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WASTEWATER RECLAMATION AND REUSE PRACTICES FOR AGRICULTURE IN KOREA

E. J. LEE[1], S. W. PARK[1,2], C. H. SEONG[2], H. K. KIM[1], K. W. JUNG[2]

[1] E. J. Lee, Research Institute for Agriculture and Life Sciences, Seoul National University, Seoul, Republic of Korea, fpdlsao2@snu.ac.kr
[1,2] S.W. Park, Department of Rural Systems Engineering, Seoul National University, Seoul, Republic of Korea, swpark@snu.ac.kr
[2] C.H. Seong, tweety45@snu.ac.kr

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ABSTRACT This paper describes the field experiment with reclaimed wastewater, and reuse practices in Republic of Korea (ROK). The objectives of this study were: 1) to assess the agro-environmental effects of wastewater reuse for agriculture; 2) to develop safe and economically feasible wastewater reclamation systems for districts where the agricultural reuse technologies are applied. Wastewater reuse systems can be greatly beneficial for irrigating crops and improving river water quality by the natural purification effects of rice paddies. The effects of various wastewater treatment levels on water quality, soil, crop growth, yields, and environment were investigated in the study field. The agricultural reuse technologies were applied to in several regions in ROK, such as Suwon, Jeju, Gangjin and so on.

Keywords: Wastewater reuse, agricultural water, wastewater treatment, reuse system

INTRODUCTION A water shortage problem is an important issue in many countries and world's population will be experiencing scarcity of water resources in the future because of increasing demand for fresh water (Marecos do Monte et al., 1996). The increased demand of water is caused by population growth, urbanization, and economic development. In addition, climate change is accelerating water shortage. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress (Bates et al., 2008). Republic of Korea (ROK) like many other countries faces a water crisis. Moreover great temporal and spatial variations of precipitation and stream flow cause frequent water shortages and floods in ROK. These hydrologic characteristics have placed serious constraints on reliable water supplies for agriculture.

In 2003, a total volume of 16 billion m^3 water was annually used for agriculture in ROK, which approximately comprised 47% of the total annual water use (MOCT, 2006). The agricultural water uses combine irrigation water for rice paddies and fields and livestock water. From among these water uses, irrigation for rice paddies has the most water, the rice paddy agricultural methods require a large quantity of water at certain times of growing season. Imbalance between water supply and demand as mentioned above is occasionally caused by temporal and spatial variations of precipitation.

The reclaimed wastewater has been recently recommended as alternative water resources and used as a source of irrigation water for centuries in many countries. The wastewater is valuable enough for irrigation water, since agricultural water does not require high-grade water quality compared to drinking water (Asano and Levine, 1996). In addition, annual reclaimed wastewater from domestic sewer treatment plants has been uniformly discharged to the rivers and lakes. According to MOE(2009), total wastewater treatment capacity in ROK is 6.6 billion m^3 per year, 0.7 billion m^3 water has been presently used as washing and cooling water. The wastewater reuse for agriculture is not only a low cost water resource but also nutritious irrigation water. Using fertilizing properties of the water eliminates an amount of synthetic fertilizers and improves water quality of rivers and lakes. The wastewater reuse projects have been governmentally supported by MOE (MOE, 2009), the practical projects have been implemented in several regions in ROK. Using untreated or inadequately treated effluents from municipal sewer treatment plants, on the other hand, could be adversely affect the soil and water environments, consequently, human health. The soil, plant, groundwater and other aspects of the local environment should be monitored to protect from contamination by reclaimed wastewater irrigation in particular if compounds accumulate in certain phases (Huertas et al., 2008). The drawback of wastewater reuse is its high initial and operational costs.

However, there are more benefits than adverse effects caused by reusing wastewater. The objectives of this study were: 1) to assess the agro-environmental effects of wastewater reuse for agriculture; 2) to develop safe and economically feasible wastewater reclamation systems for districts where the agricultural reuse technologies are applied.

MATERIALS AND METHODS In ROK, many wastewater reuse projects are now being implemented or planned for agricultural water uses shown in Figure 1. There are two methods to reuse wastewater, open (indirect) and closed (direct) wastewater reuse. The indirect wastewater reuse means that farmers take the treated effluents from wastewater treatment plant as irrigation water in downstream areas, which has been diluted with river water. In this case, the adequate indirect reuse system is required according to water quality level at reach of water intake from the rivers. The direct wastewater reuse means that irrigation water is directly supplied to arable land though irrigation system from wastewater treatment plant after reclamation of treated wastewater. These reclamation processes could be changed by purpose of wastewater reuse and characteristics of drainage area and sewer treatment plant.

The technical center is located within the Rural Research Institute in Suwon, ROK. The center provides technical supports to local government intend to reuse wastewater for irrigation. At the five districts, a volume of 68 thousand m^3 wastewater is now being used as irrigation water by indirect or direct methods. There are plan for reusing wastewater in the other districts.

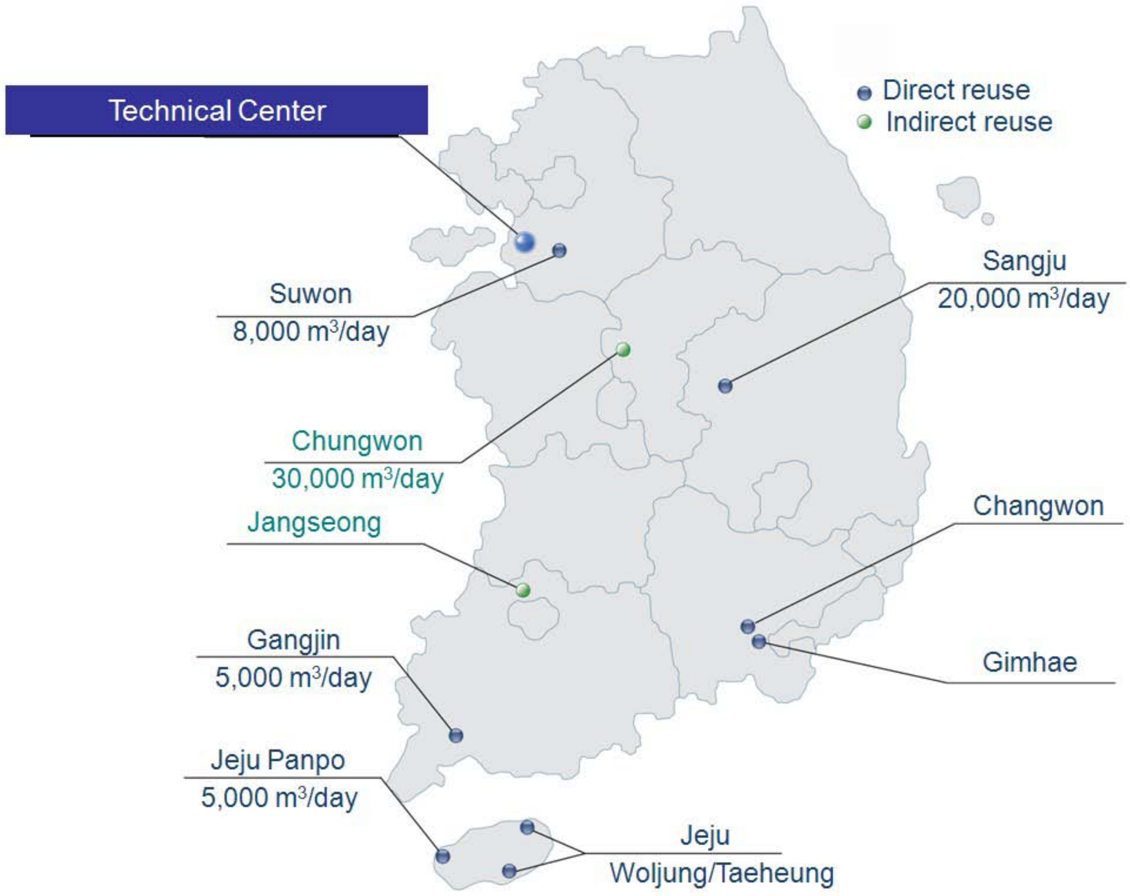

Figure 1. Technical supports for agricultural reuse projects

RESULTS AND DISCUSSIONS

Prerequisites for agricultural reuse In this study, prerequisites for agricultural reuse were suggested shown in Figure 2. Not all of wastewater effluent could be used for wastewater reuse. There are some prerequisites. First of all, effluents must be discharged from domestic sewer treatment plants, never from industrial and livestock treatment plants. Secondly, effluents though advanced wastewater treatment absolutely satisfy the irrigation water quality standard. Water quality standard for irrigation is presented in Table 1 (MOE, 2009). Finally, this treated wastewater is supplied for irrigation water after that passes through a reclamation system for guarantee of crop safety and human health hazard criteria.

Table 1. Water quality requirement for constituents in Republic of Korea

Item (mg/l)	Water quality standard of effluent from sewer treatment plant	Water quality standard for irrigation[1]	Recommended limits for wastewater reuse in agriculture	
			Directly edible crops	Indirectly edible crops
Total coliform (MPN/100ml)	≤3,000	-	ND[2]	≤200
Turbidity (NTU)	-	-	≤2	≤5
pH	-	6.0-8.5	5.8-8.5	
SS	≤10	≤15	-	
BOD	≤10	-	≤8	
COD	≤40	≤8	-	
DO	-	≥2	-	
T-N	≤20	≤1	-	
T-P	≤2	≤0.1	-	
A1	-	-	≤5	
As	-	≤0.05	≤0.05	
B-total	-	-	≤0.75	
Cd	-	≤0.01	≤0.01	
Cr^{6+}	-	≤0.05	≤0.05	
Co	-	-	≤0.05	
Cu	-	-	≤0.2	
Pb	-	0.005	≤0.1	
Li	-	-	≤2.5	
Mn	-	-	≤0.2	
Hg	-	ND	≤0.001	
Ni	-	-	≤0.2	
Se	-	0.1	≤0.02	
Zn	-	-	≤2	
CN		ND	ND	
PCB		ND	ND	

[1] In case of irrigating water from lakes or reservoirs
[2] ND: Not detected

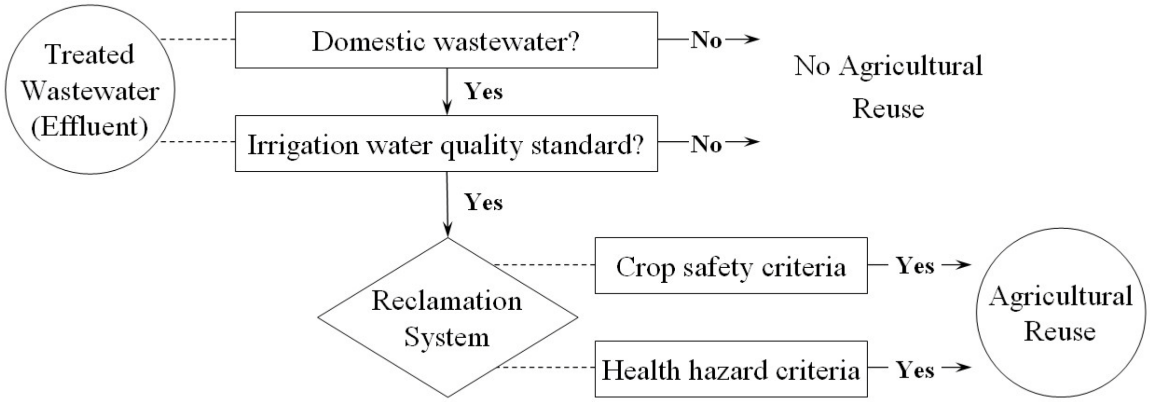

Figure 2. Prerequisites for agricultural reuse (4 Yes Plus)

Suwon reuse project In Suwon district, reclaimed wastewater has been used as rice paddies irrigation from 2006, and made from effluents of Suwon municipal sewer treatment plant. The Suwon reuse project has been implemented as a demonstration project for assessing wastewater reuse effects on broad field-scale (45ha). Reclaimed system for the Suwon district consists of screening process for removing suspended solids and ultra-violet (UV) disinfection process. The UV disinfection process is to remove various microorganisms, include *E.coli.*, coliform, and other harmful bacteria, causing some kinds of waterborne epidemic, because farming rice is done under ponding condition, so the farmers may have to intake little irrigation water. UV water sterilization inherently has the advantage that it adds nothing and does not change the chemical characteristics of the water.

Figure 3. Wastewater reuse system for the Suwon district

The design specification of sterilization facility in wastewater reuse system installed at the Suwon municipal sewer treatment plant is shown in Table 2. The capacity of the UV system is 8,000 m^3/day, and the system is operated around the clock.

Table 2. Summary of UV facility in wastewater reuse system for the Suwon district

Item	Specification	Item	Specification
Capacity	8,000 m^3/day	Lamp consumption power	145W
UV lamp type	Low pressure mercury lamp	Effective length of lamp	1,470mm
Number of module	8ea	Output of UV-C	48W
Total number of lamp	32ea	UV dose	167,945 ㎼sec/cm^2

To assess the environmental effects of reclaimed wastewater irrigation on the Suwon district, water samples of irrigation, ponding and drainage water were collected during the growing seasons. The results showed that wastewater reuse reduces the pollutant loads because of the natural purification effects of paddies (Figure 4).

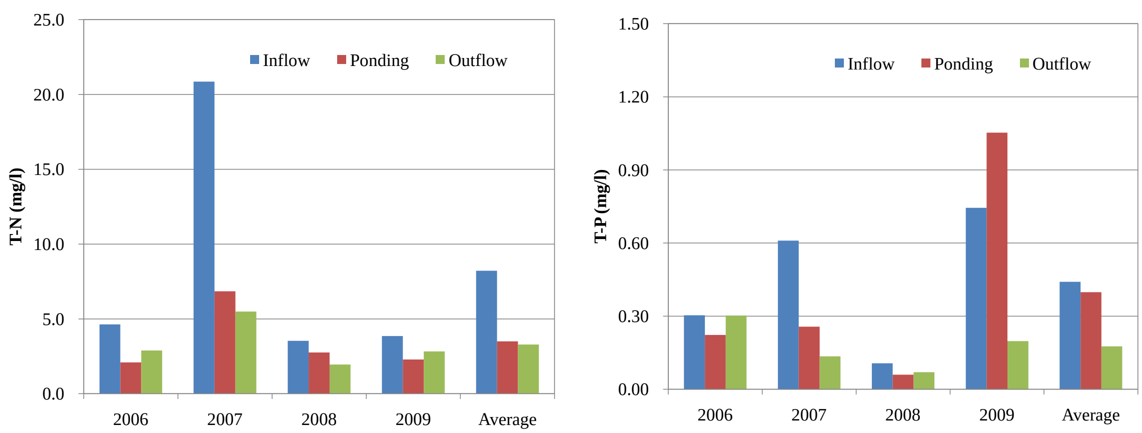

Figure 4. Nutrient changes in paddy fields during monitoring period (2006-2009): T-N (left) and T-P (right)

The experimental plots are also located adjacent to the Suwon sewer treatment plant. The field-scale test plots are monitored to assess effects of wastewater reuse according to irrigation water quality from various aspects; crop growth, yield, soil, water quality and coliform of irrigation water and ponded water in paddies, and agro-ecological environmental effects. The monitoring is going throughout the crop growth from 2002 to 2009. A randomized complete block design with spilt plot arrangements was used with three treatments and four replications on 5m × 5m plots shown in Figure 5. The three treatments are separated by irrigation water: groundwater (TR#1), wastewater (TR#2), and reclaimed wastewater through filtration and disinfection system (TR#3). A small scale wastewater reclamation system with a filter, ultra-violet treatment unit, pipeline to supply irrigation water to each plot, and groundwater well was implemented for the experiment.

Figure 5. View of experimental plots in Republic of Korea

Jeju reuse project Jeju-do is one of the volcanic island, consists of several volcanic rocks including basalt, trachyte, andesite, and various scoria from the dormant volcano function. Since this geologic characteristic makes precipitation quickly runoff to the sea, there is a shortage of surface water despite the great deal of precipitation. The average annual precipitation of Jeju-do is 1,975mm, which is 1.5 times more than that of ROK (Jeju-do, 2003). Most of the water used in Jeju-do is supplied from groundwater. However, usage of groundwater gets up to approximately 91% of groundwater sustainable yield, the excessive development of groundwater causes rapid drawdown of groundwater level and groundwater contamination. Approximately 72% of total water use in Jeju-do has been used for irrigation water, 98% of irrigation water is supplied from groundwater (MOCT, 2006).

Many farmers experience water shortage in agriculture, they make an effort to overcome this problem shown in Figure 6. In each fields, there are individual facilities to store irrigation water for the time of water shortage. Temporal storage tank would be filled up with rain water.

Figure 6. Examples of individual storage facility in fields, Jeju-do

To supply sustainable irrigation water, sewage water is becoming the alternative water resources for agriculture. But sewage water of Jeju-do has much higher concentrations of sodium than that of other sewer treatments because residential community in Jeju-do has been formed along the coast to easily obtain water. Most of the crops are vulnerable to the salt. Therefore the most important issue for wastewater reuse in Jeju-do is the desalination.

The Panpo district is located on the west side of Jeju-do (Figure 1). Main crops of this district are garlic, onion, cabbage, broccoli, and cactus. There is the Western sewer municipal treatment plant. Wastewater reuse project for Panpo district was started in 2008, the reclaimed wastewater reuse system was completed in December 2009. The capacity of system is 5,000 m^3/day. Irrigation water from reclaimed wastewater would be supplied in an instant, and the system is being tested at present.

<u>Monitoring</u> To assess environmental effects of wastewater reuse, irrigation water and soils of fields are monitored. Effluents from sewer treatment plant also have been collected and analyzed. Water quality characteristics of effluents are shown in Table 3. Electrical conductivity (EC) values are high in effluents.

Table 3. Water quality of effluents from the Western sewer municipal treatment plant (Panpo, Jeju-do)

	pH	EC (μs/cm)	BOD (mg/l)	COD (mg/l)	SS (mg/l)
Min.	6.7	980	12	13	10
Max.	8.5	1,450	18	18	20
Mean	7.8	1,200	15	16	14

<u>Design of Reclaimed wastewater reuse system in Jeju</u> The wastewater reuse system for Panpo district is installed to desalinate effluents from wastewater treatment plant. Figure 7 shows processes, from effluents to finished irrigation water. Electric carbon removal

system (ECRS) and reverse osmosis (RO) unit are used to desalination, and ERCS is also used to remove remain pollutants in effluents.

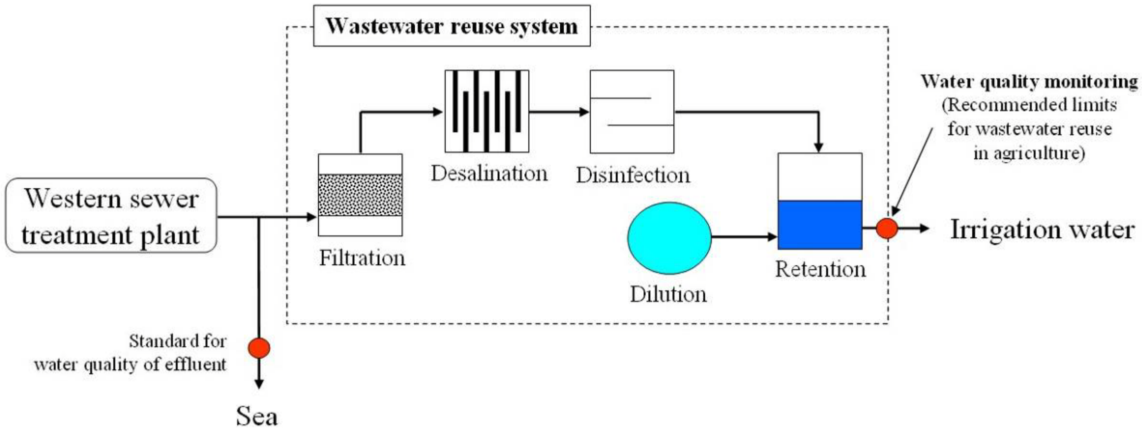

Figure 7. Design of wastewater reuse system for Panpo district, Jeju-do

The reclaimed wastewater is carried up storage tank located on high elevated area in Panpo district through pipes because of gravity irrigation. The capacity of storage tank is 1,000 m^3, made of stainless steel (Figure 8). In Figure 8, left side figure shows various instruments for wastewater reuse, installed in the Western sewer treatment plants.

Figure 8. View of wastewater reuse system (left) and storage tank (1,000 m^3) of reclaimed wastewater (right)

CONCLUSION Wastewater reuse for irrigation may be an important key to cope with water shortage problem. A wastewater reuse practice would significantly minimize adverse effects on crop growth, environments and most of all human hazards by implementing adequately wastewater reuse system, which is designed through radical field survey. In this study, the two representative projects for wastewater reuse was introduced, the Suwon project and the Panpo project. The Suwon project is a demonstration project, direct reuse method was selected to reuse effluents from sewer treatment plant. The reclaimed wastewater has been irrigated to paddy fields, and environmental aspects, crop growth, yields, water quality, soils, health risk, and agro-environmental effects, have been monitored from 2006 during growing season. The Panpo project is to reduce the groundwater usage and to supply sustainable irrigation water. Desalination process was focused because municipal wastewater has high concentration of salt in Jeju-do. The reclaimed wastewater would be supplied to arable land from this year, the wastewater reuse system has been tested at present.

Wastewater reuse for irrigation may help restore the natural hydrologic cycle by reducing the over-exploitation of fresh water from rivers.

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REFERENCES

Asano, T., A.D. Levine. 1996. Wastewater reclamation, recycling and reuse: past, present, and future. Water Sci. Technol. 33(10–11):1–14.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Huertas, E., M. Salgot, J.Hollender, S. Weber, W. Dott, S. Khan, A. Schafer, R. Messalem, B. Bis, A. Aharoni, H. Chikurel. 2005. Key objectives for water reuse concepts. Desalination. 218:120-131.

Jeju-do. 2003. Survey of hydrologic and geological characteristics and groundwater resources in Jeju-do. Jeju-do. Republic of Korea.

Marecos do Monte, M.H.F, A.N. Angelakis, and T. Asano. 1996. Necessity and basis for establishment of European guidelines for reclaimed wastewater in the Mediterranean region. Water Sci. Technol. 33(10-11):303-316.

MOCT. 2006. National water resource plan. Ministry of Construction and Transportation. Republic of Korea.

MOE. 2009. Wastewater reuse guide book. Ministry of Environment. Republic of Korea.