Current status of water reuse systems in Korea

S. Noh*, I. Kwon, H.-M. Yang*, H.-L. Choi*** and H. Kim****

* Yonsei University, Dept. of Environmental Engineering, Wonju, Korea

** The University of Seoul, Dept. of Environmental Engineering, 90 Jeonnong-dong Dongdeamun-gu, Seoul 130-743, Korea (E-mail: *h_kim@uos.ac.kr*)

*** Seoul National University Dept. of Apicultural Biotechnology, Seoul, Korea

Abstract In Korea, the current water resources will fall short by 2.6 billion tons to meet the 38 billion ton water demand in the year 2020. To overcome the future water shortage, it is desirable to minimize water consumption and to reuse treated wastewater. There are a total of 99 on-site water-recycling systems in the country. The potential capacity of the 99 systems is 429 thousands tons/day, which is 3.6% of the total service water. Compared to other industrialized countries, the number of the water recycling systems in Korea is extremely small. This is mainly due to the following reasons. First, in Korea, any building with more than 60,000 m^2 of total floor space is required to install a water reuse system by law. However, only less than 0.5% of the total buildings have more than 10,000 m^2. Therefore, the regulation is ineffective and merely nominal. Second, service water is supplied at low charge (0.20 US-dollar/m^3 water). The inexpensive service water often discourages people to recycle treated wastewater. Third, people still think recycled water is not clean enough and can cause diseases. Therefore, they should be informed that a well-maintained recycling system does not fail to produce water with high quality.

Keywords Public education; water rate; water reuse system; regulation

Water Science and Technology **Vol 50 No 2 pp 309–314**

Introduction

Due to the rapid urbanization and the growth in population and living standard, water demand in Korea has dramatically grown recently. It is anticipated that with currently available water resources there will be a 1.8 billion tons shortage of water in 2010, and 2.6 billion tons in 2020 (KMOE, 2002). To overcome the future water shortage, the Korean Ministry of Construction and Transportation (KMOCT) suggests building more dams. However, There are currently total 14 multi-purpose dams and 4 reservoir dams in Korea. These dams store about 1.5 billion tons of water (KMOCT, 2001). Currently KMOCT considers building 12 more dams capable of storing 1.2 billion ton water. Considering small land area available for beneficial use, however, it is not a good idea to build additional dams. It requires considerable amount of capital investment and is not environment friendly.

In the face of future water shortage, the Korean Ministry of Environment (KMOE) takes different approaches with KMOCT. It insists that the water shortage can be overcome by replacing old pipes, raising water rate, reducing farming water, and installing water reuse system. If the old pipes, which are responsible for water leaks (15% of supplied water is lost in the form of leak), are replaced, water rate is adjusted, and water used for farming is reduced, the potential water shortage can decrease to 0.2 billion ton in 2011 (KMOCT, 2001).

KMOE believes that additional water saving is possible by reusing rainwater and wastewater. Water reuse system was firstly stated in the Supply Water Rule in 1991. At the time, the installation of water reuse system was voluntary. However, from the March of year 2001, the law requires any building with 60,000 m^2 of surface area to install a water reuse system.

In many advanced countries, wastewater has been being reused for various purposes, e.g., irrigation water, groundwater recharge, recreation, non-potable urban application and so on (Angelakis *et al.*, 1999; Angelakis and Bontoux, 2001). Among the countries, Japan, which is located close to Korea and has the similar problem, has greatly developed water reuse systems. The treated water is mainly used for non-potable urban application such as toilet flushing, environmental uses, in-stream flow augmentation, and industrial process water (Yamagata, 2002). In the case of Israel, which was the pioneer of water reuse, more than 65% of total wastewater produced from the country is reused. They are planning to reuse more than 90% of the produced wastewater in the country by year 2015 (Friedler, 2001). In the southern European countries, secondary treated wastewater is reused mainly for agriculture and recreation. In urban environment, reclaimed water is used for landscape irrigation, toilet flushing, and/or industrial and commercial process water (Hermanowicz, 2001).

Currently, there are 99 facilities treating and reusing wastewater in Korea. The total capacity of the reusing systems in the 99 facilities is 429 thousand tons per day; less than 3% of the total service water produced. Most of them reuse the treated water as toilet flushing, landscape irrigation and/or process water. Considering the current water demand, ratio of the water being reused is quite limited, and water reuse systems should be wide spread. Moreover, only less than 20% of the systems are currently operated. To encourage many facilities to install their own water reuse system, the policy on water reuse also should be extensively reviewed and renovated. So far, few studies have been performed regarding water reuse systems in Korea.

Per request of the Korean Congress, research on the current status of water reuse systems in Korea has been initiated. The objectives of this study are to survey water reuse systems installed in Korea, to evaluate the performance of the systems in terms of quality and quantity of the treated water, to identify any obstacle in wide-spreading reuse systems, and to make recommendations to solve the problems identified.

Water reuse systems in Korea

The reclaimed water (recycled water) system means a facility treating wastewater for individual reuse or reuse in nearby communities. Generally, water reuse systems are classified into three according to the scales and the reusing types; *individual facility water recycling systems, small area water recycling systems, and wide area water recycling systems.*

Individual facility water recycling system reuses the wastewater from a facility for toilet flushing, cooling water, and washing water in the facility. All the water reuse systems currently installed and operated in Korea are included in this category. Figure 1 shows the number of water reuse systems installed over the past 20 years. Since the first water

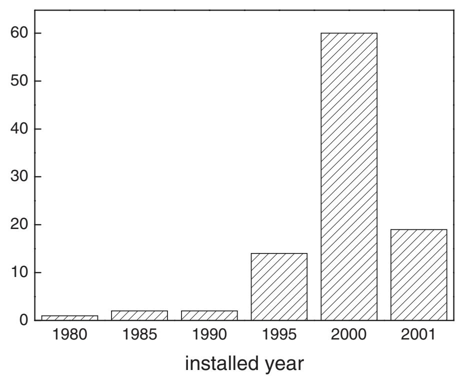

Figure 1 Number of water reuse systems installed over 20 years

recycling system was built to produce cooling water in POSTECH Steel Company in Pohang, which is located in southern part of the Korean Peninsula, a total of 99 on-site water reuse systems exist around the country. Most of the systems have been installed recently due to the requirement of water reuse system installation for building with over 60,000 m^2 of surface area; 60 systems were installed in 2000 and 15 in 2001. They are mainly installed in industrial plants, hotels, department stores, airports, and public offices (ELC, 2002). More than 50% of the installed systems have a treatment capacity of less than 500 tons/day (Figure 2).

Actually, the number of water reuse systems operated in Korea has decreased from 110 in 2000 to 99 in 2001. The capacity also has decreased from 6.5 million tons/day in 2000 to 4.5 million tons/day in 2001 (Figure 3). The reason of the decrease in water reuse systems can be explained with treatment process employed, budget imbalance, unreasonable policy on the water reuse system, and absence of public education. To operate an individual water recycling system reliably and without interruption, it is important to constantly secure feeding to the system. Especially, if a treatment system is employing a biological process, the feed with enough BOD should be supplied to the system.

Figure 4 shows major process configurations of wastewater treatment systems used in Korea for water reusing purpose. Most of them use traditional or modified activated sludge processes followed by activated carbon/coagulation and disinfection (Figure 4 (a) and (b)). Only few of them are employing membrane processes (Figure 4(c)). The source wastewater to the systems is service water, cooling water, bathing water, process water, and washing water. Generally, biological treatment followed by activated carbon filtration (Figure 4(b))

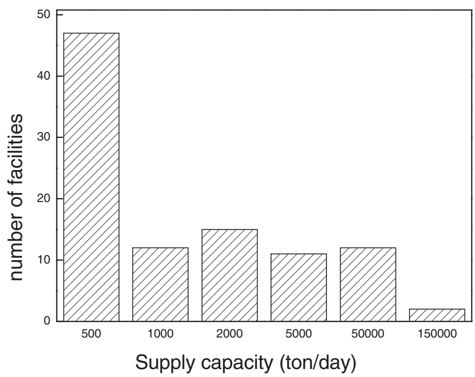

Figure 2 Number of water reuse systems in Korea according to treatment capacity

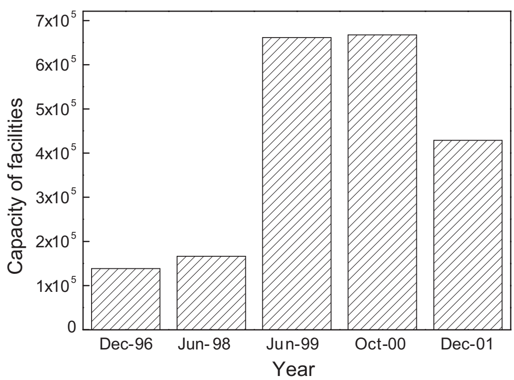

Figure 3 Change of total treatment capacity of water reuse systems in Korea over 5 years

is used to treat highly polluted wastewater, e.g., toilet flushing water. An ultrafiltration process without biological treatment (Figure 4(c)) is usually used for wastewater with less strength, e.g., cooling water.

In Korea, although the source water does not contain enough organics to support biological activities in an activated sludge system, still the biological process is the most popularly employed in water reuse systems. In other words, a water reuse system is chosen without careful analysis of source wastewater. Wastewater should be treated with a proper process based on the properties of wastewater source.

Since bathing water from domestics and hotels, which is only 11% of the total service water currently supplied, is relatively stably produced over a day and clean, a simple physical-chemical treatment can be applied. The contaminated cooling water generally has high level of dissolved salts and low organics. This water can be recycled after simple chlorination or filtration. Since in gray water (e.g., wastewater from sinks in large restaurants and hotels) there are high levels of organics, nitrogen, and phosphorus, the gray water should be treated with advanced treatment processes for reusing. In the case of toilet flushing water, which accounts for 30–50% and 50–80% of wastewater generated from a large scaled building and a small scaled, respectively (Yoon, 2002).

How to encourage widespread of water reuse system

Regulations regarding water reuse system installation

The first reason why the water recycle system is not common in Korea is unrealistic regulation for requirement of water recycle system installation. According to current regulation, any building with more than 60,000 m^2 of total floor space is required to install a water reuse system in the building (KMOCT, 2001). In Tokyo Japan, they require any building with total floor space of 30,000 m^2 or non-potable water use of 100 m^3/day to install its own on-site water reuse system (Yamagata, 2002). In the case of Fukuoka Japan, a new building with the floor space of more than 5,000 m^2 is required to submit its water saving plan including water reuse system installation to its city government.

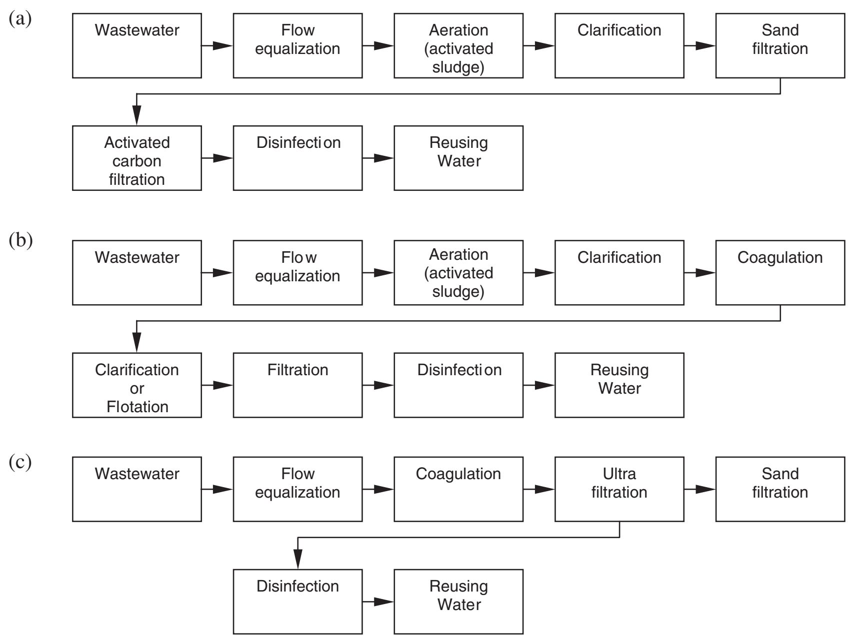

Figure 4 Major process configurations employed in water reuse systems in Korea

However, less than 0.5% of buildings in Korea have more than 10,000 m^2 of total floor space. Therefore, the regulation on the water reuse system installation is ineffective and merely nominal. The regulation should be tightened; the minimum total floor space of a building should decrease to less than 10,000 m^2. Also, the daily usage of non-potable water in a building should be accounted for.

When a building with 60,000 m^2 of floor space does not install a water reuse system, it is fined only 8,000 dollars or less. Since the fine is not intolerable to an owner of a large building, often he chooses to pay the fine rather than installs a water reuse system. Therefore, more strong enforcement should be applied.

In Korea, water reuse systems are designed by small to middle sized engineering companies, which usually do not have experience and technology, and do not work properly resulting in complaints from clients. Therefore, the government should allow only reliable companies to design and install a water reuse system.

Inexpensive water rate

In Korea, service water is currently charged only at 0.22 US-dollars/m^3 water, which is only 13% of what is charged in Germany (Table 1). With the inexpensive water rate, Koreans can afford to consume three times more water than Germans (395 liter/capita-day). Even for industry, service water is often cheaper than recycled water production. In an apartment complex near Seoul in which a water recycle system was installed, 1.11 dollars was spent to produce one m^3 of recycled water. Therefore, there was no motif to install or operate a water reuse system; the apartment complex no longer operates its system. In reality, less than half of the installed recycle systems are currently being operated. For example, in 2001 the POSTECH steel company, which installed the first water recycling system in Korea, decreased the treatment capacity of its system down to 10% of that in 2000 to save its operation cost (KMOCT, 2001).

According to KMOE, water rate charged to the public is only 75% of the water production cost in 2000 (KMOE, 2000). As of year 2000, Korean Department of Water and Sewer has total 3.4 billion dollar debt due to the continued imbalance between water rate and water production rate. Therefore, if the water rate is raised to the level of other country like Japan or Germany, the debt can be paid off and the water reuse system installation will be encouraged.

Table 1 Comparison of water rate between different countries (ELC, 2002)

Nation	Korea	Italy	USA	Australia	Japan	England	France	Germany
Water rate	0.22	0.53	0.58	0.76	1.20	1.43	1.59	1.69

Unit: US dollars/m^3

Table 2 Recycling water quality criteria for urban use

	Korea	Japan	USA
Coliforms (number/mL)	ND*	10	ND
Chlorine residual (mg/L)	0.2	Trace amount	1
Color	Not unpleasant	–	–
Turbidity (NTU)	2	–	2
BOD (mg/L)	10	20	10
Odor	Not unpleasant	Not unpleasant	Not unpleasant
pH	5.8–8.5	5.8–8.6	6–9
COD_{Mn} (mg/L)	20	30	–

*ND: Should not be detected

Public education

People in Korea think recycled water is not cleaned enough and may cause disease. This is due to the lack of proper public education. The quality of the effluent from any water reuse system is regulated to protect the public health. The regulation on the effluent quality of a water reuse system in Korea is provided in Table 2 along with those of Japan and USA. As shown in the table, the Korean regulation is comparable with or stricter than one in Japan or USA. These criteria can be easily met with a water reuse system. Therefore, the public should be informed that a well maintained recycling system does not fail to produce water with the quality specified in the table.

Conclusions

The present status of water reuse systems in Korea was investigated. Since the first water recycling system was built to provide cooling water for a steel plant in 1980, a total of 99 on-site water recycling systems have been built in industrial plants, hotels, department stores, airports, and public offices around the country. The recycled water is mainly used for toilet flushing and floor washing or cooling-water. Most of the water reuse systems are using traditional or modified activated sludge processes. The total potential capacity of the 99 systems is 429×10^3 tons/day, which is minimal and is equivalent to only 3.6% of the total service water supplied in the nation. In the near future, the country is expected to suffer from water shortage. To overcome this, it is highly desirable to reuse treated wastewater. However, as presented above, the unrealistic regulation requirements on the installation of water recycle system, relatively inexpensive service water, and failure in the public education were found to pose an obstacle in recycling wastewater.

Government should actively encourage more wastewater to be recycled by setting stricter requirement for water reuse system installation. Any building with 10,000 m^2 of floor space rather than the current 60,000 m^2 might be required to install a system. Installation requirement based on daily water usage can also be applied. By imposing higher water rate and providing more comprehensive education about recycled water, the government should drive people to reduce water consumption and to use recycled water.

Acknowledgement

Financial support from The National Assembly of The Republic of Korea, Environment and Labor Committee is greatly appreciated.

References

Angelakis, A.N. and Bontoux, L. (2001). Wastewater reclamation and reuse in European countries. *Water Policy*, **3**, 47–59.

Angelakis, A.N., Maeco Do Monte, M.H.F., Bontoux, L. and Asano, T. (1999). The status of wastewater reuse practice in the Mediterranean basin: need for guidelines. *Water Res.*, **33**, 2201–2217.

ELC (2002). *Development of Policies for Water Reuse and Conservation*. Environment and Labor Committee The National Assembly of The Republic of Korea, Korea.

Friedler, E. (2001). Water reuse – an integral part of water resources management: Israel as case study. *Water Policy*, **3**, 20–30.

Hermanowicz, S.W., Sanchez Diaz, E. and Coe, J. (2001). Prospect, problems and pitfalls of urban water reuse. *Wat. Sci.Tech.*, **43**(10), 9–16.

Higgins, J., Warnken, J., Sherman, P.P. and Teasdale, P.R. (2002). Survey of user and providers of recycled water: quality concerns and directions for applied research. *Water Res.*, **36**, 5045–5056.

KMOE (2000). *Environmental Fact Sheets*. Korean Ministry of Environment, Korea.

KMOCT (2001). *Long Term Comprehensive Plan for Water Resources*. Korean Ministry of Construction and Transportation, Korea.

Ogoshi, M., Suzuki, Y. and Asano, T. (2001). Water reuse in Japan. *Wat. Sci. Tech.*, **43**(10), 17–23.

Oron, G., Campos, C. and Gillerman, L. (1999). Wastewater treatment, renovation and reuse for agricultural irrigation in small communities. *Agri. Water Management*, **38**, 223–234.

Yamagata, H., Ogoshi, M., Suzuki, Y., Ozaki, M. and Asano, T. (2002). On-site insight into reuse in Japan. *Water 21*, **8**, 26–28.

Yoon, J.Y. (2002). The characteristics of recycling water and water saving in Korea. *http://www.ecoi.or.kr/book/35/bk35-10.asp*.