 90% (Percentage of residual quantity after abrasion by steel ball.)
2) Apparent density by JIS K1474:
   Within the range of 0.40 to 0.53 g/cm^3
3) Particle distribution
   a) Particles within the range of 1,680 to 420 μ should be more than 95%
   b) Uniformity coefficient should be less than 1.7
   c) Contains dust as few as possible
4) Adsorption Performances:
   a) Iodine adsorption performance by JIS K 1474:
      More than 1,000 mg/g-c
   b) Methylene blue decoloration by JIS K 1470:
      More than 180 ml/g-c

c) ABS value by Japan Water Works Ass'n (JWWA) K 113: Less than 40

5) Chemical stability:
Less reactive to oxidizing gas such as oxygen and steam

The basic specifications of activated carbon regeneration facility installed in this demonstration plant are as follows:

1) Operation period: 8 months per year
2) Capacity: 2 tons per day by continuous regeneration, as calculated in term of new carbon
3) Activated carbon to be treated:
Granular type
4) Regeneration system:
External heat rotary kiln
5) Recovery rate of adsoption performance:
More than 95%
6) Maintaining rate of hardness:
More than 90%
7) Regeneration rate:
More than 95% in term of volume
8) Should be trouble free and low maintenance cost

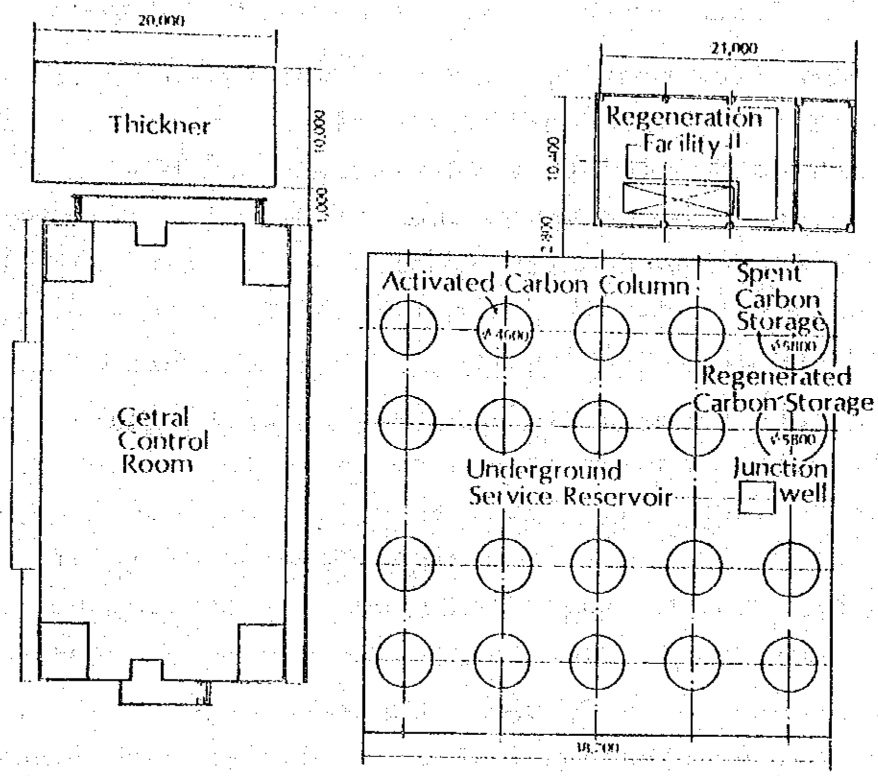


Fig. 1: Layout of Demonstration Plant

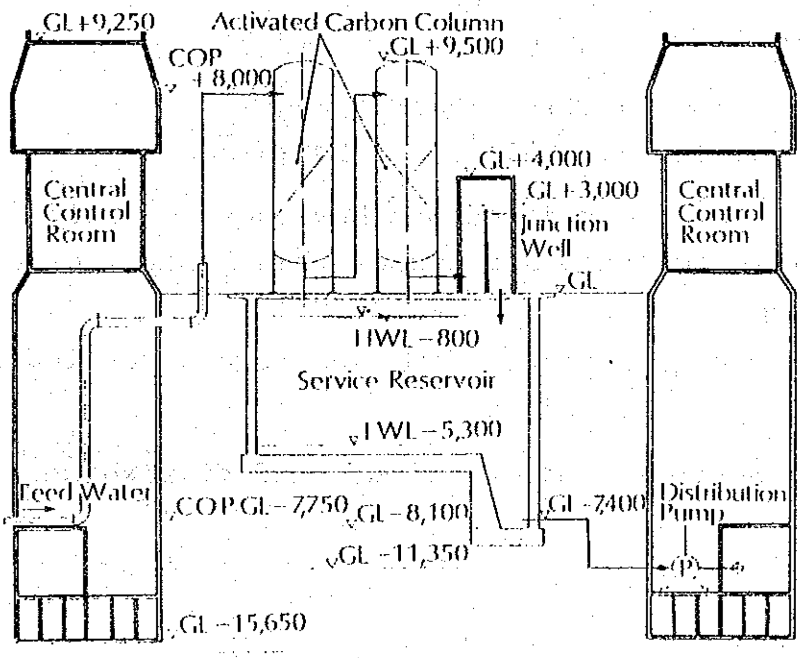


Fig. 2: Flow Diagram of Demonstration Plant

(2) Experiment for Developing Technologies of Gravity Type Activated Carbon Adsorption

The down flow gravity contactor was not adopted for the above-mentioned demonstration plant due to technical problems noted in the bed structure and device for activated carbon make-up and withdrawal. This equipment is designed based on the rapid sand filter which has been employed extensively for purification plants of water works and industrial water works.

It is easy to maintain like the conventional water purification equipment and suitable for large capacity water reclamation. Reinforced concrete construction is also possible, thus providing longer useful life. For that reason, there has been a strong demand for practical use of the equipment among local governments.

In response to this, WRPC conducted experiments for its technical development in fiscal 1974 through fiscal 1976.

Outline of experimental equipment is as fallows:

Place: Sewage treatment center located in the southern basin on the left bank of River Arakawa, Saitama Pref.

Capacity: 2,000 m^3/day.

Activated carbon filter tank: Steel made. 3,000(W) x 4,500(L) x 6,000(H)mm.

Experiments on bed structure have been made for strainers, flat plate screens, and Leopold blocks by modifying them in sequence.

Activated carbon used: Granular carbon ranging 8 to 30 mesh.

Way of washing: Back washing, surface washing and air washing.

(3) Experiment for Developing Technologies of Water Reclamation Centering Around Biological Denitrification

This experiment was designed to obtain basic data necessary for utilizing sewage effluent for industrial water or nonpotable water for housing complexes and so on. For the purpose, a pilot plant experiment centering around biological denitrification was conducted in fiscal 1974 through fiscal 1976.

Outline of experimental equipment is as follows:

Place: Sewage treatment plant located at Senpoku in Sakai City, Osaka Pref.

Activated sludge type denitrification process: Capacity 300 m^3/day

Rotary disc type denitrification process: Capacity 100 m^3/d

Coagulation and sedimentation tank: Capacity 50~100 m^3/d

Rapid sand filter: Capacity 50~100 m^3/d

Activated carbon adsorption column: Capacity 50~100 m^3/d

The flow sheet is shown in Fig. 3.

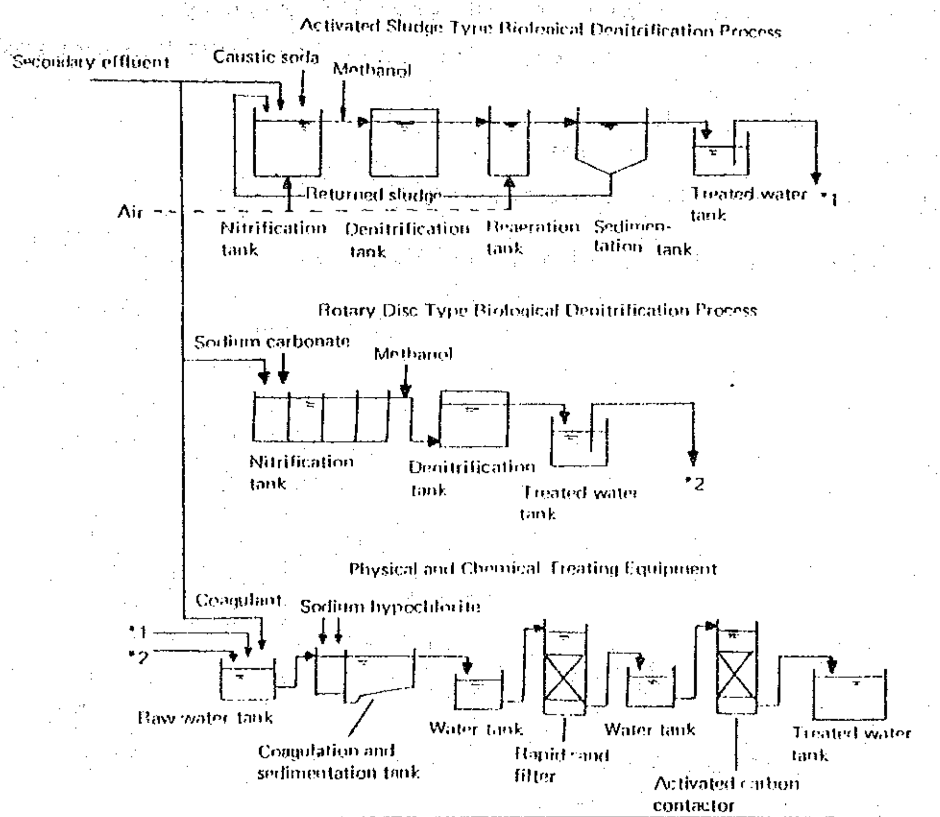


Fig. 3: Flow Sheet of Water Reclamation Centering Around Biological Denitrification

(4) Experiment for Developing Technologies of Water Reclamation utilizing Powdered Active Carbon

In applying activated carbon to water reclamation, available are methods of using granular activated carbon and powdered active carbon.

Up to the present, powdered active carbon is superior to granular activated carbon in adsorbing effect and cost but hard to regenerate and also difficult in treating sludge. Due to these problems, it has failed to be adopted for water reclamation. This experiment was designed and conducted in fiscal 1976 through fiscal 1978 for developing practical technologies for water reclamation and regeneration of powdered active carbon, as such shortcomings were almost solved through basic studies.

Outline of experimental equipment is as follows:

Place: Central sewage treatment plant located in Chiba City

Powdered active carbon/activated sludge combination treating equipment: Capacity 300 m^3/day

Powdered active carbon adsorbing/separating equipment: 300 m^3/day

Wet oxidation regenerator

Dry distillation regenerator

The flow sheet is shown in Fig. 4.

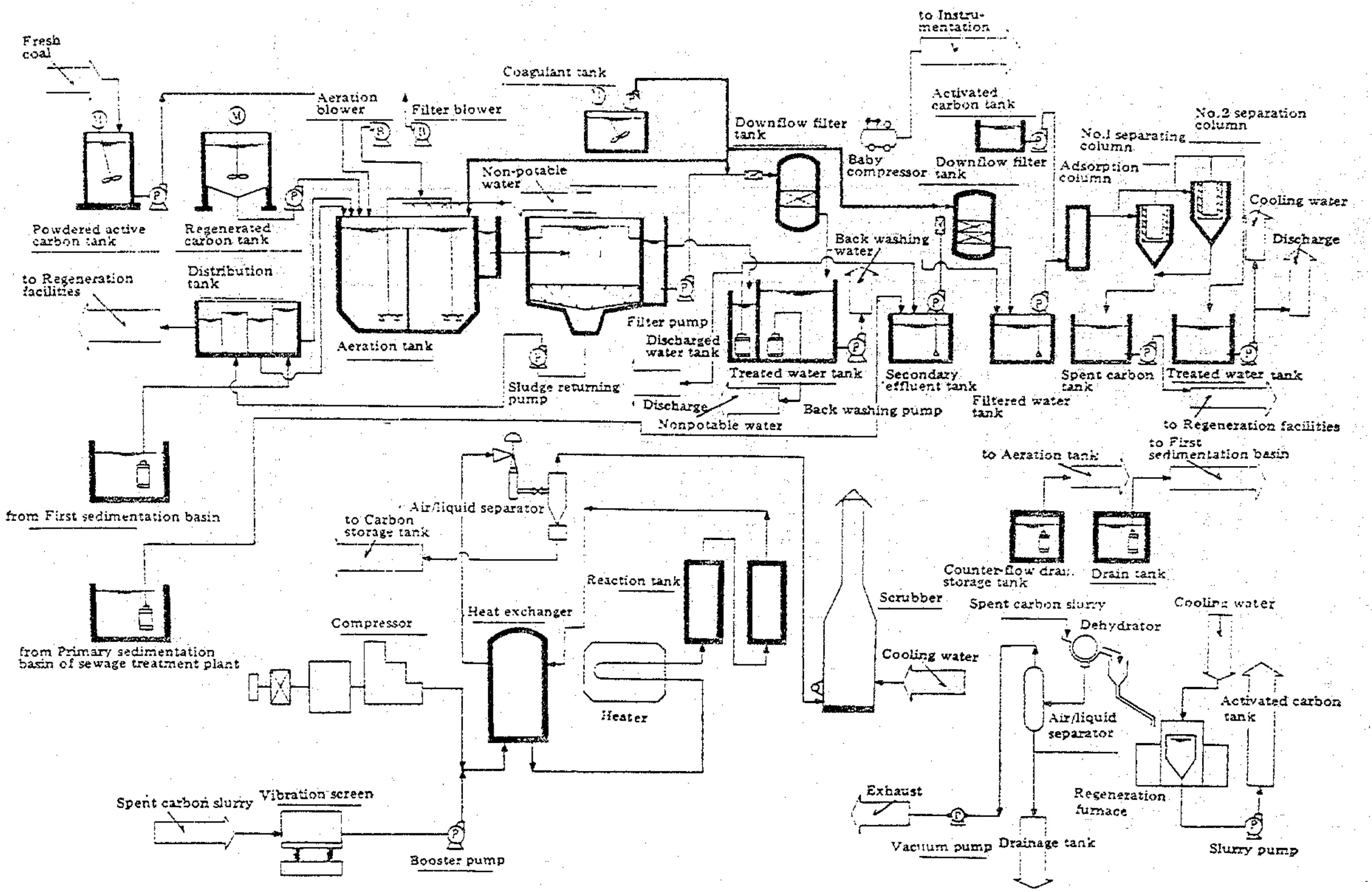


Fig. 4: Flow Sheet of Water Reclamation using Powdered Active Carbon

(5) Experiment for Developing Re-Use Technologies of Drainage from Office Building

In view of the recent trends of the concentration of political, economic and social activities in the metropolitan areas, the demands for city water in these areas are anticipated to keep increasing.

The breakdown of city water usage in the Tokyo Metropolitan area is shown in the table below:

Usage	%
A. Domestic	
Laundry	19.7
Bathing	8.8
Cleaning	5.1
Sprinkling	0.5
Car Washing	0.2
Drinking & Cooking	13.5
Hands and Face Washing	10.4
Toilet Flushing	4.8
Sub Total	63.0
B. Municipal Function	
School	4.4
Public Bath	1.7
Hospital	2.8
Pool	2.5
Others	25.6
Sub Total	37.0
Total	100.0

The "Domestic" water, which is 63% of the total consumption, is considered to be reaching the ceiling as a whole, although slight and gradual increase is anticipated in the future.

"Others" among "Municipal Function", which is composed of office buildings, department stores, hotels, stations and so on, consumes 25.6% of the total and its increase rate is anticipated to be the highest in the fugure. To cope with this forecast and to use beneficially the city water in the metropolitan areas, the technological developments on re-use of drainage from buildings have been taken up by WRPC since fiscal 1977 in cooperation with local governments and concerned firms.

The tests include the following items:

1) To establish stable process to the change of quantity and quality of drainage
2) To develop a compact equipment since the space is so limited
3) To develop the technologies on automatic operation to save manpower as much as possible.

Tests on several types have started in fiscal 1977 which treat drainage excluding toilet flushing and completed in fiscal 1979.

Tests on additional types have started in fiscal 1978 which treat drainage including toilet flushing

Figs. 5, 6 and 7 show the flow diagrams of three types of the pilot plants.

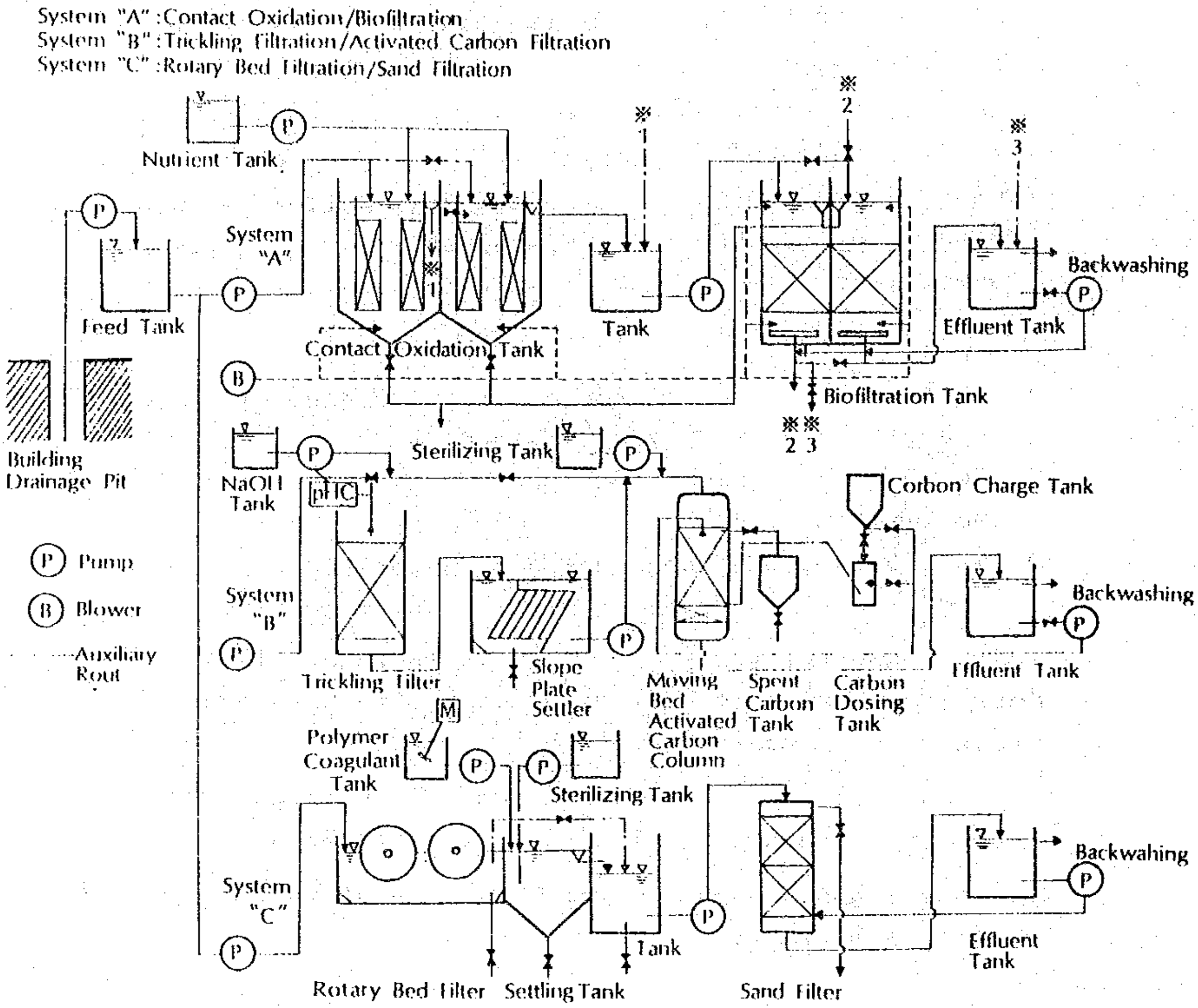


Fig. 5: Flow Sheet of a Pilot Plant for Re-Use of Building Drainage

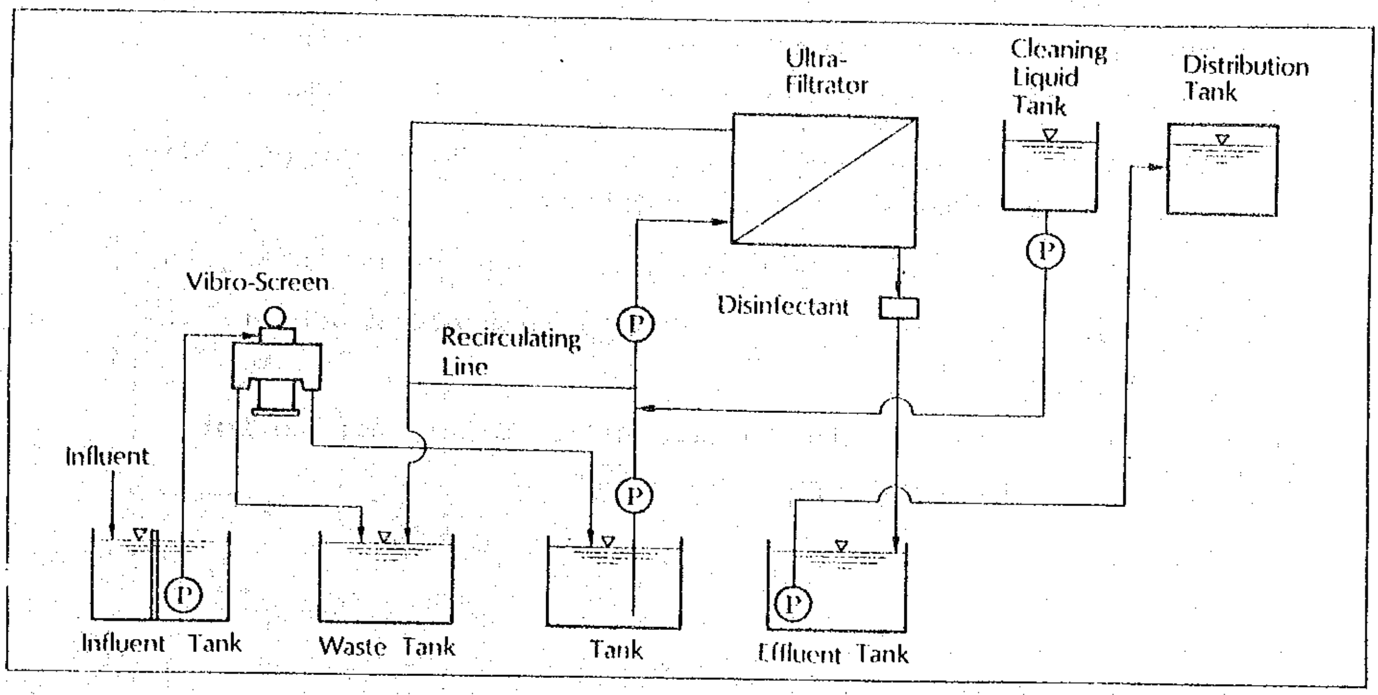


Fig. 6: Flow Diagram of Vibro-Screen/Ultra-Filtration Process

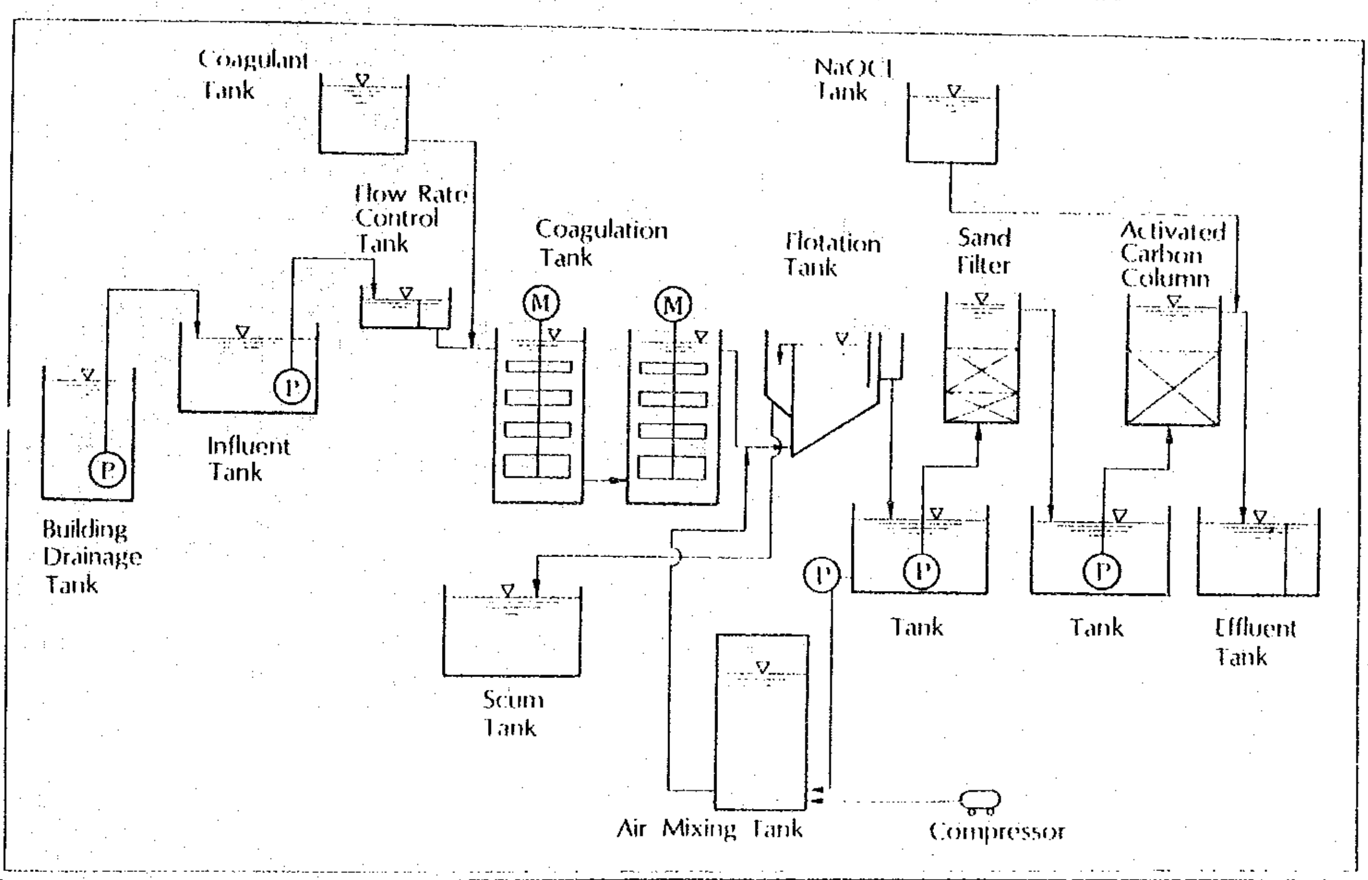


Fig. 7: Flow Sheet of Flotation/Sand Filtration/Carbon Adsorption Process

(6) New Programs of Technological Developments

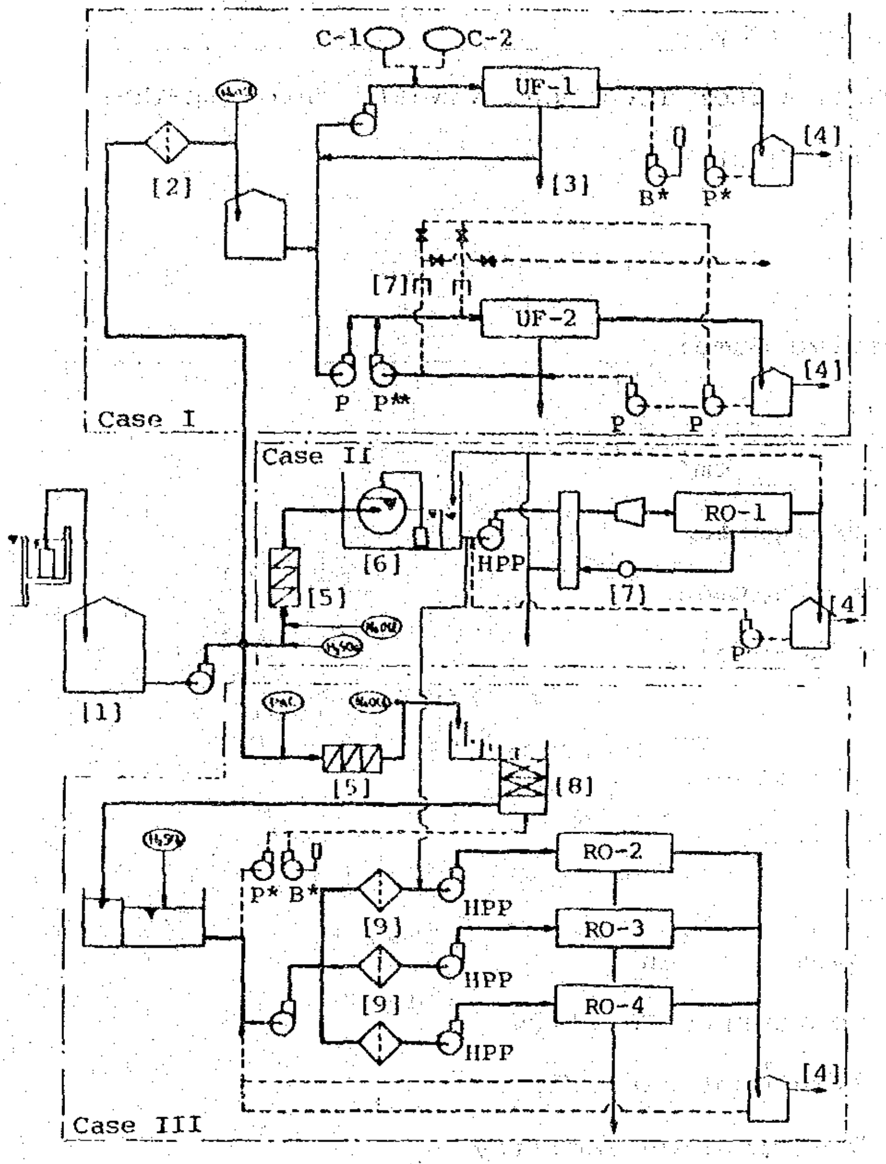
WRPC have started since fiscal 1979 new grograms of technological developments on the following themes:

1) Re-use of municipal waste water by membrane process--reverse osmosis and ultrafiltration.

   The flow sheets of pilot plants are shown in Fig. 8.

2) Total system of waste water re-use and sludge treatment.

3) Re-use of municipal waste water mainly aiming for removal of eutrophic pollutants.



UF-1: Hollow Fiber Module
UF-2: Tubular Module
RO-1: Tubular Module
RO-2: Tubular & Spiral Wound Modules
RO-3: Spiral Wound Module
RO-4: Hollow Fiber Module
[1]: Receiving Tank
[2]: Strainer
[3]: Concentrated Waste
[4]: Reclaimed Water
[5]: Line Mixer
[6]: Microstrainer
[7]: Ball Washer
[8]: Sand Filter
[9]: Cartridge Filter
P: Pump
P*: Pump for Back Washing
P**: Pump for Recycling
HPP: High Pressure Pump
B*: Blower for Back Washing
C-1: HCl
C-2: NaOH

Fig. 8: Flow Sheet of Reverse Osmosis or Ultrafiltration Process for Water Re-Use

7.3

QUESTIONNAIRE [1]

Waste Water Re-Use Program in the Kingdom of Saudi Arabia

Answered by: ______________________________

1. Investigations of Waste Water Treatment & Waste Water Re-Use

1.1 Investigations in the Past

[1] Year: __________

[2] District

[A] Administrative Name: ______________________________

[B] Population: __________

[C] Area: __________ km^2

[3] Purpose of Investigation

[A] Waste Water Treatment

[B] Waste Water Re-Use

[C] [A] & [B]

[4] Items of Investigation

[A] Feasibility Study

[B] Basic Plan

[C] Scope of Investigation

[a] Water Conveyance Facility

[b] Water Treatment Facility

[c] Water Distribution Facility

[5] Availability of Investigation Report: Yes No

[6] Actualization of Investigation: ______________________________

____

[7] Consignee: ____

____

1.2 Investigations that are currently conducted or planned

[1] Period: From ________________ to ________________

[2] District

[A] Administrative Name: ________________________________

____

[B] Population: ________________

[C] Area: __________ km^2

[3] Purpose of Investigation

[A] Waste Water Treatment

[B] Waste Water Re-Use

[C] Waste Water Treatment and Re-Use

[4] Items of Investigation

[A] Feasibility Study

[B] Basic Plan

[C] Implementation Plan

[D] Scope of Investigation

[a] Water Conveyance Facility

[b] Water Treatment Facility

[c] Water Distribution Facility

[E] Consignee: ____

____

2. Waste Water Programs that are currently planned

[1] District

[A] Waste Water Treatment

District: ____________________

Population: ____________

Area: __________ km^2

[B] Irrigation

District: ____________________

Population: ____________

Area: __________ km^2

[2] Description and Percentage of Waste Water

Description	Percentage
Domestic Waste Water	
Industrial Waste Water	
Others	

[3] Water Supply Condition in the Subject District

Use	Source	Treatment Process	Distribution System
Potable Water			
Industrial Water			

[4] Location of Waste Water Treatment Plant

Availability of Location Map: Yes No

[5] Capacity and Flow of Treatment Plant
[including Sludge Treatment Process]

[A] Capacity: Average: __________ m^3/day

Maximum: __________ m^3/day

[B] Flow:

Availability of Flow Chart: Yes No

[6] Seasonal Variation of Waste Water Quality and Quantity

Description	Items	Variation
Quality	pH	~
	BOD	~
	SS	~
	TDS	~
	Cl^-	~
	T. Hardness	~
	Na^+	~
	K^+	~
	T-N	~
	T-P	~
	Coliform	~
Quantity [m3/day]		

[7] Quality of Reclaimed Water

[A] Recorded Value

pH: ________ BOD: ________ SS: ________

TDS: ________ Cl^-: ________ T.H.: ________

Na^+: ________ K^+: ________ T-N ________

T-P ________ Coliform: ________

[B] Standard [Design Value]

pH: ________ BOD: ________ SS: ________

TDS: ________ Cl^-: ________ T.H.: ________

Na^+: ________ K^+: ________ T-N ________

T-P ________ Coliform: ________

[8] Distance between Sewage Treatment Plant and Distributed District, and other Geographical Conditions

[A] Distance: ________ km

[B] Conditions: ____________________

____

____

[9] Distribution System of Reclaimed Water

[A] System: Pipeline Tank Car

[B] Installation Method of Pipeline: Underground

Land Surface

[C] Material of Pipeline: ____________________

[10] Use of Reclaimed Water

[A] Agriculture

Name of Cultivated Plant: ______________________

____

[B] Roadside Tree

[C] Tree Planting

[D] Others: ______________________________

____

[11] Required Quality for Reclaimed Water

pH: ________ BOD: ________ SS: ________

TDS: ________ Cl^-: ________ T.H.: ________

Na^+: ________ K^+: ________ T-N ________

T-P ________ Coliform: ________

[12] Required Quantity for Reclaimed Water and Seasonal Variation:

____

____

____

____

Quantity: ________ m^3/day

3. Present Condition of Waste Water Treatment ~~and~~ and Related Problems

[1] Condition of Waste Water Treatment

[A] Subject District

Administrative Name: ______________________________

Population: ______________

Capacity: __________ m^3/day

Flow of Treatment Process: ____________________________

____

____

[B] Discharge Point of Reclaimed Water:

____

____

[2] Problems

[A] Problems related to Treatment Facility:

[a] Structural: ____________________________________

____

[b] Operational: ___________________________________

____

[B] Pipeline

[a] Material: _____________________________________

____

[b] Installation Method: ___________________________

____

[C] Sludge Treatment

[a] Process: ______________________________________

____

[b] Method of Disposal: ____________________________

____

QUESTIONNAIRE [2]

General Matters

Answered by: ______________________________

1. Programs of Water Sources Developments

[A] Demand

	∿1980	1985	1990
Potable			
Industrial			
Agricultural			

[B] Supply

	∿1980	1985	1990
Groundwater			
Desalinated Water			
Reclaimed Water			

2. Quantity supplied by Water Works and Industrial Water Works
Quantity treated by Sewage Works and Extension and Construction Program of Works

Use	Qt. [m^3/d]	Extension [%]	Construction Program
Potable			
Industial			
Agricultural			

3. Standard of Water Quality required for Water Works, Industrial Water Works and Sewage Works

[A] Potable Water [Supply Standard]

pH: ____________ BOD: ____________ SS: ____________

TDS: ____________ Cl^-: ____________ T.H.: ____________

Na^+: ____________ K^+: ____________ T-N: ____________

T-P: ____________ Coliform: ____________

[B] Industrial Water [Supply Standard]

pH: ____________ BOD: ____________ SS: ____________

TDS: ____________ Cl^-: ____________ T.H.: ____________

Na^+: ____________ K^+: ____________ T-N: ____________

T-P: ____________ Coliform: ____________

[C] Agricultural Water [Supply Standard]

pH: ____________ BOD: ____________ SS: ____________

TDS: ____________ Cl^-: ____________ T.H.: ____________

Na^+: ____________ K^+: ____________ T-N: ____________

T-P: ____________ Coliform: ____________

[D] Sewage [Discharge Standard]

pH: ____________ BOD: ____________ SS: ____________

TDS: ____________ Cl^-: ____________ T.H.: ____________

Na^+: ____________ K^+: ____________ T-N: ____________

T-P: ____________ Coliform: ____________

4. Service Charge

[A] Potable Water: ____

[B] Industrial Water: ____

[C] Agricultural Water: ____

[D] Drainage: ____

5. Allowable Cost for Reclaimed Water:

____

____

6. Sewage Disposal Method in District where Sewage Systems are not Installed: ______________________________

____

____

____

7. Installed or Planned Water Treatment Facilities [Desalination, Water Re-Use or Sewage Treatment]

Name of District	Purpose	Capacity [m^3/day]	Installed or Planned	Const. Period	Engineering, Manufacturing & Const. Firms

8. Administrative Office related to Water

[A] Administrative System: ______________________________

____

____

Availability of Organization Chart: Yes No

[B] Legistlative System: ______________________________

____

____

[a] Potable Water: ______________________________

____

[b] Ind. Water: ______________________________

____

[c] Agr. Water: ______________________________

____

[d] Sewage: ______________________________

____

[C] Budget: ______________________________

____

____

____

# # #

The following data are necessary as to the area to be developed.

1. general features of agriculture

2. climate ---- rainfall, temperature, evapotranspiration etc.

3. topographical maps, 1 to 50,000; larger scale maps are desirable

4. chemical property of soil, especially as to salts and soil mechanics

5. present cropping pattern

6. surface water and ground water ---- quantity and quality

7. present methods of irrigation

7.4

June 24, 1980.

H.E.Sheikh Abdullah Mohamed Al-Ghulaikah
Deputy Minister for Water
Ministry of Agriculture and Water.

Excellency,

We have the honour to report to Your Excellency our tentative comments and observations on the problems of water re-use and brine treatment in the Kingdom of Saudi Arabia as follows:

1. During the priliminary meeting held between us and the responsible officials of the Saudi Ministry of Agriculture and Water on June 15,1980, the Saudi side presented the points of discussion as shown in Annex I.

   The Japanese side studied them and prepared its comments in general way which were explained in Annex 2.

2. The Japanese team visited some agricultural and water facilities in the Kingdom of Saudi Arabia. During these visits, the Japanese team observed certain problems concerning the plan of waste water re-use and discussed a few points about irrigation in Hofūf irrigation and drainage project. We pointed out some problem and comments in Annex 3.

   But our detailed report will be prepared after our return to Japan and submitted later to Your Excellency.

3. Concerning the possible cooperation between our two countries in the field of water re-use, our initial findings are the following:

   (1) As to the re-use of sewage water, there may be possibility of Japanese participation, for instance, in the detailed study, if the Saudi side defines a specific area for such a purpose.

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(2) Regarding the Qassim and Medina projects, it is premature for us to mention definite opinions. The possibilities of the Japanese cooperation should be studied later on basis of more concrete information such as the reports of the consulting companies.

We will recommend to our Government to pay the positive consideration for implementing the cooperation in the field of re-use of sewage water, and the problem of treating the brine, if specific requests and detailed information are communicated by your esteemed Ministry to Japanese side.

We wish to take this opportunity to express our deep gratitude for your kind guidance and all facilities extended to us by your esteemed Ministry during our stay in the Kingdom of Saudi Arabia.

Please accept our best regards.

Hiroyuki MAKI	Delegation Leader Deputy Director Industrial Water Division Industrial Location and Environmental Bureau Ministry of International Trade and Industry
Takamichi IWAI	Irrigation Engineer Disaster Prevention Division Agricultural Structure Improvement Bureau Ministry of Agriculture, Forestry and Fishery.

ANNEX I

POINTS OF DISCUSSION

1- Reuse of Sewage Water

- Methods of Conveyance
- Methods of Application
- Restricted use/and/or unlimited use
- Choice of Crops
- Methods of disposing additional sewage water.

2- Disposing of brine rejects from R.O. Plants.

- Effect of directly dioposing in Sewage Systems
- Availability of Space
- Methods of Collection
- Minimum areas required for city plants.

ANNEX 2

I. THE BASIC CONCEPTION ON WASTE WATER RE-USE.

1) Water re-use for multiple purpose after waste water reclamation is the beneficial usage and is the effective way to minimise water demand.

2) There are two systems for waste water re-use. One is the system that treats the waste water, accumulated by pipe line, at the same plant of which the reclaimed waste water is re-used and supplies the reclaimed water to users by pipe line.

Another is the system that consumers of large quantity of water respectively, for example office building or factories, reclaim and reuse waste water at the place where their facilites are.

3) These two systems have the following characteristics related to cost estimation.

a. The system that treats waste water, accumulated by pipe line.
In case that the many consumers of reclained water stay at a limited area, such as agricultural re-use, this system is much effective.

b. Individual circulating system
In case consumers are distributed in extensive area, for example buildings or factories, this system is beneficial, because no pipe line is used.
However, factories should be constructed in the industrial zones whenever possible. Also, it is possible to re-use waste water with a unit, contains several buildings, without individual re-use.

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4) In selection of these systems, comprehensive waste water re-use programs should be designed and discussed, according to allowable cost for waste water re-use, the characteristics of objective area, waste water re-use demand, required water quality, distribution of consumers, and waste water quality. Therefore, the waste water re-use program in a large city, where large quantity of water is consumed for municipal functions such as Riyadh City, is different from programs in cities which contain farms such as Al Hassa.

5) Examples of waste water re-use in Japan

The examples are shown in the following Table I.

No.	The type of waste water reuse	Use	Treatment	Cost yen/m^3	Capacity of project	Recovery of waste water (%)
1	The system that treats waste water accumulated by pipe line	Industrial	Coogulation, Sedimentation, Sand filtration & Chlorination	15 -30	a. 140,000m^3/d (Tokyo metropolis) b. 60,000m^3/d (Nagoya city)	100
2	Ditto	Ditto	Granular carbon Adsoption influent, treated water of 1) system	30	50,000m^3/d (Tokyo Metropolis)	100
3	Individual circulating system	Toilet flushing	Biological treatment and filtration.	300	100-300m^3/d in the case of an office building (3000-5000 people)	30
4	Ditto	Industrial	Biological treatment, coagulation sedimentation & filtration	Misscellaneous with industrial classification		70

Comment

a. The water resource of 1) is the secondary sewage effluent, and the reclamation cost contains no secondary treatment cost.

b. Water charge in Japan (contains initial cost, repayment, personal cost power cost etc.)

Industrial water (national average) 20 yen/m^3
Municipal water (for business in Tokyo Metropolis) 250 yen/m^3

c. As above the cost of individual circulating system is about 300 m^3/m^3 higher than municipal water charge, but can minimize sewage charge
(145 yen/m^3: for business in Tokyo Metropolis)
Therefore, total cost decreases, and the economic advantage of individual circulating system will be recognized.

II. WASTE BRINE TREATMENT METHOD IN REVERSE OSMOSIS DESALINATION PLANT

For solving the problem of treating the brine, the idea of thorough recovery of water contained in the brine and the complete isolation of salt from water resources should be investigated with great care for conditions inherent in the area.

(1) WASTE BRINE TREATMENT

For the purpose of solving problems of strong demand for fresh water and treatment of brine, the following three methods are considered:-

1) Brine will be disposed to artificial salty pond and separated from water resources to prevent contamination. Water would not be recovered.

2) Through concentration, salt will be crystallized, separated from brine and rejected. The salt rejected is disposed in a specified place. Water would be recovered.

3) Through concentration, the brine will be disposed into the ocean by way of pipeline. Water would not be recovered.

(note) For concentration methods of brine, several methods are considered. These are chelating resin method, electrodialysis, multi-effect evaporator and solar pan etc.

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Among those, the recommended methods would be 1) or 2). The recovery of water and crystallization of salt from brine are recommended in order to prevent accumulation of salt in the underground water.

Method 3) is considered to be expensive owing to the usage of pipe line. A special technical study would be necessary to decide the optimum method. In case of adoption of method 2), a pilot plant test in site on long term basis would be required.

(2) RECOVERY OF WATER IN SLUDGE FROM SOFTENING PROCESS OF WELL WATER.

At the present time, the sludge including water from the softening process of well water has been discharged to desert.

If a dehydrator for the sludge including water will be adopted, more water would be recovered. The water contents of the present sludge is about 97% and the amount of the sludge including water in volume is about 10 - 18% in volume of raw well water.

When the water contents of the sludge are minimised to about 80% by the usage of dehydrator, the amount of the recovered water shall be about 88% of the initial amount of water in the sludge, and such amount of the recovered water shall correspond to 8.8% - 15.8% of the raw well water.

The above mentioned method is so far a mere idea , therefore, it will be necessary to confirm the effect of such method by some test.

If this method would be available, the amount of the discharged sludge would be minimised,therefore the problem of the space disposing sludge will be reduced.

III. ENVIRONMENTAL EFFECTS OF SEWAGE RE-USE.

(1) Industrial use

In Japan, reclaimed sewage has been used for industrial purposes for more than 15 years. Comments based on this experience are as follows:-

1) Criteria of characteristics of supplied water for industrial uses.
Standards of supplied water for industrial uses in Japan are shown in Table 2. For some uses, water of worse quality than these standards could be used and when higher quality is required, supplied water should be treated to the demanded grade in each factory.

Examples of sewage re-use for industrial purposes are shown in Table 3.

Table 2- The Standard Quality of Industrial Water in Japan

PH 5.8 - 8.6	
Turbidity 15°	
M-Alkalinity (as $CaCo_3$)	80 mg/l
T-Hardness (as $CaCo_3$)	100 mg/l
Cl^1	80 mg/l
TS	250 mg/l
Fe	0.3 mg/l
Mn	0.3 mg/l

../.

Table 3-1: Type of Industry using Reclaimed Water Supplied by Tokyo Metropolis

Type	%
Chemical	25.2
Iron and Steel	6.8
Metal	8.5
Foods	9.4
Leather	11.7
Paper and Pulp	15.1
Textile and Dyeing	3.6
Gas	1.8
Rubber	0.8
Others	17.1

Table 3-1: Use of Reclaimed Water Supplied by Tokyo Metropolis

U s e	%
Cooling	49.8
Washing	29.4
Process	13.7
Material	1.7
Boiler	0.1
Others	5.3

2) Distinction of pipelines

The supply line of industrial water should be distinct from the potable water supply line. Counterconnection of these lines should be strictly eliminated. The habit not to drink industrial water should be inculcated in factory's workers.

(2) Agricultural use

In Japan, we have no experience having used reclaimed water directly for agriculture. It is discharged into the river and used after diluted. Therefore, we don't have enough knowledge of using reclaimed water directly for agriculture.

We mention within our knowledge as follows:

1) The standard of water quality to be requested

a. The standard of water quality for Japanese paddy rice is shown in Table 4. However, as the weather, the climate and soil of the Kingdom of Saudi Arabia are entirely different from those of Japan, the standard cannot always be applied in the Kingdom of Saudi Arabia. Moreover, paddy rice in Japan is quite different from Saudi Arabian paddy rice. The former is short grain called Japonica, while the latter is long grain. In Japan, paddy rice is cultivated by flood irrigation for about 130 days in summer, while paddy rice here in the Kingdom is irrigated everyday as deep as evapotranspiration for the purpose of avoiding salinity problem. So the standard should be treated just as reference in the Kingdom of Saudi Arabia.

b. The standard for the other crops such as vegetables, fruits, pulses and cereals is not yet decided in Japan. There, rivers and lakes are going to be polluted by sewage, Ministry of Agriculture, Forestry and Fisheries and other organizations are now studying to decide the standard of water quality.

Table 4: The standard of Agricultural Water (Quality)

PH		6.0 -7.5
COD	less than	6 mg/l
SS	"	100 mg/l
DO		5 mg/l
TN	"	1 mg/l
AS	"	0.05 mg/l
CN		No Detection
Methyl-Hg		No Detection
Organic-P		No Detection
CD	less than	0.01 mg/l
Pb	"	0.1 mg/l
Cr6+		0.05 mg/l

2) Hygienic problems of sewage re-use

a. Pathogenic Problems

Sewage contains many kinds of micro-organisms,in some cases pathogenic microorganisms, and treated sweage also has a possibility to cause pathogenic deseases, not only for mankind but also for cattles and plants. Especially, in case of overhead irrigation, as water droplets scatter around the field and stick to surface of crops, pathogenic problems are important.

So, in case of agricultural re-use, reclaimed water shauld be steralized according to potable water criteria, though we have a question that coliform bacteria in water can decide the safety of water or not.

../.

Now in Japan, though some water resources are beeing poluted by incompletely treated sewage, we have no pathogenic problem.

b. Heavy metals

In the Kingdom of Saudi Arabia, evaporation rate is so high that poisonous materials such as heavy metals are highly concentrated during irrigation process. So, the allowable concentrations of heavy metals in reclaimed sewage should be determined considering arid climate of the Kingdom.

Generally, heavy metals in sewage are caused by industrial waste water discharged to sewer line, the problem can be dissolved by removing heavy metals from waste water in each factory before discharging to the sewer line.

c. Injury from high salinity

Because of high salinity of sewage and arid climate, during irrigation, salts will be concentrated in fields and spoil the soil. Considerable countermeasures are as follows:-

i) Leaching accumulated salts in soil with fresh water (well or spring water) intermittently.

ii) Selection and improvement of breeds to get high salinity resistant plants.

iii) Desalination of reclaimed water.

(3) Other uses.

1) Flushing water for toilet of Buildings Reclaimed water line should be distinct from potable water line.
In Japan, to eliminate counterconnection of these two lines, in some cases, reclaimed water is coloured by pigment and in some case different materials are used to distrinct each line.

Now in Japan, this system is being introduced to some new government office buildings.

2) Sprinkling for pavement trees law grade reclaimed water can be applied to sprinkling for pavement trees. In this case, to avoid misuse (drinking, washing hand and face etc.), reclaimed water should be supplied by tanker and carefully sprayed.

3) Recreation use.
Water for recreation use should not be drunk by the people by mistake, or the reclaimed wated should be treated to match the criteria of potable water quality.

A N N E X 3

Some coments about the plan of sewage re-use for irrigation and present irrigation in Al-Hassa region.

1. Sewage treatment

The present Hofuf sewage treatment plant is not suitable for agricultural re-use. The reasons are as follows:

Present treatment plant consists of screen, stabilization pond and sterilization equipment only. So,

(1) Effluent contains high concentration of olgae. This means effluents SS is very high.

(2) Sludge can not be drown off from the ponds. So sludge accumulation will make worse the effluents quality.

(3) The ponds have so wide surface area (40 ha for 4 ponds), evaporation less in the pond is too much quantity.

(4) Heavy metals cannot be removed by present system.

2. Irrigation

(1) Effective water use in winter season

In all Al-Hassa, the large portion of spring water is discharged directly into the drainage in winter. So, it may be worthwhile to study about effective water use in winter.

(2) Weeds in the drainage

In al-Hassa, people suffer from weeds in the drainage As they dare not use chemicals for fear of pollution, they have to cut them down by cutting machines. It takes much labour to cut weeds down by machines. So, it may be worthwhile to study how to avoid them without chemicals nor much labour.

As the result of our visit to the Kingdom of Saudi Arabia, we find that the following items may be appropriate subjects for the detailed study by the Japanese side.

However, it is hoped that the government of Saudi Arabia designate the specific area to be studied and give information related to these items, placing the priority on them.

We will report the above to our government and recommend the positive consideration for it.

1- Re-use of sewage

- Methods of Conveyance
- Methods of Application
- Restricted use/and/or unlimited use
- Choice of Crops
- Methods of disposing additional sewage water
- Recoverble water quantity for uses of agriculture, industry, office building and recreation
- Construction and operation cost
- Design of treatment plant and pipeline (including investigation of materials)

2- Disposing of brine rejects from RO plant

- Effect of directly disposing into sewage systems
- Availability of space
- Method of collection
- Minimum areas required for city plants
- Design of plant and pipeline (including investigation of materials)
- Construction and operation cost
- Cost of pilot plant experiments.

../.2

3- Water recovery from RO pretreatment sludge by dehydration

- Design of plant and pipeline (including investigation of materials)
- Construction and operation cost
- Cost for experiment
- Recoverble water quantity and sludge volume after dehydration.

7.5 ホフーフ(Hofuf)下水処理場ならびにハッサ かんがい・排水局(HIDA)プロジェクトに関する若干のコメント

1. オフーフ下水処理場の問題点と改善策(案)
ーかんがい用水への処理水再利用を前提としてー

1. まえがき

廃水再利用に関する調査団が1980年6月18日〜21日 Hassa Irrigation and Draining Authority(HIDA)訪問に際し、処理下水をかんがい用水に利用することを前提とした場合の既設Hofuf下水処理場の問題点および改善策につき見解を求められたので、検討結果をとりまとめ報告する。

なお、Hofuf 下水処理場の調査にあたって、設計諸元、水質などに関し詳細データを入手できなかったので、推定値にもとづく推論によらざるを得ない部分があったことをお断りしておく。

2. 既設処理設備概要

2−1 処理フロー

流入 → [揚水ポンプ] → [機械式スクリーン] → [スタビリゼーションポンド(注−1)] → [滅菌池 ← $C\ell_2$] → 放流

(注−1) 処理の主役をなしている池を、こゝでは最も一般的な名称であるスタビリゼーションポンド(Stabilization pond)と呼ぶこととする。HIDAでは腐敗池(Septic pond)と呼んでいるが、厳密には通性嫌気ラグーン(Facultative lagoon)と呼ぶべきである。処理の原理は後述する。

2−2 設備概要

詳細は不明であるが、我々が入手し得た情報をとりまとめると下記の通りである。

(a) 処理水量　最大　15,000 m^3/d

(b) スタビリゼーションポンド　要項

総表面積　40 ha

水　深　約2 m

池　数　4池

エアレーション設備　　なし

(c) 水　質

流入水、処理水とも不明

2－3　処理の機構

問題点を明確にするため、処理の機構につき簡単にふれておく。

スクリーンで粗大な固形物を除去された下水は池に流入する。池の表層部では、水面から酸素が溶解するとともに藻類が繁殖し、光合成作用によって酸素を放出するため溶存酸素濃度が高くなる。したがって好気性細菌が繁殖して水中に溶解している有機物を酸化分解する。なお、この際発生する CO_2 は藻類の光合成に利用される。一方、底層部では浮遊物質や藻類の死がいが沈殿堆積して有機物が多く、しかも酸素はほとんど供給されないため嫌気的な条件となり、メタンなどに分解される。嫌気的分解の結果生成した有機酸類は表層近くの好気性菌の分解の対象となり、CO_2 は藻類の光合成に用いられる。結局、廃水中の有機物は池内の嫌気性および好気性細菌によって分解されるが、その大部分は光合成作用によって藻類の細胞体に再合成される処理水中に流出する。したがって、この方法による処理においては、細菌による有機物の分解と藻類による光合成とそれに伴う酸素の補給がうまくバランスすることが重要なポイントとなるが、これらの生化学反応についての量論的取扱いが難しく、藻類の生育が外的環境とくに日照強度に大きく支配されるので、理論的に統一された考え方は確立されていない。いずれにせよ、処理水から藻類を除去しない限り、処理水水質は生物化学処理（２次処理）としては簡易処理の域を脱しないといえよう。

3. 既設処理設備の問題点

かんがい用水として処理水を利用することを目的とした場合、既設処理場が前述のようなプロセスを採用していることから、いくつかの問題が指摘される。

3－1　藻類を除去する機能を持たないこと。

２－３において述べたように、下水中の有機物の大部分は藻類の細胞に変換するが、この藻類を除去する設備をもっていないので、生成した藻類は処理水とともに流出する。その結果処理水ＳＳ，ＢＯＤ（ＣＯＤ）が高いこと、滅菌のための塩素消費量が大となることなどの問題がある。死滅した藻類細胞は用水路中の低流速の部分に沈積腐敗し、また畑地表面土壌の目づまりの原因となり、透水性を低下させる。藻類細胞の腐敗は、悪臭発生の原因となり、場合によっては発生した硫化水素などが直接作物に悪影響をもたらす可能性も考えられる。

3－2　水分蒸発量が大きく、溶解塩類が濃縮されること。

当地方の地下水は一般に溶解塩濃度が高く、1,０００～1,５００㎎／ℓである。従って地下水を直接かんがい用水に用いる場合でも、畑地における塩類の蓄積について、塩類の洗脱

などの対策が必要とされている。生下水中の塩濃度もほぼこれと同等と考えられる。ところで、現在の処理プロセスは広大な表面積を必要とするFacultative lagoon を採用しているため、水面からの蒸発量は極めて大きく、蒸発による濃縮を無視することはできない。蒸発量は１８㎜／dということから、処理池全面積（４０ha）から蒸発によって失われる水量を求めると

０.０１８m／d×４００,０００㎡＝７,２００㎥／d

となり、流入下水量１５,０００㎥／dの実に４８％に相当することとなる。従って処理水塩濃度は生下水の１.９２倍となる。いま、生下水中の塩濃度を１,５００㎎／ℓとすると、処理水においては２,８８０㎎／ℓとなり、かんがい用水として適用できる作物の種類は大きな制約をうけるものと考えられる。[1)]

なお、塩濃縮と同時に、７,２００㎥／dの水が回収されずに失われていることをも忘れてはならない。

3－3　<u>重金属が除去できないこと。</u>

かんがい用水中に重金属塩が含まれている場合の影響としては、作物の発芽、成育を阻害するという直接的な影響と、作物中にとりこまれた重金属を食物とともに摂取することによる人体への影響とが考えられる。

現在下水中に重金属イオンが含まれているかどうかは明らかでないが、金属表面処理工場、皮なめし工場、化学工場などの廃水が下水道に放流されると、重金属が混入する可能性が大きくなる。

また、当地方のように、高温・乾燥地帯においては、かんがい時の畑地における濃縮も充分考慮に入れて検討すべきである。

一般に、下水を生物化学的に処理すると、重金属は生物体にとりこまれて濃縮される。充分馴致した活性汚泥を用いて処理した場合、水銀、カドミウム、亜鉛などの重金属は、生物体中の濃度が周囲の水中の濃度の４,０００～１０,０００倍で平衡に達するという報告もある。[2)]
しかし、現在の処理方式においては、処理過程で発生した生物細胞は、処理系外に排出されることなく、池内に蓄積するか、処理水とともに流出する。池内に蓄積された生物体は腐敗分解するため、生物体にとりこまれた重金属は再溶出することとなり、結局生物処理過程での重金属除去は全く期待し得ないこととなる。

3－4　<u>滅菌が不完全になりやすいこと。</u>

現設備においては、安定池流出水に塩素を注入し滅菌している。塩素滅菌自体には問題はないが、安定池流出水に多量の藻類を主体としたＳＳを含み、これが塩素を消費するため、過剰の塩素注入が必要であろう。

なお、かんがい用水として利用する過程で、誤って飲用に供せられる可能性が高い場合は、処理水中の微量有機物の塩素化に伴う毒性についての検討が必要となる。最近、飲料水水源

の汚染が進むに伴い、塩素滅菌によるトリハロメタン等の生成が問題としてとりあげられつつある。現在、充分なデータが得られてはいないが、滅菌用薬剤の変更をも含めて検討すべき課題であろう。

3－5　栄養塩類について

下水をかんがい用水、とくに穀類のかんがいに用いる場合、窒素化合物が過剰に存在すると、徒長し、結実を妨げることが考えられる。これは、日本における水稲栽培において特に問題化している例が多い。しかし、当地方におけるかんがい方式によれば、塩類の洗脱に際し同時に肥効成分が流失するので問題化することはないといえよう。用水路における藻類の増殖を助長する程度と考えられる。

4．設備改善案

4－1　改善方針

前章で既設設備の問題点を列記したが、改善策については、生下水水質、かんがいの方式、適用する作物等によって異って来る。たとえば、塩の濃縮について問題としなければ、現在の安定池流出水を凝集沈殿することにより水質を大巾に改善することができる。また、塩濃度を問題とするならば、高度の運転管理技術を要求されるが、生物化学処理には活性汚泥法を採用すべきである。

いずれにせよ具体案を提示するには生下水水質の測定データが必要であるが、こゝでは、下記の理由から現在の安定池による処理をやめ、標準活性汚泥法を採用するものとする。

(1)　高度の処理水質が得られる。

(2)　処理効率が気象条件に左右されず安定している。

(3)　水分の蒸発損失が少い。

(4)　重金属の除去をある程度期待できる。

(5)　寄生虫卵等の除去率が高い。[3]

4－2　改善計画

改善案作成にあたり下記水質を仮定する。

生下水水質	BOD	250 mg／ℓ
	SS	300 mg／ℓ
	TDS	1,500 mg／ℓ

1) "Water Quality Criteria" SWPCB, California, 1952

2) R.D. Naufeld and E.R. Herman: "Heavy metal uptake by aclimated activated sludge" Journal of W.P.C.F 47 310 (1975)

3) S. Aiba and R. Sudo: "Parasites in sewage and the possibilities of their extinction" (Discussion paper) 2nd Int. Con. Wat. Poll. Res. II-13 (1964)

2. ハッサ かんがい・排水プロジェクトにおける問題点

廃水再利用調査団は、１９８０年６月１８日から６月２１日までハッサ (Al－Hassa)地域においてプロジェクト の現地調査を行ったが、その調査中に気づいたかんがい及び排水関係の2.3の問題点につき以下の通り報告する。

(1) 排水路の水の再利用について

ＨＩＤＡにおいては、現在２４ ha の試験ほ場において、排水路の水の再利用の可能性について栽培試験を実施中である。

この試験の方法は、２４ haを ８ ha ずつ3ブロックに分割し、対象作物として野菜、小麦、牧草等に対し、第１ブロックでは排水路の水のみ、第２ブロックでは、排水路の水と未使用の泉の水とを種々の割合に混合したものを、また第3ブロックでは泉の水のみをかんがいし、それぞれその成育ぶり、塩分集積の状況を比較検討し、排水路の水を希釈して再利用することとの可能性を調べようというものである。

試験の結果は来年の夏頃得られるとのことであるが、適当な割合で希釈すれば利用可能との結論が得られれば、１で述べたホフーフ 市の下水を処理した水と排水路の水との混合により、新規のかんがい水が得られる可能性を開くという点で貴重な試みであると言えよう。

ただし,これらの水の再生利用の成否は、乾燥地におけるかんがいで最大の障害となる塩分について、これを抑えるだけでなく、 有害な重金属、過剰なリン、窒素等についても適切な試験を行い、これらを除去する手法、施設を確立することにかかっていると言えよう。

(2) 冬季排水路に捨てられる水の有効利用について

ハッサ地域において、現在かんがいされている 8,０００ ha に対し、夏季のピーク時には9.５m^3／sec の水が必要とされているが、冬には必要量が極端に下がってしまう。一方、泉の湧出量は一年を通じてほぼ一定と推定されるため、冬季においては8,０００ ha の下流に存在する4,０００ ha の農地についても一部かんがいが可能となっている。それでもなお余剰が生じるため、冬には、湧出量のうちある程度の部分がかんがいに利用されることなく排水路に直接放流されている現状である。この、冬季排水路に直接放流される水を適当な場所に貯留し、夏季に利用できれば、夏作の面積を現在の8,０００ha 以上とすることも可能となる。

ただ厳しい自然条件のため、貯留は日本で考えられる程簡単ではない。まず、地表面上に水面を有する、単純なダムによる貯水池では、降雨が期待できないうえに、蒸発量が大きいため、水量の減少、塩分濃度の上昇による水質の劣悪化等の問題が生じよう。また夏季においては、かんがいの必要水量が非常に大きいため、小規模な貯留では、作物の成育期全体をカバーするかんがい水の確保が出来ないと考えられる。仮に、対象面積を1,０００ ha、かんがい期間１２０

日、必要水量を平均10㎜／dayとした場合、12百万㎥の純用水量を確保する必要がある。蒸発によるロスを極限まで小さくするような構造の施設を建造したとしても、送水ロス等を考慮すれば、12百万㎥÷0.8＝15百万㎥程度の貯水池が必要となろう。平均水深5mの場合300 ha の水面積を有する貯水池でなければならない。

このように考えてくると貯留の技術的可能性はかなり狭められてはくるが、水が非常に貴重で、生産増大の鍵となっているサウディアラビア王国では、無為に捨てられる水の貯留の可能性を細かに調査検討し、実現可能なプロジェクトを仕組んでいくことは、有意義なことと思われる。

(3) 排水路の雑草の処理について

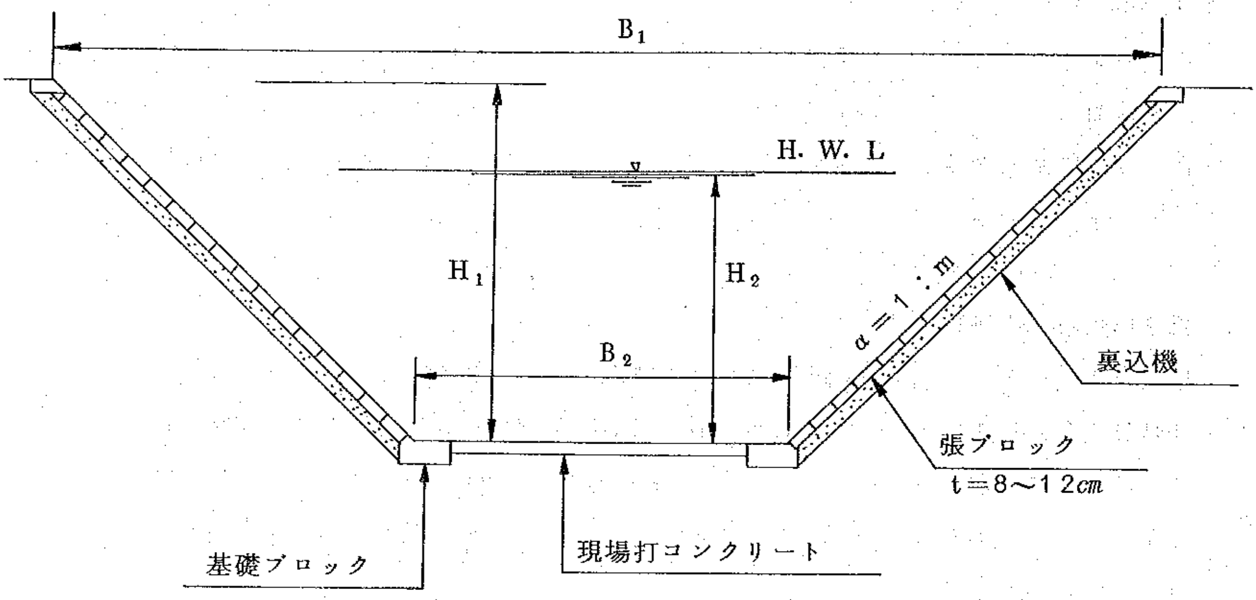
総延長60㎞余りの素掘りの幹線排水路の法面には草丈2mにも達する雑草が繁茂し、この処理にHIDAは手を焼いている。HIDAでは除草剤の使用については、沿線の住民が飲み水等生活用水に利用する習慣があること、evaporation sea，地下水及びアラビア湾の汚染につながる恐れのあることから好ましくないとして、もっぱら草刈機を用いて刈り取っているが、これに要する労働力は膨大である。

対策の一案としては、法面のライニングがあり、HIDAにおいても、ラバー・シートによる被覆を検討中の由であるが、日本でよく行われている張ブロックについても検討の価値があろう。張ブロックの略図は別図の通りであるが、排水路は、本来リーチング用水のキャッチという機能を有す必要性から底面をコンクリート張りしないB－type が、当地では適していよう。日本においてはB－typeの㎡当りの工事費（材料費込み）は約5,500円すなわち約80SRである。

また当国では、アスファルト材料が安価に入手できると思われるので、アスファルトによる被覆についても検討すべきであろう。

排 水 路 標 準 図

A TYPE



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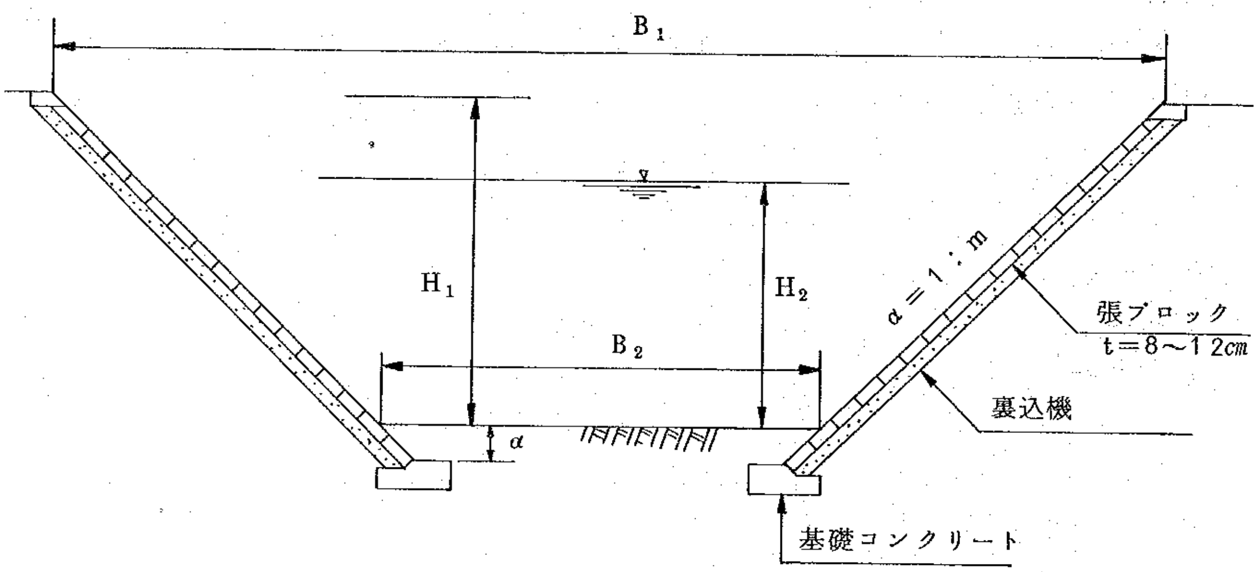

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