中 水 道 開 發 硏 究

A Study on the Water Reuse Systems

朴 仲 鉉*
Park, Chung Hyun
李 性 淇**
Lee, Seong Key
鄭 載 澈***
Chung, Jae Chul

要 旨

우리 나라는 水供給을 주로 댐開發에 依存하여 왔으나 이와 같은 方式은 앞으로 댐適地의 減少, 建設費의 昂騰, 水沒地域住民의 生活再建對策, 環境影響 등의 諸要因으로 인하여 계속하여 開發하기 어려운 狀況에 있다. 한편 水需要는 都市로의 人口集中, 生活水準의 向上, 産業發展 등으로 인하여 계속 增加되고 있으며 앞으로도 人口의 增加와 經濟活動의 高度化에 따른 都市機能의 向上에 의해 增加될 것으로 豫想된다. 따라서, 앞으로 늘어날 水需要에 對處하기 위해서는 地下水의 開發, 海水의 淡水化, 그리고 물을 循環再利用하는 中水道의 導入이 切實하며 그 硏究 또한 시급하다.

中水道란 從來 水道에 의해서 給水되고 있던 用途가운데 반드시 飮用水와 같은 程度의 淸淨을 要하지 않는 用途에 對하여 各 用途에 適合한 水質의 中水를 供給하는 것으로써 사람이 마시기에 適合하지 않은 물을 供給하는 施設의 總體라고 定義한다. 이와 같은 中水道의 用途로는 水洗式 便所用水, 에어컨冷却用補給水, 洗車用水, 撒水用水, 街路淸掃用水, 造景用補給水, 消火用水 등을 들 수 있으며, 原水로는 建物內에서 發生하는 雜排水, 水洗式 便所用水, 冷凍冷却排水, 下水處理水, 汚濁河川水, 그리고 雨水, 地下水 등을 생각할 수 있다. 그러나, 原水를 選定할 때는 水質과 함께 水量이 豊富한가에 대해서도 考慮하여야 한다. 中水道의 形態 및 分類는 開放系 循環方式과 閉鎖系 循環方式으로 大別되며, 이를 規模에 따라 個別循環方式, 地區循環方式, 廣域循環方式의 3가지로 나눈다. 中水道處理方式은 活性汚泥法, 回轉圓板法, 接觸曝氣法을 包含한 生物化學的 處理法과 凝集沈澱法, 砂濾過法, 活性炭處理法, ozone 處理法, 鹽素處理法, 膜處理 등을 包含한 物理化學的 處理法으로 大別된다. 또한 現在 外國에서 實施하고 있는 中水道의 例를 調査하였으며, 中水道利用의 效果를 直接的 效果와 附隨的 效果로 나누어 記述하였다. 또한 中水道 開發時의 問題點을 循環方式別로 調査하였으며, 技術, 衛生, 管理上의 問題와 費用問題, 法令上의 問題를 다루었다. 中水道를 開發하기 위해 事業者(設置者)와 行政機關의 役割, 中水道를 위한 施設의 構造基準 및 維持管理基

* 正會員·서울大學校 工科大學 敎授, 土木工學科
** 朝鮮大學校 環境工學科 專任講師
*** 서울大學校 大學院

準, 財政的 措置 등에 대해서 硏究하였다.

Abstract

Water supply has been mainly dependent on the construction of the dams in Korea. It is difficult, however, to continue to construct dams for many reasons, such as the decrease of construction sites, the increase of construction costs, the compensation of residents in flooded areas, and the environmental effects. Water demands have increased and are expected to continue increasing due to the concentration of people in the cities, the rise of the living standard, and rapid industrial growth. It is acutely important to find countermeasures such as development of ground water, desalination, and recycling of waste water to cope with increasing water demands.

Recycling waste water includes all means of supplying non-potable water for their respective usages with proper water quality which is not the same quality as potable water. The usages of the recycled water include toilet flushing, air conditioning, car washing, yard watering, road cleaning, park sprinkling, and fire fighting, etc. Raw water for recycling is obtained from drainage water from buildings, toilets, and cooling towers, treated waste water, polluted rivers, ground water, reinfall, etc. The water quantity must be considered as well as its quality in selecting raw water for the recycling. The types of recycling may be classified roughly into closed recycle systems and open recycle systems, which can be further subdivided into individual recycle systems, regional recycle systems and large-scale recycle system. The treatment methods of wastewater combine biochemical and physiochemical methods. The former includes activated sludge treatment, bio-disc treatment, and contact aeration treatment, and the latter contains sedimentation, sand filtration, activated carbon adsorption, ozone treatment, chlorination, and membrane filter.

The recycling patterns in other countries were investigated and the effects of the recycling were divided into direct and indirect effects. The problems of water reuse in recycle patterns were also studied. The problems include technological, sanitary, and operational problems as well as cost and legislative ones. The duties of installation and administrative organization, structural standards for reuse of water, maintenance and financial disposal were also studied.

1. Introduction

1.1 The Background of study

Water demands for domestic and industies have been increased rapidly since 1960s' economic development plan which causes people concentration in the cities and raising the living standard.

We have done our best for rational use of water resources by constructing the multi-purpose dams to cope with increasing water demands.

In Korea[16], the annual average precipitation is 1,159 mm which is 1.2 times of worlds' annual average, 970 mm. But the average precipitation per year per capita is 3,100 m^3/cap. which does not reach the one-tenth that of worlds', 34,000 m^3/cap. (Fig. 1). The seasonal variations of precipitation are so marked that over 60% of precipitation is concentrated between June and September. The most parts of land are mountainous regions, which makes precipitations flow out at one time. Water

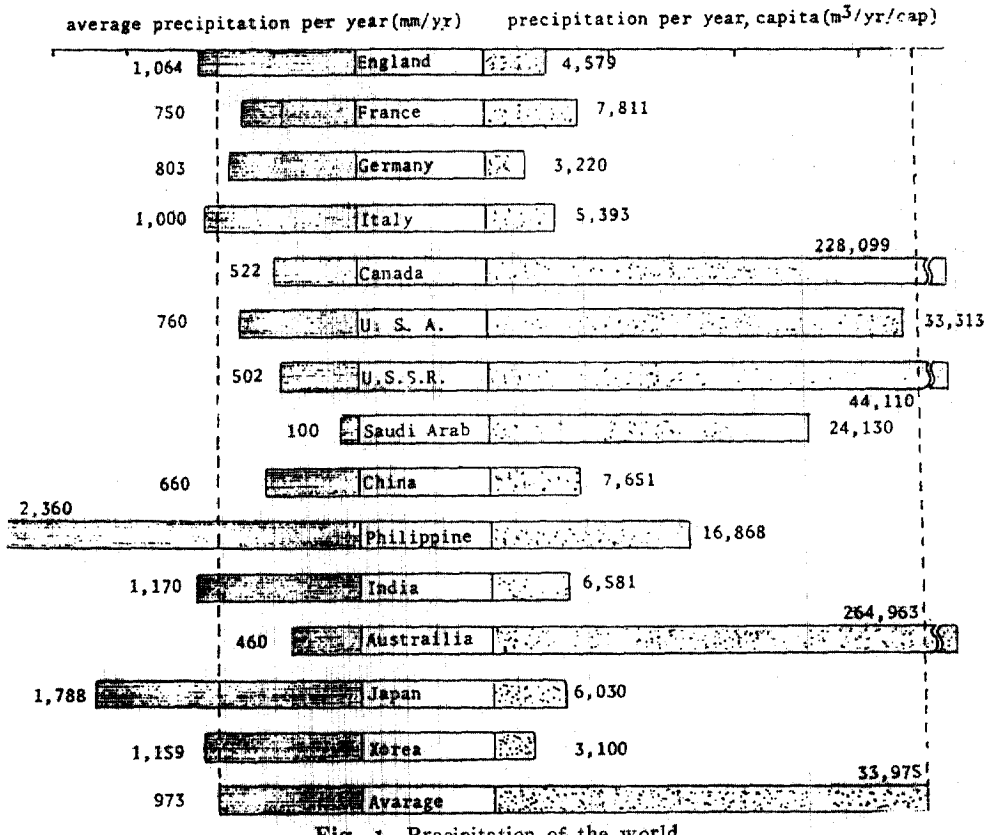
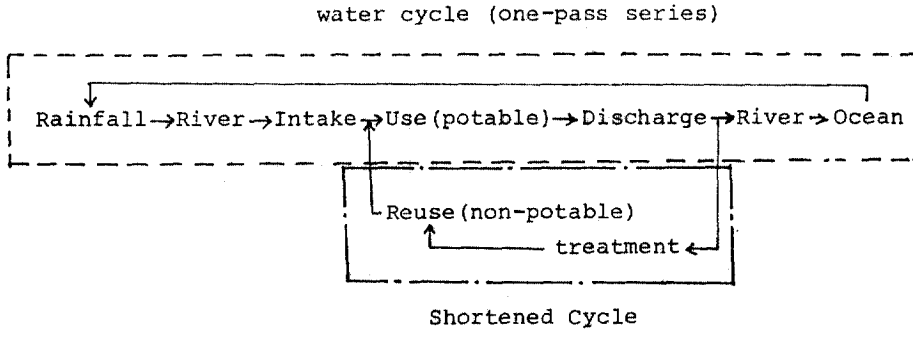


Fig. 1. Precipitation of the world

demands is out of balance to the charge of watersheds. Water pollution which is come from the abuse of agricultural chemicals and fertilizers, and the uncontrolled outflow of sewage and wastewater is also an important problem in water supply. Besides the many disadvantages relating to the use of water resources. The political investigation should be done in many relative fields to cope with increasing water demands in the future.

Therefore the development of "water reuse systems" as an alternative is the subject of this study. Water cycle system up to now is one-pass series, but in reuse patterns, additional shortened cycle should be introduced to accelerate water cycle artificially:this is the con-



cept of "water reuse systems".

2. General Concepts of "Water Reuse Systems"

2.1 General Concept and Definition[1,2]

Water demands should increase in the future as mentioned before. And countermeasures for water demands to construct dams are in front of many problems such as the increasing construction costs, the decreasing construction sites, the compensation for residents in flooded areas, and the environmental effects. Therefore the rational use of limited water resources should be investigated and the methods of securing water resources should be researched.

Direct measures to secure water resources

(a) construction of dams
(b) surplus water use for agricultural water
(c) desalination of seawater
(d) prevention of water leakage in distribution systems
(e) economization and rationalization of water use

Indirect measures to secure water resources

"Water Reuse Systems"

—includes all means of supplying non-potable water for their respective usages with proper water quality which is not the same quality as potable water.

The water reuse systems are able to relax the pressing water demands in the water shortage area, and have additional effects such as the alleviation of water shortage in dry seasons and the decrease of discharge sewers.

2.2 Classification of Usage

The usages of water in urban area may be classified roughly into domestic, commercial, industrial, agricultural and miscellaneous use, which can be further subdivided into drinking, cooking, bathing, washing, sweeping, flushing toilet, water sprinkling, etc[3].

It must be considered the social acceptance and the health safety for reuse water to determine the recycle of waste water. The social acceptance for reuse water is the reflection of social understanding, but we have little data because the concept of water reuse does not widespread yet. The health safety depends on

Table 1. Classification of water use

Quality / Use	very high	high	moderate	low
Domestic	drinking	cooking	bathing, washing cleaning	flushing toilets car washing water sprinkling
Commercial	drinking	cooking	air conditioning	flushing toilets, car washing water sprinkling floor sweeping
Industrial		raw material water boiler water processing water	cooking water	floor sweeping
Agricultural				irrigation
Miscellaneous				road cleaning, fire fighting, water sprinkling, depth control in river
Required quality	mineral water	advanced water treatment	general water treatment	treated wastewater, polluted river water, ground water, storm water

the possibility that reusing water contacts human body. It is difficult to use reuse water for potable and cooking water which would be unavoidable to eat, and bathing, and washing water which would be unavoidable to contact human body. The usage of reuse water therefore, should be limited as follows.

(1) toilet flushing
(2) air conditioning and cooling tower supplying
(3) car washing
(4) sprinkling and road cleaning
(5) yard watering
(6) fire fighting

Among them, relatively large quantity is (1), (2), (3), (4). Also, what is easy for control is (1), (2).

It is practical, therefore, to limit the usage to toilet flushing, air conditioning, and cooling tower supplying water that is relatively large amount and avoidable to contact. The ratio of water use in domestic and commercial buildings is as follow; Table 2.

Table 2. The ratio of water use in domestic[4,10,12,13]

usage	portion (%)
Drinking, cooking	20~30
Bathing	15~20
Washing(hands and face)	5~15
Washing(clothes)	about 25
Cleaning	4~ 8
Toilet flushing	about 20
Car washing, Sprinkling	2~5%

2.3 Raw water for water reuse

The available raw waters for water reuse are miscellaneous building drainage, toilet drainage, cooling tower drainage, treated wastewater, polluted river water, estuary water, storm water, sea water, etc. The storm water and polluted river water depend on the geological and environmental conditions. Ground water depends on the geological conditions, and the ground settlement may occur when overpumped. Therefore, in general, the raw water is confined to miscellaneous building drainage, toilet drainage, and treated wastewater.

Another classification of the raw water is inner source, external source, and combined source. The inner source is the wastewater in pertinent area, and the external source is the wastewater from outside of the area.

2.4 Water reuse patterns[1]

Water reuse patterns are classified roughly as open and closed recycling system. The former type is to reuse the discharged effluent in the downstream or ground water through sprinkling the wastewater on the ground surface, while the latter is to reuse the treated effluent directly. In this case, advanced treatment may be necessary. The closed recycling system may

Table 3. The ratio of water use in buildings[4]

Buildings	Scale	$\frac{\text{Toilet flushing}}{\text{Total water use}}\times 100$	$\frac{\text{Cooling tower supply}}{\text{Total water use}}\times 100$
Office buildings	Large	30 ~ 50	about 25%
	Small	50 ~ 80	
Hospital		20 ~ 30	30 ~ 40
Department store		15 ~ 35	30 ~ 50
University	Social	35 ~ 70	
	Science	10 ~ 20	

be subdivided such as individual, regional and large-area recycling according to the size.

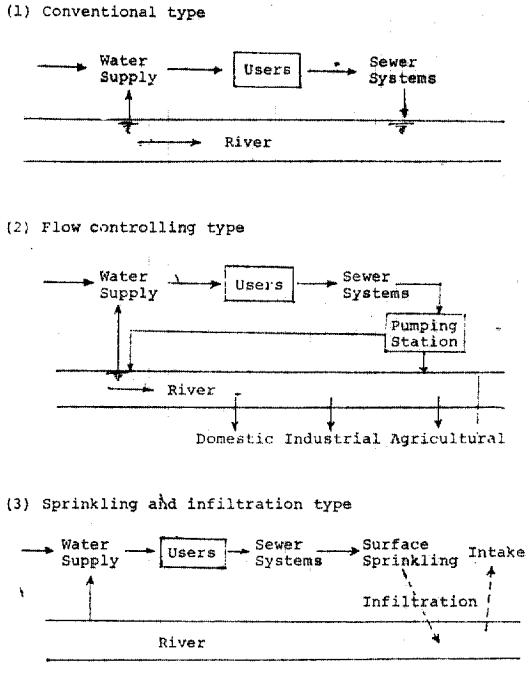


Fig. 2 Open recycling systems

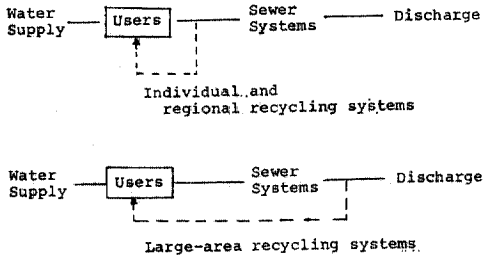


Fig. 3 Closed recycling systems

The use of treated wastewater for other usage in one of the modification of the closed recycling systems.

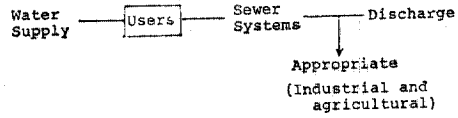


Fig. 4 Modification of closed recycling.

2.4.1. Individual recycling system.

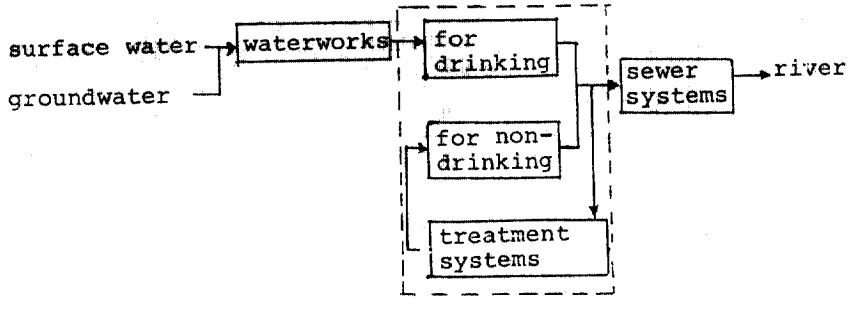
The individual recycling system refers to the recycling water after the self-purification of the drainage from buildings. The raw water for reuse can be all of the drainage. The sanitary problems could be mitigated by excluding toilet flushing from raw water when the amount of drainage is enough.

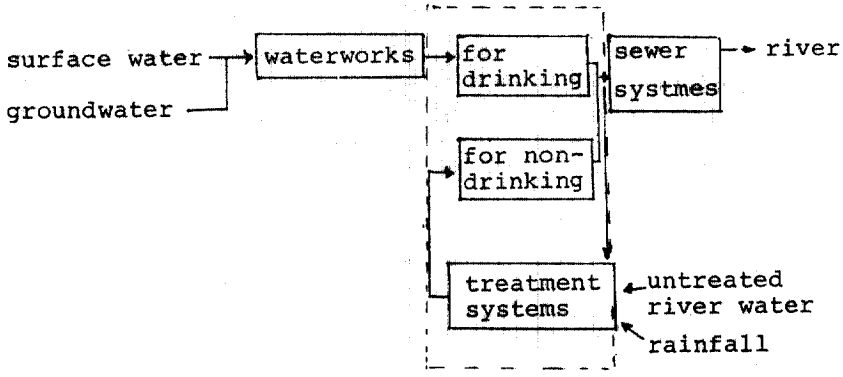
2.4.2. Regional recycling system[11]

The Regional recycling system supplies recycling water where the buildings are congregated. The raw water for reuse is stormwater and untreated river water as well as the treated wastewater in that area. It is most useful in the residence complex and building complex area.

2.4.3. Large-scale recycling system

The large-scale recycling system supplies the recycling water to the residences and buildings in the pertinent area in large scale and amount. The raw water for reuse is obtained from the





treated wastewater, untreated river water, storm-water, and the discharges of industries.

2.4.4. Modification of regional recycling system

It is economically advantageous if less polluted water can be taken in short distance and large amount.

These systems have both merits and demerits respectively. The large-scale recycling system has advantages, operation, maintenance, scale merit, and sludge disposal. And the individual and regional recycling system is advantageous to spread. Therefore, which system should be selected is dependent on the regional conditions where reuse systems are to be installed. It is practical that each building has, generally, the individual recycling system at first, and then, several buildings should be combined for regional recycling system, and finally construct a large-scale recycling system. It is possible to introduce the large-scale recycling system at first where the redevelopment districts in ubarn and residence complex.

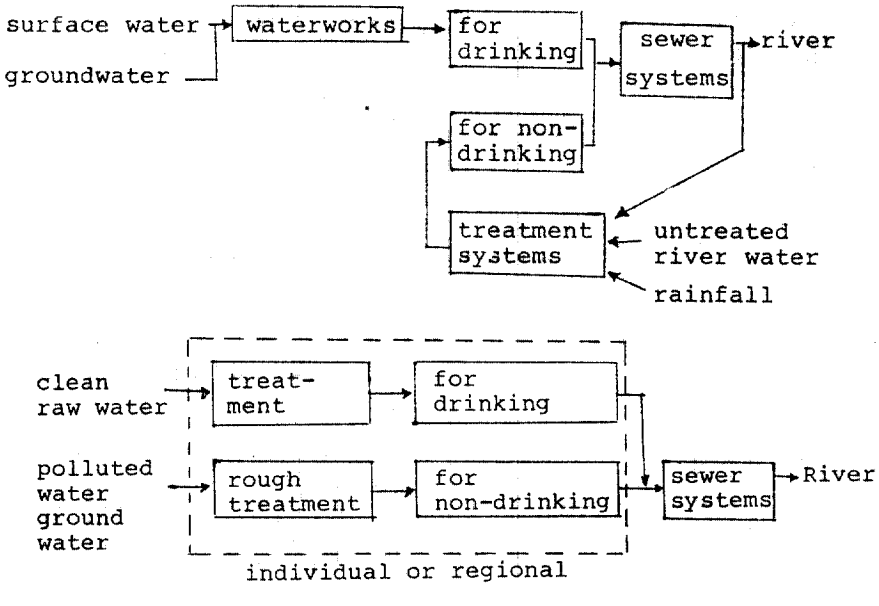


Table 4. Water quality criteria for reuse

	Items	Toilet flushing	Sprinkling	Park sprinkling*
Criteria quality	E. coli (ea/m*l*)	below 10	not detectable	not detectable
	Residual chlorine (mg/*l*)	** detectable	above 0.4	—
Target quality	Color	not unpleasant	not unpleasant	not unpleasant
	Turbidity	—	—	below 10
	BOD (mg/*l*)	—	—	below 10
	Odor	not unpleasant	not unpleasant	not unpleasant
	pH	5.8~8.6	5.8~8.6	5.8~8.6

* Park sprinkling water includes the artificial ponds and flows in residence complexes and urban areas.
** After chlorination for sanitary, residual chlorine should be detected near the point of use.

2.5 Water quality for reuse[9]

The quality of treated wastewater is no less than that of secondary treatment effluent, and it should be satisfied following criteria. (Table 4).

2.6 Treatment methods[5~8]

The treatment of wastewater for reuse includes primary, secondary, tertiary treatment. The primary treatment is physicochemical, secondary is biological, and tertiary is advanced treatment. The treatment methods for water reuse depend on the quality of raw water and the reuse water criteria. The object materials of treatment are as follows;

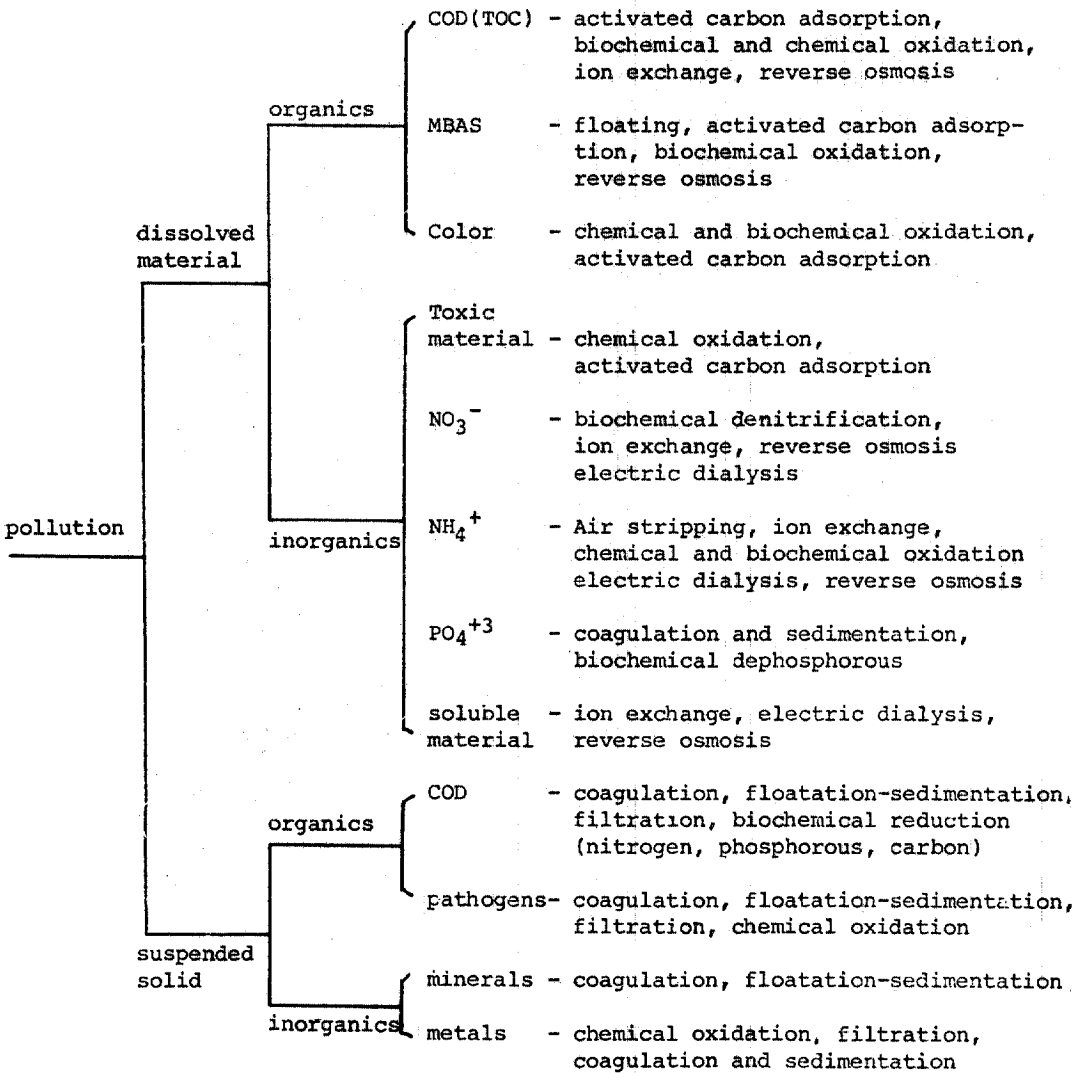
- turbidity
- color
- odor
- organics(BOD, COD, TOC, MBAS, oil, etc.)
- nitrogen
- phosphorous } if needed
- dissolved salts
- bacteria
- virus

Physicochemical processes include screening, coagulation and sedimentation, filtration, activated carbon adsorption, ozone treatment, chlorination, membrane filter, etc. Biological processes include extended aeration method, biological rotating discs, and contact aeration method.

Table 6. The combinations of physicochemical and biological treatment

Recycling system	Usage	Raw water	Treatment processes
Individual	toilet flushing	drainage, polluted water	biological treatment→(coagulation and sedimentation)→filtration→chlorination
	toilet flushing cooling tower supplement, park sprinkling	drainage, polluted water	biological treatment→(coagulation and sedimentation)→filtration→activated carbon adsorption→chlorination, (biological treatment)→membrane filter→chlorination
Regional	toilet flushing	treated wastewater	(coagulation and sedimentation)→filtration→chlorination
	toilet flushing, cooling tower supplement park sprinkling, road cleaning	treated wastewater	(coagulation and sedimentation)→filtration→activated carbon adsorption→chlorination membrane filter→chlorination

Table 5. Classification of treatment methods



Above methods must be combined properly according to properties of raw water and required quality of treated wastewater.

In general, biological methods are adopted when raw water is the miscellaneous drainage or sewage. Physicochemical methods such as coagulation, sedimentation, sand filtration are adopted when raw water is treated sewage or biochemical treatment effluent. It is desirable that the raw water should have better quality. As it costs high to remove inorganic salts in reuse water, sewer systems should be prevented from the intrusion of marine water or industrial wastewater.

3. Development of Water Reuse System

3.1 The effects of recycling wastewater

There are many advantages in recycling wastewater. First, it could mitigate the local imminent water demands. If it is used for toilet flushing, the same amount of fresh water can

be used for other purposes. So it is one of the important countermeasures for water shortage. Generally imminent areas for water demands are urbans and surburbs that have many populations, residences and buildings. The installation of dual distribution system for existing buildings costs too high distribution therefore, it is advantageous to introduce the dual system in residence complex and large buildings in redevelopment areas. Second, it could decrease sewage amount in sewer systems. When a large building is constructed in certain area, it may overload the sewer systems and wastewater treatment plants. In that area, the introduction of recycling wastewater give the solution of over loading problem. Third, it plays good roles in dry seasons. As the usage for toilet flushing cut off water supply and restriction on water supply, it could mitigate water demands regardless of above restrictions. Fourth, it has the effects on increasing the econominization and rationalization of water use. Fifth, it could make public investigation optimal. In other words it is possible to decrease the amount of transmission from long distance, therefore, it saves the money for energy and installation. Sixth, the enterprise may receive a good impression by cooperating with the policies of securing of water resources and contributing to prevention of water pollution.

3.2 The problems and countermeasures for developing water reuse system.[9,13]

3.2.1. The problems in technological, sanitary operation.

(1) The technological problems.

1) The establishment of target quality and technology of wastewater treatment for the usage of recycling water.

2) The effects of recycling water on the distribution systems and instruments.

(a) corrosion

(b) scale

(c) slime

(d) others

3) The treatment and disposal of sludge

4) The prevention of cross-connection

(2) The sanitary problems

1) The prevention of misuse

2) The possible danger to human body by long time contact with low-concentrated specific materials.

3) The elimination of pathogenes such as bacteria, virus.

4) Water drops scattering from the cooling tower.

(3) The operational problems

1) The disposition of qualified technicians.

2) The periodic inspection of the recycling systems.

3) The establishment of administrative quidances.

3.2.2. Legal problems and countermeasures.

(1) Waterworks law

Article 18 of waterworks law has provision of the duty of water supply for waterworks undertaking. In case of the charge of recycling is high in comparison to that of fresh water, a mendatory injunction should be made to promote the use of reuse water. Therefore it should be amended this article.

(2) Sewageworks law

As the recycling of wastewater is closly related with public sewageworks, it should be regulated with sewageworks law. As the sludge from treatment plant would be discharged to sewer systems, the effluent must be satisfied the limit which is stipulated in article 16 of sewageworks law, which should be mitigated for recycling of wastewater.

(3) Construction law

The dual piping systems must be installed in buildings for recycling wastewater. Therefore the provisions for dual piping should be intro-

duced to the construction law. The inspection stages such as planning or permission would be utilized to install the dual piping system.

3.2.3. The financial problems and countermeasures

(1) Cost evaluation

The one of the greatest problems for reuse system is the economical feasibility. The cost is dependent on the reuse pattern, scale, usage and required quality. In the case of individual recycling system of office buildings, the treatment cost is high because the demand of reuse is small. Though the cost difference between fresh and reuse water is decreasing in the future, the systematic provisions is necessary now. The regional recycling system in building complex has merits because the demand of reuse water is great and the demand to unit area is high. Because the regional recycling system in residence complex has small volume to substitute the reuse of treated wastewater for the water supply and total demand per unit area is low, treatment cost is high. Also the cost of piping is high due to pipe length. As the water rate for domestic is cheap in comparison with that for commercial, the reuse may have not propriety. In the region where public sewer system is supplied, the treatment cost could be decreased if the effluent of more than secondary treatment is used for the raw water of reuse. In large-area recycling system, the treatment cost and facility cost are decided according to the distribution system for the use of treated wastewater in the region.

(2) Financial aids

The recycling of wastewater impose high cost on the consumers because of advanced wastewater treatment and dual piping systems. Also the charge of recycling water may be expensive in contrast to that of fresh water. This is opposed to economic principles, so it may be obstacle to spread the recycling systems. It must offer, therefore, administrative, financial and legal provisions such as water supply, sewage works and industrial water supply.

(3) Urban planning law

The recycling systems should be introduced in addition, and "The promotion region of recycling of wastewater" should be provided.

3.2.4. The problems and countermeasures of each system.

(1) The individual recycling system

The first problem of recycling of wastewater is economical problems. The charge of recycling water is expensive in contrast to that of fresh water due to facilities and maintenance of recycling systems. The cost difference between recycling and fresh water may be lessened in the future because of the increase of charge for water and sewage. The second problem is the disposal of sludge. As the sludge from the individual system in small, it would need relatively high cost in case of sludge treatment and disposal separately. The sludge might be discharged to the public sewer systems and treated in the municipal sewage treatment plant, but it would overload the plant and clog the sewer systems with the sediments. The third problem is technological operation. The qualified thechnicians might be disposed or circulated periodically in several individual recycling systems. The fourth problem is that the system should require some area in buildings. It could be solved that the required area for recycling system in buildings should be excluded from the limiting volume ratio of construction law.

(2) The regional recycling system

The new large buildings in reconstruction area of central business district would have a lot of water demand and discharge. In this area, therefore, the distribution networks should be extended, and also the sewer systems and treatment plants should be enlarged. The recycling system in this area would decrease

these overloadings. Introducing the dual distribution system to the existing buildings in a certain area would require a lot of cost. If the supply of reuse water is limited to the buildings in that the dual distribution system is installed, already, the efficiency of supply is reduced and the consumers are under heavy burden. The problems of regional recycling system are the determination of the main body of undertaking and the sludge disposal like individual recycling system. The application of regional recycling system to residence area confined to new residence complex and the usage of recycling water is only toilet flushing which is about 20 % of domestic usage.

(3) Large-scale recycling system

As the large-scale recycling system would need the dual piping of all buildings in a certain area, the efficiency of reuse water supply would be reduced. The piping underground is so complex and many works would participate in the installation that it might have possibility of cross connection. This is, therefore, not adaptable immediately.

3.3 The development of water reuse system

3.3.1. The method of spread

In order to promote the spread of the water reuse system the owner and user of building should be imposed the duties of installation and usage. This could be done by regulating the pertinent stipulations of waterworks law, sewage works law, construction law and urban planning law. As it would include many important problems, it should be not good to determine immediatly. The policy to promote the spread of water reuse system is as follows:

(1) The successive diminution system of charge should be introduced to the consumers of large-amount of recycling water.

(2) A low interest loan for installation of dual distribution systems.

(3) The successive increment system of charges should be introduced to the consumers and dischargers of large-amount of water supply and sewage discharge.

(4) The obligation of usage of recycling water in certain area.

3.3.2. The main body of undertaking

The main body of undertaking of water reuse system should decide the introduction of water reuse system in consideration of the regional long-term water supply and demand, water resources, the condition of sewer systems and treatment plants collectively, and the regulation of many relative laws.

The main body of undertaking, therefore, should be the governor of a province.

3.3.3. Administrative roles for spread

In consideration that this project has the duty of steady supply, safety, monopoly, public services. The governor of a province should play important roles as follows:

(1) Establish "the facilitating district" of wastewater recycling.

(2) Determine the object buildings, pattern, scale, etc. in the facilitating district.

(3) Regulate the relative administratives(water supply, sewage works, urban planning, construction, etc.).

(4) Persuade the owner of building to introduce the recycling system.

(5) Inspect the installation of recycling and maintenance.

(6) Financial aids.

4. Conclusion

(1) The water reuse system should be introduced immediately to the cities of the shortage and large requirement of water resources.

(2) The individual recycling system for large buildings and the regional recycling system for

urban redevelopment area and apartments complex would be adaptable in this country.

(3) The systematic provisions should be established to introduce the water reuse system. Financial aids, tax reductions, administrative enlighments are required.

(4) The study and development for waste water treatment should be done continuously because the water reuse system should require advanced treatment in comparison with conventional method.

(5) A specific building or region would be selected as a sample and investigated practically in order to enlight and spread the water reuse system.

(6) The study on the water reuse system should be done continuously and the direction of study is as follows:

- The study on sanitary problems.
- The study on scale, slime, corrosion and sediments in distribution systems and water tanks.
- The study on the standards of design and maintenance of the water reuse system.

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參 考 文 獻

1. 雜用水道實施上の諸問題に關する調査報告書，日本水道協會 (1983. 3).
2. 雜用水道實施上の諸問題に關する調査報告書，日本水道協會 (1981. 3).
3. 下水處理水の循環利用に關する調査報告概要書，東京都下水道局計劃部計劃第1課 (1979. 3).
4. 下水處理水循環利用技術指針(案)，日本下水道協會 (1981. 9).
5. 水道施設設計指針・解說，日本水道協會 (1977).
6. 下水道施設設計指針と解說，日本下水道協會(1972).
7. 水道維持管理指針，日本水道協會 (1970).
8. 下水道維持管理指針，日本下水道協會 (1979).
9. 雜用水利用の制度化に關する基礎調査報告書，水利用合理化推進協議會 (1981. 6).
10. 下水處理水の循環利用に關する調査，福岡市下水道局建設部 (1980. 3).
11. 住宅團地における中水道方式の開發研究 (芝山團地追跡調査)，日本住宅公團
12. 雜用水道適應性調査研究報告書，日本水道協會 (1979. 3).
13. 雜用水道の衛生管理に關する調査研究報告書，厚生省環境衛生局水道環境部 (1980. 3).
14. 雜用水道技術指針に關する調査研究，日本水道協會 (1977. 3).
15. *Water Reuse Highlights*, The American Water works Association Research Foundation (1978).
16. 中水道開發方案研究，建設部 (1984).

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