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2012 Modularization of Korea's Development Experience:

Small-scale Waterworks and Sewerage Systems

2013

MINISTRY OF ENVIRONMENT

Korea Environment Institute

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Preface

The study of Korea's economic and social transformation offers a unique opportunity to better understand the factors that drive development. Within one generation, Korea has transformed itself from a poor agrarian society to a modern industrial nation, a feat never seen before. What makes Korea's experience so unique is that its rapid economic development was relatively broad-based, meaning that the fruits of Korea's rapid growth were shared by many. The challenge of course is unlocking the secrets behind Korea's rapid and broad-based development, which can offer invaluable insights and lessons and knowledge that can be shared with the rest of the international community.

Recognizing this, the Korean Ministry of Strategy and Finance (MOSF) and the Korea Development Institute (KDI) launched the Knowledge Sharing Program (KSP) in 2004 to share Korea's development experience and to assist its developing country partners. The body of work presented in this volume is part of a greater initiative launched in 2010 to systematically research and document Korea's development experience and to deliver standardized content as case studies. The goal of this undertaking is to offer a deeper and wider understanding of Korea's development experience with the hope that Korea's past can offer lessons for developing countries in search of sustainable and broad-based development. This is a continuation of a multi-year undertaking to study and document Korea's development experience, and it builds on the 40 case studies completed in 2011. Here, we present 41 new studies that explore various development-oriented themes such as industrialization, energy, human resource development, government administration, Information and Communication Technology (ICT), agricultural development, land development, and environment.

In presenting these new studies, I would like to take this opportunity to express my gratitude to all those involved in this great undertaking. It was through their hard work and commitment that made this possible. Foremost, I would like to thank the Ministry of Strategy and Finance for their encouragement and full support of this project. I especially would like to thank the KSP Executive Committee, composed of related ministries/departments, and the various Korean research institutes, for their involvement and the invaluable role they played in bringing this project together. I would also like to thank all the former public officials and senior practitioners for lending their time, keen insights and expertise in preparation of the case studies.

Indeed, the successful completion of the case studies was made possible by the dedication of the researchers from the public sector and academia involved in conducting the studies, which I believe will go a long way in advancing knowledge on not only Korea's own development but also development in general. Lastly, I would like to express my gratitude to Professor Joon-Kyung Kim and Professor Dong-Young Kim for his stewardship of this enterprise, and to the Development Research Team for their hard work and dedication in successfully managing and completing this project.

As always, the views and opinions expressed by the authors in the body of work presented here do not necessary represent those of the KDI School of Public Policy and Management.

May 2013

Joohoon Kim

Acting President

KDI School of Public Policy and Management

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Summary

Water is essential for human life, to the extent that the right to clean water and proper water sanitation can be considered a basic human right. Nevertheless, many people in the poorest developing countries do not have access to clean water and proper water sanitation because their governments lack the financial and/or administrative capacity to resolve such problems. In particular, residents in rural areas tend to have inferior water supply and sanitary facilities.

Korea was able to rapidly increase its clean water supply rate in a short period of time thanks to the active efforts of its government, the introduction of loans from foreign countries and the issuing of local government bonds for the restoration of water supply facilities destroyed during the Korean War. Still, rural communities in Korea had experienced numerous water-related problems, such as water-borne epidemics because the wells (the main water supply facility in the 1970s) were located mostly adjacent to livestock pens and domestic sewage. To resolve such problems, the government promoted small-scale water supply facilities as part of the community development policy enacted in 1967. To provide a safe water supply in rural areas, small-scale water supply facilities started to be built and operated formally with IBRD loans, with the active leadership of the government as part of the Saemaeul (translation: New Community) Movement in the 1970s.

The small-scale water supply system in Korea can be classified into 20-500 ton/day waterworks for communities with populations of 100-2,500 people (community waterworks) and less than 20 ton/day waterworks for communities with populations of less than 100 people (small-scale water supply facilities). By late 2010, the small-scale water supply rate in *Eup* and *Myeon* units was 18.5%, serving around 1.87 million people. Small-scale

waterworks have the advantages of relatively low maintenance costs and easy maintenance, as water is usually supplied directly from water tanks without special water treatment, or is supplied after disinfection. However, as the quality of life of rural residents improved and the risk of raw water being polluted increased due to a rising number of regional development projects, an integrated small-scale water supply system, considering the merits and demerits, of each process has recently been applied. Small-scale water supply facilities should, in principle, be designated and controlled by mayors, county governors or ward chiefs, but in practice have been controlled by non-expert representatives from the relevant communities. For this reason, the government is leading cities and counties to outsource the management of small-scale waterworks or introduce an integrated operation system, and has been making efforts to improve the expertise of local public servants through training programs. Water supply in rural communities, together with telephone communication and traffic networks, is one of the most important factors in modernizing rural areas, as it has enabled an improvement in rural living conditions and health hygiene by preventing water-borne epidemics and other diseases, thus contributing to reducing disparities in the living standards between urban and rural communities. The national water supply rate in Korea reached 97.7% in 2010, but the water supply rates in *Eup* and *Myeon* units were no more than 89.8% and 55.9%, respectively. But once the community waterworks and small-scale water supply facilities are included, the water supply rates in *Eup* and *Myeon* units reached 94.7% and 85.4%, respectively, which indicates that community waterworks and small-scale water supply facilities have contributed to improving the water supply in rural areas and promoting the health of residents in those areas.

The small-scale sewerage system project started with the construction of sewerage facilities in 91 communities on a trial basis from 1991 to 1994, and was formally put into operation as public funds were invested according to the government's policy, through the establishment of a rural villages special tax to revive the depressed atmosphere of rural communities following the UR (Uruguay Round) Negotiations of 1995. Small-scale sewerage facilities were primarily provided to rural areas in which there was an urgent need for water pollution prevention, the water pollution prevention effects could be significant through the installation of such facilities, there were twenty or more households with waste water of less than 500 tons per day, and houses are densely packed within $300m^2$ into self-supporting villages. Small-scale sewage treatment plants had initially been operated as non-statutory facilities, but have been operated as statutory facilities for communities since 1996. The Sewerage Act defines a *Maeul-hasudo* (community sewerage system) as 'a public sewerage system constructed in natural villages to prevent rural water pollution at an early stage' with a sewage treatment capacity of 50-500 tons per day. In 2007, the term "community sewerage systems" was replaced with the term "small-scale sewerage system" as part of an effort to improve the efficiency of maintenance; this was simply defined as a community sewerage system with a sewage treatment capacity of less than 500 tons per day. The distribution of community sewerage systems was multilaterally promoted as a project to improve the rural living environment, with the government securing finances through Special Tax for Rural Development (local grants) and Agriculture & Fisheries Structure Adjustment Special Account (national treasury), but with the abolition of local grants it is now supported by the Environmental Improvement Special Account, the Regional Development Special Account, and the Agriculture & Fisheries Structure Adjustment Special Account. Suspended growth systems or attached growth systems are largely applied as small-scale sewage treatment technology with advantages such as easy maintenance and low cost. However, the existing treatment technology has recently been improved to meet constantly-tightening water quality standards. To enhance the technical and economic efficiency of small-scale sewerage systems, operators' expertise is being improved through the organization of technical support teams and the introduction and promotion of an integrated operation system. Sewerage systems had been largely constructed in urban areas, and were relatively lacking in rural areas, but the supply of small-scale sewerage systems in rural areas constantly increased from 4.9% in 1997 to 52.7% in 2010, greatly contributing to the creation of a comfortable living environment in rural areas by preventing the pollution of public water and improving public health. The national sewerage system supply rate reached 90.1% in 2010; 98.8% for Seoul metropolitan city and the other megalopolises and 88.3% for cities, but there is still a great disparity between urban and rural areas in terms of sewerage system supply. Thus, the government is continuing its investment, targeting a sewerage system supply rate of 75 % in rural areas by 2015.

Small-scale water supply and sewerage systems are useful for developing countries with poor water infrastructures and weak financial and administrative bases because treatment systems are simple and have relatively low maintenance costs and easy operation compared with large-scale systems in densely populated cities. Thus, based on Korea's experience, which introduced and operated small-scale water supply and sewerage systems for the safe water supply and environmental improvement that was promoted as part of the Saemaeul Movement in 1970, contributing to improvements in the rural living environment, some methods for the efficient construction and operation of small-scale water supply and sewerage systems have been proposed for developing countries.

1) Phased Development through Government Support

In general, waterworks and sewerage infrastructures are mainly provided to cities; rural areas with a relatively low population density have insufficient infrastructure. This leads to an increasingly wide gap between cities and rural areas in waterworks and sewerage coverage. Improving the coverage of small-scale waterworks facilities and their effective operation requires the government's active will, cooperation and budgetary support.

In Korea, the government had started the installation of village waterworks systems in 1967 as a part of its local community development policy. Then, with the 5-Year Economic Development Plan and the Samaeul Movement providing momentum, promoted waterworks projects in rural areas in earnest. In the early 1970s in Korea, when the GDP was less than 2 million dollars, the government had selected priority areas for waterworks installations, including those vulnerable to the spread of water-borne diseases and those in which water pollution prevention projects were urgent or potentially effective in disease prevention. The beneficiary residents actively participated in facility construction and operation, with no wage. As a result of the 5-Year Economic Development Plan and the Saemaeul Movement, the improved standards of living in both rural and urban areas and an increase in water contaminant discharge from the increased use of agricultural chemicals and fertilizers had led to poor water quality. For this reason, in 1995 the government established a Special Tax for Rural Development and pushed ahead with the construction of village sewer systems in rural areas. In 2007, when the GDP per capita of Korea exceeded 20,000 dollars, the government began to introduce the integrated operation of village waterworks systems and village sewerages to improve their operation efficiency. In this way, facility operation management, water quality standards, and water treatment technology have been developed through phased application in line with economic development, industrialization, and public awareness.

2) Appropriate Technology and Active Community Engagement

For developing countries, which have relatively low economic levels and environmental awareness, it is very important to introduce appropriate technologies that do not require a large amount capital and which are very simple to apply. In particular, small-sized waterworks and sewerage facilities are located in remote villages, and thus are difficult to manage. Accordingly, such facilities require systems that are optimized for local circumstances, a manual for systematic operation management, and the active engagement and awareness of the residents who are the main agents of facility operation and management.

① Small-scale Water Supply Systems

First, water intake stations should be operated and managed based on each intake station's characteristics. Intake stations for small-scale tap water facilities largely deal with underground water and valley water. If the water supply source is underground water, anti-septic automatic injectors must be installed after the construction of pollution prevention facilities to prevent the expansion of point and non-point pollutant sources. If valley water, spring water or stream water are used, special care should be taken to manage water supply sources because pollutants such as earth and sand, and animal and plant waste, can accumulate on the bottom of a water tank, and pathogenic microorganisms causing water-borne epidemics such as typhoid and dysentery may be present in untreated water. Thus, before determining the location of a public water source, the water should be examined by the technicians in charge of the relevant area to determine its suitability as a water source. Sites where it is easy to control access by livestock and people should be selected, and structures such as fences and information boards should be erected around water sources to restrict their access. In addition, anti-septic automatic injectors should be installed in water tanks where there is no risk of damage from freezing.

Second, small-scale water supply facilities and water quality should be managed in an appropriate way. Community waterworks or small-scale water supply facilities require SOC infrastructures such as civil engineering and power. Volume, weight and required power must be considered in advance of other things as space is usually limited and unsatisfactory; small high-efficiency unit processing facilities are recommended as treatment systems. For optimum economy and efficiency, a treatment process should only be selected after considering the sources of the water supply in the relevant area, to ensure safe water quality and convenient operation of small-scale water supply facilities. In addition, a process is needed that has low maintenance cost and easy operation and management, considering that it is difficult to operate such facilities and secure the financial resources for maintenance and professionals after installation.

Water from small-scale water supply facilities is usually supplied to users without any water purification, or after disinfection only. For chlorine disinfection, a fixed number of chlorine tablets should be put into water tanks periodically, at a regular hour. An intermittent input of solid chlorine by non-professional administrators makes it difficult to maintain an optimum level of residual chlorine, and may result in civil complaints due to the smell of disinfectants. Thus, for chlorine disinfection, the introduction of automatic disinfection facilities should be considered for the removal of fecal pollution sources and the maintenance of consistent standard values of residual chlorine; suitable disinfection means such as chlorine, ultraviolet rays and/or ozone should be selected, depending on the conditions of relevant areas; and, regular examinations of water quality should be conducted.

Third and finally, most community waterworks or small-scale water supply facilities are operated by non-professionals that are representatives of their communities, and thus to ensure systematic maintenance, operation and management manuals should be developed, specialized training should be provided to community representatives, or the services should be subcontracted to private professionals. For commissioned services, subcontracting services to firms that install either tube wells or anti-septic automatic injectors should be considered.

② Small-scale Sewerage Systems

First, rural communities have many different forms of houses, and to make an economical and reasonable sewage treatment plan, treatment areas should be determined by considering the geographical features of the communities. The most economical way to place piping, treatment facilities and drains for discharging treated sewage water is the natural flow type. Pipelines should be buried along farm roads or community roads; roads with heavy traffic should be avoided to the greatest extent possible. The locations of treatment facilities should be chosen after considering community life zones for more convenient operation and easier participation of local residents.

Second, economic conditions should be considered. The cost of laying pipeline rises in inverse proportion to population density, as unlike urban areas, rural communities have a low population density due to their geographical features. Thus, having the correct piping plan for the target area will affect the economic value of sewerage facilities, and as maintenance cost is affected by burying conditions, and the installation of equipment such as relay and pressure pumps incurs additional maintenance cost, a pipeline laying plan should be made after considering all such conditions.

Third, items to consider when selecting a location for a small-scale sewage treatment facility include: i) the extension of pipelines and the ground surface of inlet pipelines, ii) the risk of submersion due to floods, iii) ground sinking and geological conditions, iv) the presence of infrastructure such as power and water supply, v) the availability of space for equipment, and vi) the possibility and ease of discharging treated waste water. In planning small-scale sewerage facilities, i) sewage volume should be estimated by looking ahead 5-10 years in consideration of population growth, ii) loading amount should be estimated, considering inlet wastewater and discharge water qualities, and optimum treatment facilities selected, and iii) facilities should be resident-oriented facilities.

Fourth, as rural areas are definitely lacking technical personnel for the maintenance of community sewage treatment facilities, and financing maintenance is not easy, management by lay people should be possible, and maintenance costs should be low. Treated wastewater should be made available for reuse as agricultural water or stream maintenance water, and adequate processes should be selected that are eco-friendly, making the most of the characteristics of the relevant rural communities, and meeting the legal water quality standards that will inevitably be strengthened in the future.

Fifth and finally, for more efficient maintenance, divisions and sections in charge should be streamlined, specialized training should be continuously provided to public servants in charge, and the active cooperation and participation of residents should be sought, as mentioned in the section on small-scale water supply systems above. Referral to private service providers, unmanned automatic operation with advantages over manual control such as reduced operation costs, accuracy, increased efficiency and stable operation, and the use of remote control technologies, depending on financial conditions in relevant regions, are worth being reviewed.

But above all, as small-scale water supply and sewerage facilities are generally located in remote areas that are far from communities, they need to have systems that are optimized for local environments; a systematic operation management manual; a high sense of management from people in the community, who are the principal body of operation and management; active concern of local governments for small-scale waterworks and efficient operation and management, and cooperation and financial support from local governments.

Chapter 1

Introduction

Introduction

As populations become more concentrated and there is greater urbanization, water demand increases and there is a stronger need for a clean water supply and sewerage systems that can control water pollutants. Water supply and sewerage systems are essential facilities to improve the quality of civic life through convenient water supply and healthy surroundings, and core social overhead capital facilities for improving national health and welfare.

Waterworks in Korea started when a patent for waterworks construction and management was granted to the Americans C.H. Collbran and H.R. Bostwick in 1903, which was then transferred to Korea Waterworks Co., a company set up by an Englishman in 1905. Following this, the construction of a slow sand filter bed for Ttukdo Water Purification Plant was launched in early August, 1906 and completed in August, 1908. Finally, water supplies for 15,000 people in Seoul started on September 1, 1908 with water production of 12,500 tons a day, ushering in the era of modern water supply, and followed by the construction of waterworks in cities across the country (100 History of Seoul Waterworks).

Korea's waterworks project can be divided into the stages of i) introduction of waterworks under the Japanese colonial period before independence in 1945; ii) turmoil, with national independence, the Korean War and restoration from 1945 to 1960; iii) facility capacity expansion from the 1961 enactment of the Water Supply and Waterworks Installation Act to 1990; iv) water quality improvement with advanced water treatment from the 1961 revision of Water Supply and Waterworks Installation Act to 1999; and v) consumer-oriented service for a new millennium since 2000 (Water Journal, 2008).

The Korean Empire Government codified regulations on waterworks with the enactment of water supply regulations (41 articles in the full text) under Internal Ordinance No. 13 on November 9, 1909. Later, in 1911, waterworks management rights were transferred to the Japanese Government-General of Korea, which proclaimed the government-run waterworks regulations (Japanese Government-General of Korea Ordinance No. 18), and classified water suppliesinto 5 types: intrinsic water supplies, public water supplies, fire water supplies, marine water suppliesand special public water supplies.

In 1945, the population with access to water supply in 83 cities reached 2 million, with a daily maximum water supply of 270,200 tons and a daily water supply per person of 13 liters, and a majority of people in Korea used water from wells, valleys and streams as drinking water (Yu Gwang-ho, 1999). Due to overseas Koreans returning home following Korea's independence from Japan and the increasing concentration of the population in urban areas, the waterworks were insufficient and there were water shortages; serious problems took place in relation to securing technical personnel in the waterworks industry for technology management and maintenance, as the field had previously been monopolized by Japanese providers. During the Korean War, the country suffered unprecedented damage to its waterworks, with 30-90 % of water purification plants, 5-10 % of water pipes and 60-80 % of pumping stations destroyed. Damage to waterworks in Seoul was estimated at a total of 5,181,300,000 *hwan*[1], converting to the currency value before the Korean War, as of March 31, 1953 (Office of Waterworks, Seoul Metropolitan Government, 2008).

After the Korean War, the waterworks restoration project was launched with the help of foreign loans and the issuing of bonds by local governments due to the country's weak financial position. There was aid provided from the Foreign Operation Administration (FOA) in 1954 and the renamed International Cooperation Administration (ICA) in 1956 for the restoration, expansion and new construction of waterworks. The country received a total of $1.742 billion in aid from the ICA and DLF (Development Loan Fund) and their consolidated organization, the AID/DG (Agency for International Development/ Development Grant) until 1961. All waterworks destroyed during the Korean War were completely restored by 1955, and the volume of the water supply increased to 600 thousand tons/day in 1961.

The country established a systematic waterworks technology supported by the United States during the postwar restoration stage from 1945 to 1960, enacted the Water Supply and Waterworks Installation Act in 1961, and implemented planned investments in water supply facilities under the Five-year Economic Development Plan in 1962. At this point, the countries providing aid were diversified from the United States alone to include Japan, Germany, and other countries, and Korea also received support for the development of its waterworks from the IBRD (International Bank for Reconstruction and Development), the IDA (International Development Association) and the ADB (Asian Development Bank) in

1. *Hwan* is a now-defunct unit of Korean currency. As of Dec. 1953, $1USD = 180 *hwan.*

a variety of forms, including free technical cooperation and loans. The Korean Government signed an AID loan agreement with the United States for the construction of waterworks in Seoul on June 2, 1966, and received a total of $2,853,094 in November 1968, which was used in building the Bogwang-dong water treatment plant. The loan was provided at an interest rate of 5.75 % on the condition of a twenty-year level payment and four-year grace period, and was completely paid off on November 29, 1988.

Eleven Korean cities, including Seoul and Incheon, had 14.192 billion won of the required total of 16.872 billion won invested in key waterworks projects funded by loans in 1970. The Seoul Municipal Government signed an ADB loan agreement in 1971, and received a total of $8,737,028 on the condition of a seventeen-year level payment with a three-year grace period, which was completely paid off on December 3, 1990.

During the Third Economic Development period, the waterworks project was converted into a self-support system when seven major Korean cities – Seoul, Busan, Incheon, Daegu, Daejeon, Gwangju and Cheongju – launched water supply facility improvements with loans from the central government, and local governments' waterworks projects were also activated with these loans.

The Multi-regional Water Supply Project that began in the late 1970s consists of 6 stages and is the biggest project that Korea promoted to develop a stable and smooth residential and industrial water supply to 24 local communities in the metropolitan area, including Seoul, from the raw water at Paldang Dam. The project was led by the Ministry of Construction due to the lack of funds on the part of local governments at that time. The first-stage project from 1973 to 1979 for the metropolitan area had a total of 44.1 billion won invested with 1.2 million tons of water supply. The second-stage project, in which a total of 40.2 billion won was invested, was launched in 1977 and completed in 1981, and started to supply water in 1982 with 1.40 million tons per day. The third-stage project, with a total investment of 188.7 billion won, saw facility construction started in November 1984 and finished in 1989 with 1.33 million tons of water supplied daily. It was followed by the fourth stage (December 1989 to April 1994), the fifth-stage (August 1995 to April 1999) and the sixth stage (November 1999 to December 2004), and the water supply facilities constructed under the project are currently operated and managed by the Korea Water Resources Corporation (KOWACO), supplying an average of 3.60 million tons of water per day to around 10.0 million people in 24 communities in the metropolitan area. To meet water demands from local small and medium-sized cities, a waterworks expansion project was promoted for 18 cities selected under the Fifth Five-year Economic Development Plan (1982-1986), and $25,949,594 of the estimated cost was borrowed from the ADB at an interest rate of 10.5 % on the condition of a twenty-year (1987-2007) level payment with four-year grace period.

When the water supply facility modernization project was promoted in the 1980s, the Seoul Municipal Government acquired loans from the OECF in 1983 (KO-22) and 1984 (KO-30). The loans were used to fund the basic plan and design for water supply modernization and the purchase of leakage repair equipment.

Local government bonds, together with the introduction of loans, played an important role in financing waterworks. The Seoul Municipal Government enacted and proclaimed the 'First Postwar Restoration Public Bond Act for Water Seoul Metropolitan City Waterworks Expense Special Account' under Ordinance No. 23 in May 1953. This was later followed by the 'First Waterworks Expansion Project Local Government Bond Act for Seoul Metropolitan City' under Ordinance No. 625 in July 1970, the 'Second Waterworks Expansion Local Government Bond Act for Seoul Metropolitan City' under Ordinance No. 657 in February 1971, and the 'Waterworks Public Bond Act for Seoul Metropolitan City' under Ordinance No. 1292 in December 1978, all as means of financing all construction for a smooth supply of tap water. In this way, issues of local government bonds played an important role in financing waterworks during the period from 1960 to 1970, but this type of funding slowed after 1993, and was reduced to 73.6 billion won by 2005. After 1990, the need to depend on local government bonds was lowered through rational financial operation, efficient administration and budgeting based on long-term project plans.

The construction of water supply facilities – funded by loans and local government bonds issued until the late 1980s to solve the problem of a lack of funds after the Korean War – promoted technology transfer from foreign designers who participated in those construction projects to domestic designers, which paved the way to improving the design technology of Korean engineers. By 1990, these efforts had resulted in an increase of the capacity of water supply facilities to 16.27 million tons, an increase in the population using water to 33.63 million and an increase of the water supply rate to 78.4%. Following this, a policy to expand the distribution of the water supply continued to be promoted, and the supply rate reached 97.7% by 2010. Currently, the government's policy on water supply places a greater emphasis on improving water quality and providing a customer-centered service than on quantitative expansion. The following <Table 1-1> shows the phases of development of Korea's water supply system.

Table 1-1 | Phases of Development of Korea's Water Supply System

By step Division	Step. 1 (1946-1960s)	Step. 2 (1961-1990s)	Step. 3 (since the 1990s)
Policy objective	Recovering from the ravages of war and acquiring water supply system techniques	Quantitatively expanding water supply facilities to resolve water shortage issues	Shift in water supply policy from quantitative expansion to qualitative improvement. Providing customer-centered water supply service and improving equality of access to the service
Policy means	- Restoration through foreign aid (FOC, ICA)	- Water resource development through programs for land development - Development of multi-regional water supply system	- Complete revision of Waterworks Law and tightening of water quality standards - Built water quality inspection stations and tightening water quality inspections - Established water treatment criteria and implementing comprehensive water quality management measures - Expanded water supply service to under-served rural areas
Success factors	- Localized technologies for water supply system by acquiring foreign capital and skills	- Designated investment in water supply facilities according to the Five-Year Economic Develop-ment Plan - Secured large-scale water supply facilities by building multi-regional water supply system - Acquired advanced technologies through water supply construction collaboration with foreign designers based on loans	- Introduced a program to improve river water quality, such as a Special Act on the four major rivers for river water quality improvement, and limiting total emission volume of water pollutants - Introduced advanced water treatment system - Focused on the improvement and maintenance of current facilities

By step Division	Step. 1 (1946-1960s)	Step. 2 (1961-1990s)	Step. 3 (since the 1990s)
Organization	Ministry of Home Affairs	Ministry of Home Affairs, Ministry of Construction, Environmental Office	Ministry of Environment
Constraint factors	- The rate of increase of the water supply service was far less than the rapid rate of urban population growth	- Since water supply facilities were constructed in big cities and industrial areas first, facilities in rural, rural communities were left wanting - Unstable water supply in the outskirts and hilly areas. Insufficient water supply system, leading to water restriction in the event of drought	- Distrust of tap water continues due to water quality problems, and rate of direct tap water consumption decreased
Effects	- Capacity of water supply facilities increased from 240,000m^3/d in 1947 to 600,000m^3/d in 1961 through restoration and expansion of facilities - Ttukdo water supply plant designed and constructed with Korean technology	- Rapid increase in water supply ratio, from 17.1% in 1961 to 78.4% in 1990 - Modern design technology of water treatment plant established	- Water supply ratio improved to the level of advanced countries, from 78.4% in 1990 to 94.1% in 2010 - Rate of water usage in rural communities improved, from 27.9% in 2000 to 56.1% in 2010

Source: KEITI (Korea Environmental Industry & Technology Institute), (2012)

Korea's first modern sewerage system consisted of a main line and branch lines amounting to 225 km. These were improved by investing 475 million won over 22 years from 1918 to 1943, for the purpose of preventing overflow in the city, stagnation of sewage and pollution and disposal of discharged human waste. This became the basis of Seoul's sewerage system. While some of those facilities were destroyed during the Korean War, a project for improving the sewerage system was restarted with the postwar restoration project in 1954.

Before the 1960s, as part of the reorganization of city streets in an attempt to drain rainwater, sewerage was constructed. After that, since the five-year economic development plan began, its full length amounted to 1,057 km with a distribution rate of 21.1% in 1967 and 2,517km with a distribution rate of 57.1% in the 1970s. In August 1966, the Sewerage Act was established, which included requirements for the construction and management of a public sewerage system that could eliminate and treat urban sewage. In 1973, a legal basis to define the range of collecting charges for sewer and to restrict alternate uses of sewerage was prepared.

The rapid industrialization and growth of the urban population caused by the 1st and the 2nd five-year economic development plans resulted in an increased amount of waste water, causing the problem of river pollution, and as a result the interest in the construction of a sewage treatment plant for water quality conservation increased. Finally, in June 1976, the Cheonggyecheon sewage treatment plant – Korea's first terminal sewage disposal plant – was constructed, with a capacity of 150,000 tons/day, and in 1979, the Jungrang sewage treatment plant with a capacity of 210,000 tons/day was completed.

In order to procure investment resources, the implementation of sewer charges began in October 1983, the Tancheon sewage treatment plant was constructed in 1983 and the Seonam and Nanji sewage treatment plants were constructed in 1984. To prepare for the Seoul Olympic Games in 1988, as a part of the Han River comprehensive development project, the four sewage treatment plants (Jungrang, Tancheon, Gayang and Nanji) were newly constructed or expanded, and a daily facility capacity of 3.06 million tons was secured. In 1996, since the daily facility capacity of 4.05 million tons was secured in 1996, approx. 81% of 4.98 million tons, the total amount of sewage generated in Seoul per day, was able to be treated.

For the City of Busan, a master plan for sewerage was established in 1974 with the technical support of the West German government, and sewage treatment plants were planned targeting the Suyeong, Nambu, Bansong, Haeundae and Songjeong regions, and the Jangrim, Jungang Yeongdo, Gangdong, Jisa, Myeongji, Noksan and Gadeok regions.

Also, expansion of sewerage facilities was mostly performed with foreign loans that were acquired for supplementing insufficient finances from the late 1970s to the 1980s. According to the status of the foreign loan in March 1995 from the internal data of the Ministry of Environment, with foreign loans acquired from the ADB, IBRD, KFW, OECF, etc., the sewage treatment plants and the required sewers were constructed in 15 localities including Seoul, Incheon, Busan, Daegu, Chuncheon, Daejeon.

Projects implemented by acquiring foreign loans are largely classified into sewage treatment projects in manufacturing areas, and projects in urban areas. In terms of projects in manufacturing areas, with a loan acquired from ADB, the sewage treatment projects for typical manufacturing areas such as Gumi, Banwol, Ulsan, Changwon, Masan and Yeocheon were generally performed. In 1979, a master plan for a sewage treatment project in five manufacturing areas was established, including a legal and institutional review related to a sewage project of the region affected, a review on the regional rates, a feasibility study on constructing the facilities and a maritime survey, and thus the pre-project planning phase was completed. Then, by acquiring additional loans two times, finances were secured to construct the sewage treatment plant, the intercepting sewer, the pressure sewer and the pressure pump stations in Gumi and Banwol, and to construct the sewage treatment plant, ocean sewer, intercepting sewer and the pressure pump station in Ulsan, Changwon/Masan. In this way, sewage treatment plants were secured in five manufacturing areas. But due to the high rate of interest (7.6-10.5%) for the ADB loan, the governments have been working to repay it early since the mid-1990s. For the sewage treatment project in urban areas, financial resources were mostly secured from the OECF. Typical projects for constructing municipal sewage treatment plants are those in the cities of Daegu, Daejeon and Jeonju, for which agreements were signed in 1980, through which financial resources were secured to construct municipal sewage treatment plants with a combined capacity of 500,000 tons/day, intercepting sewer of 57km and branch sewer of 520km.

Table 1-2 | Status of Introduction of Major Loans for Sanitation
(as of March 31, 1995)

Organizations	Number of loan	Name of project
Asian Development Bank (ADB)	409-KOR*	Sewage treatment project (Gumi, Banwol, Wulsan, Changwon, Yeocheon)
	498-KOR	Wewage treatment in industrial area project (Gumi, Banwol)
	650-KOR	Construction of sewage treatment plant (Ulsan, Changwon, Masan)
	763-KOR	City of Incheon sewage treatment plan
	854-KOR	Construction of 4th sewage treatment plant (Daegu)
	909-KOR	Construction of sewage treatment plant (Suwon, Jinju)

Organizations	Number of loan	Name of project
International Bank for Reconstruction and Development (IBRD)	3450-KO	Construction of Busan/Daejeon sewage treatment plant
	3590-KO	Construction of Gwangju/Seoul sewage treatment plant
	3830-KO	Construction of Janglim sewage treatment plant (Busan)
Kreditanstalt Fur Wiederaufbau (KFW)	AL-75-65-617	City of Busan sewage treatment plant
Overseas Economic Cooperation Fund (OECF)	KO-16	Construction of municipal sewage treatment plant (Daegu, Daejeon, Jeonju)
	KO-21	Construction of Seoul Tancheon sewage treatment plant
	KO-23	Construction of Seoul Jungrangcheon sewage treatment plant
	KO-24	Busan Sueong sewage treatment plant
	KO-36	Construction of Janglim sewage treatment plant (Busan)
	KO-37	Construction of Gwangju sewage treatment plant
	KO-38	Construction of Chuncheon sewage treatment plant
	KO-50	Construction of sewage treatment plant (Cheongju, Jeju)

Source: Internal data from Minstry of Environment

Subsequently, to achieve water quality control of public waters, the Korean government implemented a policy of distributing and expanding the sewerage system, investing 26.1 trillion won in the sewerage project, which accounted for 91% of the total investment amount (287 trillion won) for the water quality control project, from 1993 to 2005. As a result, the sewerage penetration rate increased from 45.5% in 1995 to 83.5% in 2005. In this way, thanks to a policy of steadily expanding sewerage facilities, the sewerage penetration rate reached 90.1%, which is the level of advanced countries, in a very short period of time.

<Table 1-3> shows the phases of development of the sewerage system in Korea.

Table 1-3 | Phases of Development of the Sewerage System in Korea

By step Division	Step 1 (1960-1970s)	Step 2 (1980-1990s)	Step 3 (Since the 2000s)
Policy objective	Preparing measures to counter environmental pollution, and working to change social consensus	Preventing water pollution by expanding sewage treatment facilities. Improving implementation by establishing policy and revising laws.	Expanding the maintenance of sewers by proclaiming the first year of maintenance of sewage pipes (2002). Strengthening the foundation for science-based sewage management
Policy means	- Establishment of anti-pollution laws (1963) - Establishment of Sewerage Act (1966)	- Six comprehensive measures for water management passed, including measure to supply clean water (1989) - Revision of Sewerage Act (1990, 1994)	- Preparing measure for constructing sewerage treatment facilities on the upper part of dam (2002) - Comprehensive measure for maintenance of sewage pipes (2002)
Success factors	- Change in public awareness due to environmental issues being raised by the press and experts - Rise of environmental problems worldwide, related academic studies, and the introduction of overseas environmental information resulted in a paradigm shift	- Expanding sewerage treatment facilities in a short period of time through large scale investment under comprehensive measures for water management - Systematically establishing and implementing policies by unifying sewerage works (Ministry of Environment)	- Korean government proclaimed first year of sewage pipes and established and executed comprehensive measures for the maintenance of sewage pipes (2002)
Lead department	Ministry of Health and Social Affairs	Environmental Office, Environment department	Ministry of Environment

By step Division	Step 1 (1960-1970s)	Step 2 (1980-1990s)	Step 3 (Since the 2000s)
Constraint factors	- Most government policies focused on rapid economic growth, resulting in a low level of awareness on environmental issues	- Concentration of sewerage treatment facilities in urban areas resulted in an imbalance between urban and rural areas in terms of the sewerage penetration rate - Due to a delay of access to sewage pipes, actual treatment rate of wastewater flow less than the penetration rate of sewerage.	- Due to a lack of funding for the maintenance of sewer pipes, finance program and auxiliary BTL project of sewer pipes were adopted - Concern about shrinking of sewer industry caused by long-term repayment of BTL principal
Effects	- Change in awareness of environmental issues affected major policy issues in Korea - Scientific measurement to identify environmental problems and introduce pollution reduction technology	- Rapid increase in sewerage penetration rate. 8.3% in 1981 → 35.7% (1991) → 70.5% (1999) - 4 sewerage treatment plants (1981) → 22 plants (1991) → 150 plants (1999)	- Increase in general sewerage penetration rate. 52.5% in 1996 → 85.5% in 2005. (90.1% in 2010) - 86,000Km of sewer pipes in 2005. 68.2% penetration rate of sewer pipes (78.0% in 2010)

Source: KEITI (Korea Environmental Industry & Technology Institute) (2012)

This report aims to meet the goal of halving the number of people who are not served by safe drinking water and basic sanitary facilities by 2015, which is one of the MDGs (Millennium Development Goals), and to introduce Korea's small-scale water and sewage system, which is relatively easy to apply, to the developing countries in which poor water and sewage systems still cause serious health problems for the public. A small-scale water and sewage system is thought to be particularly appropriate for countries in which there is poor distribution and expansion of water and sewage facilities, such as Mongolia, Afghanistan, Indonesia, Sub-Saharan Africa. Therefore, this report focuses on Korea's small-scale water and sewage system and the experience of running it.

This report covers the small-scale water supply system (Chapter 2) and the small-scale sewerage system (Chapter 3), and each chapter describes the background to the introduction of the system, facility installation and treatment technology, water quality standard and the status of water quality and system evaluation. Lastly, Chapter 4 describes the implications of applying the system to developing countries based on Korea's experience.

Chapter 2

Small-scale Water Supply System

1. Background
2. Framework of Small-scale Water Supply
3. Small-scale Water Supply Facility and Treatment Technology
4. Drinking Water Quality Standard and Status

Small-scale Water Supply System

1. Background

1.1. Background and Rationale

In Korea's rural areas, people would traditionally access drinking water by digging a well or carrying the water home from a natural spring. As standards of living gradually improved, people who could afford it would install a manual or electric water pump in their yard. However, as the public wells or tube wells that the majority of farmers depended on were mostly located on the same site as their residences, there was a high risk of pollution from adjacent toilets and pens, and domestic sewage. In addition, due to the thinness of the aquifers, the filtration capacity was poor. Sanitary management of the well was difficult, and people would use it without disinfection. In most cases, wells were in unsanitary condition. For this reason, water-borne infections and water shortages during drought were quite frequent. To address this problem, the Korean government started to install simple water supply systems (renamed the village drinking water system in 2005) in rural areas in 1967 as a community development project. Since the early 1970s, those systems have been more actively distributed through the Saemaeul Movement. The Korean government provided 4,073 village drinking water systems for 2 years from 1976 to 1977, with government funds and a 2.57 billion won ($5.35 million) loan for the Saemaeul Movement from IBRD. 1.5 million people were able to benefit from this program, and the village drinking water system played an important role in supplying safe drinking water to the rural areas at that time (Korea Rural Economic Institute, 1978).

1.2. Definition and Classification

1.2.1. Definition of Small-scale Water Supply

Small-scale water supply facilities include the village drinking water system and small waterworks. Under the 9th clause of Article 3 in the Waterworks Law, the "village drinking water system", according to the water supply system determined by Presidential decree, refers to local governments' general water supplies that provide purified water to a water-using population of 100 to 2,500 with a water supply amount of $20m^3$-$500m^3$ a day or a similar scale, and should be designated by the special metropolitan city mayor, the metropolitan city mayor, the special local city head, the special province governor, the mayor or the county governor (excluding the county governor of a metropolitan city). Under the 14th clause of Article 3 in the Waterworks Law, 'small waterworks' refers to waterworks that are installed and managed by the community in common, with a population of less than 100 using the water and a daily water supply amount of less than $20m^3$, and should be designated by the special metropolitan city mayor, the metropolitan city mayor, the special local city head, the special province governor, the mayor or the county governor (excluding the county governor of a metropolitan city).

Figure 2-1 | Small-scale Waterworks System

1.2.2. Classification of the Small-scale Water Supply Facilities

Small-scale water supply facilities can be classified according to the method of water service and the fountainhead. Classification by the method of water service is divided into three types: natural flow, pumping-up and compression (See <Table 2-1>).

Table 2-1 | Classification of Small-scale Water Supply Facilities According to the Method of Water Service

Classification	Natural flow type	Pumping-up type	Compression type
Definition	Water is supplied to the hydrant through water treatment facilities and distribution reservoir using gravity rather than power, as its fountainhead is in a high place.	Water is pumped out to the distribution reservoir, and then supplied to the hydrant through non-pressure flow, since its fountainhead is in a low place.	This method is used when the natural flow type is not practical or it is impossible to build a distribution reservoir because there is no high ground. Water is supplied to the hydrant through the reaction force generated from the process of pumping water to the compression tank.
Fountainhead	Spring water, Valley water	Underground water, Stream water	Underground water, Stream water
Merits	Most economical method No electric power required Easy management	Possible to secure stable water quantity and quality The deeper underground the water source, the less water pollution	No distribution reservoir needed Can secure stable water quantity and water quality
Demerits	Distribution reservoir needed Difficulties in managing fountainhead Water quantity depends on the season	Water pump and electric power needed Difficulties in management Need to construct distribution reservoir at a high place	Compression tank needed Electric power needed Difficulties in management

Source: Jeon, Je-sang (2010)

2. Framework of Small-scale Water Supply

2.1. Relevant Law and Operation Management System

Urbanization, industrialization and improved standards of living increased public demand for water, and the need for the state to supply the people with safe and clean tap water emerged. Therefore, the Korean government established the Waterworks Law on Dec.31, 1961, so that waterworks could be properly managed and the water source protected.

The Waterworks Law defined the basis of the designation of a water source reserve, restraints and prohibitions and, to reflect changes in the management system, has been revised 40 times. On Dec 14, 1991, the full text of the law was revised, significantly reforming the water supply management system and bringing the work related to the designation and management of a water source reserve under the jurisdiction of the Ministry of Environment. Since then, it has been partially revised many times, most recently on July 1, 2012.

From 1967-1980, the village drinking water system and the small waterworks were installed on the basis of a program guidance by order of the Ministry of Health and Human Services (now the Ministry of Health and Welfare Affairs). At the early stages of the small water supply program, under the general superintendence of the Ministry of Health and Human Services (now the Ministry of Health and Welfare Affairs), and according to budget allocations, villages in a city or a county were selected to receive the benefit. The city and the county would review the request from the Saemaeul council and set the priorities. The priority rule of allocation was as follows:

1. Area in which water-borne diseases had occurred, or which was considered vulnerable to water-borne diseases
2. Exemplary area in Saemaeul Movement
3. Island, Remote island
4. A village capable of funding more than a third of construction costs independently

According to the guideline from the Ministry of Health and Human Services, design of the waterworks was conducted by the construction division of the city or county office. The required materials based on IBRD loans were to be purchased through international bidding. In case of construction, as part of Saemaeul Movement, area residents would provide free labor and bore a portion of the construction cost.

Small-scale water supply systems were usually completed in 5-6 months, and after being completed, would be inspected by the construction division of the city or county office. After that, on the basis of the guidelines for Saemaeul small-scale water supply systems, a facility maintenance council would be organized. The membership and the composition of the council were as follows:

1. The head of the council (1)
2. Manager (1)
3. Conservator (1)
4. Guard (1)
5. Others

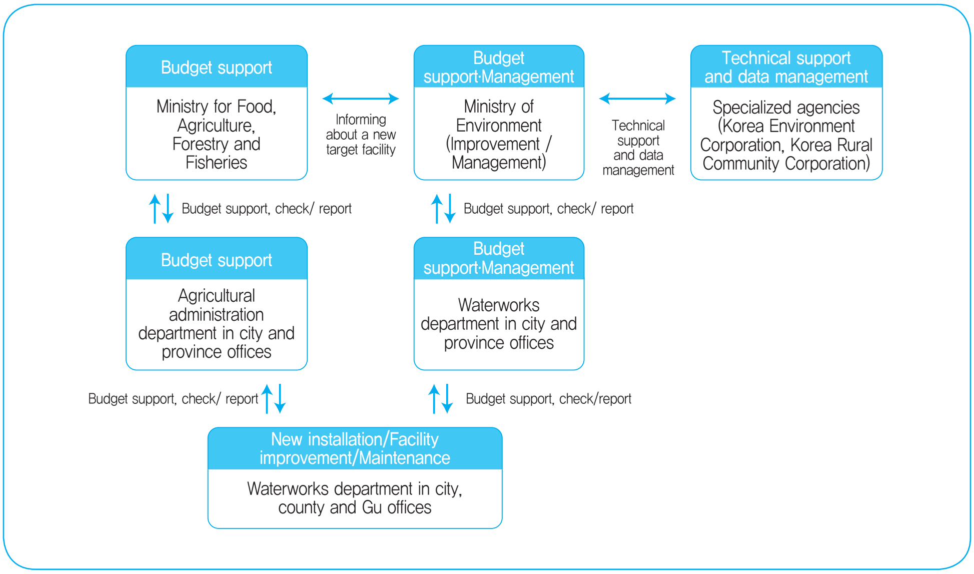
The duties of facility maintenance were as follows:

1. Sanitary management and record-keeping for the facility
2. Repair and expansion of the facility
3. Water quality control
4. Water quality management
5. Emergency restriction of water supply
6. Facility protection
7. Procuring maintenance and administration fees

However, according to a report from KREI, when the head of a village or a leader of Saemaeul was actually in charge of the small water facility, householders were involved in that work and only a few villages employed employees for that work (KREI, 1978).

Through a revision of the Waterworks Law and Public Health Act in 1993, small waterworks were included in the village drinking water system and the responsibility for that project was transferred to the Ministry of Construction and Transportation. In April 1994, it was transferred again to the Ministry of Environment. Since August 2008, to improve the waterworks for living under two authorities, i.e., the Ministry of Environment and the Ministry for Food, Agriculture, Forestry and Fisheries, the Ministry of Environment has been in charge of the arrangement of Waterworks Law-related regulations, the improvement of the management system, water quality control of the small-scale water supply facilities, etc., and the Ministry for Food, Agriculture, Forestry and Fisheries has been in charge of the installation of the new waterworks for living/agricultural use according to the Rural Villages Rearrangement Act.

Figure 2-2 | Procedures for the Operation/Management of Small-scale Water Supply Facilities



Source: Ministry of Environment ·Ministry of Food, Agriculture, Forestry and Fisheries (2008)

Currently, the mayor, the county governor and the head of a *Gu* (district) take legal responsibility for managing the village drinking water system and the small waterworks. According to Article 47 of the Waterworks Law, the state and local governments should provide technical and financial support for sanitary management of the village drinking water system, and the special metropolitan city mayor, the metropolitan city mayor, the special local city head, the special province governor, the mayor and the county governor (excluding the county governor of a metropolitan city, hereinafter a local government head), according to an ordinance of the local government, should properly run and manage the village drinking water systems under their jurisdiction.

Furthermore, Article 55 says that a local government head, according to the regulation of the Ministry of Environment, should check the water quality of the small waterworks and, according to the ordinance by the local government, endeavor to improve and manage their small waterworks.

In relation to the small-scale water supply facilities, each local government is responsible for their management. However, as they are difficult for a limited number of people to manage, in many cases, a representative of a village who is not a professional is designated as a manager and runs and manages them, and the local government only conducts inspections of water quality, training of the manager and the supply of drugs for disinfection.

Table 2-2 | Management System of the Small-scale Water Supply Facilities

Division	Managing body	Financing
Village drinking water system	A local government head (Article 47 in the Waterworks Law)	Local government
Small waterworks	A representative of the users' council (According to the ordinance of the local government)	Users (Local government can bear a portion of the cost)

Source: Ryu Mun-hyeon and Kim Sang-moon (2008)

2.2. Financial Support

As mentioned above, under Article 47 of the Waterworks Law, the state and the local government ought to provide the technical and financial support required for sanitary management of the village drinking water system. As for the small waterworks, Article 55 of the same Law specifies that the state and local governments could provide the technical and financial support required for the installation and sanitary management of the small waterworks.

The general details related to budget preparation, execution and settlement with an assisting (financing) organization such as the Ministry of Environment and local government must comply with "National Finance Law", "Law on budget and management of subsidy", "Special law on balanced national development" and "Determination on the lending conditions for environmental improvement special account (Notice from Ministry of Environment)", and for the effective implementation of budget-related tasks, detailed principles and procedures should be established. The budget that the Ministry secures for improving the small-scale water supply facilities and allocates to the local governments was converted from the Special Account for Environmental Improvement to the Special Account for Balanced National Development (currently the Special Account for Regional Development) in 2005. <Table 2-3> shows the national subsidies ratio for the water supply system, which shows that projects for developing drinking water sources in urban areas, projects for developing water for living in rural areas, projects for improving small-scale water supply facilities, etc., are allocated as special accounts for regional development and receive national subsidies of 70%.

Table 2-3 | The National Subsidies Ratio for the Water Supply System

Division	Name of the project	Type of financial support	Subsidies ratio (%)
Special account for environmental improvement	Local water service development in small and medium sized cities	Loan	50 (Cities) 60 (Counties)
	Work of connecting water supply manifold for households receiving public assistance	Subsidy	50
	Indoor water pipe improvement support for low-income groups	Subsidy	50
	Project to expand drinking water-only dams and secure their stability	Subsidy	50 (Improvement), 70 (New construction)
	Project to remodel deteriorating purification plant	Subsidy	50
Special account for regional development	Project to develop riverbank filtrate	Subsidy	70 (New construction), 50 (Ongoing)
	Project to develop drinking water source in island areas	Subsidy	70
	Project to develop water for living in rural areas	Subsidy	70 (New construction), 80 (Ongoing)
	Advanced water treatment system	Subsidy	70 (New construction), 50 (Ongoing)
	Project to improve small-scale water supply facilities	Subsidy	70
	Project to construct optimal management system for water pipe network	Subsidy	30±20

Source: Practice for budget preparation, execution and management for water supply field (Ministry of Environment, 2011)

3. Small-scale Water Supply Facility and Treatment Technology

3.1. Installation Status of Small-scale Water Supply

As an initial policy attempt to solve the issue of drinking water in rural areas, the Korean government started this project of installing small-scale water supply systems with IBRD loans in the 1970s. In 1995, the number of systems installed amounted to 25,882, and the rural population using water reached 3.65 million. From this, we may understand that this project has greatly contributed to supplying drinking water to rural areas. <Table 2-4> shows the status of the small-scale water supply facilities in 2003-2010. As of the end of December, 2010, there were 19,847 small-scale water supply facilities being run all over the country, including 8,811 village drinking water systems and 11,038 small waterworks. A total of 1.87 million people were using the small-scale water supply facilities, and of these, the population using the village drinking water system amounted to 1.263 million, and the small waterworks 0.607 million.

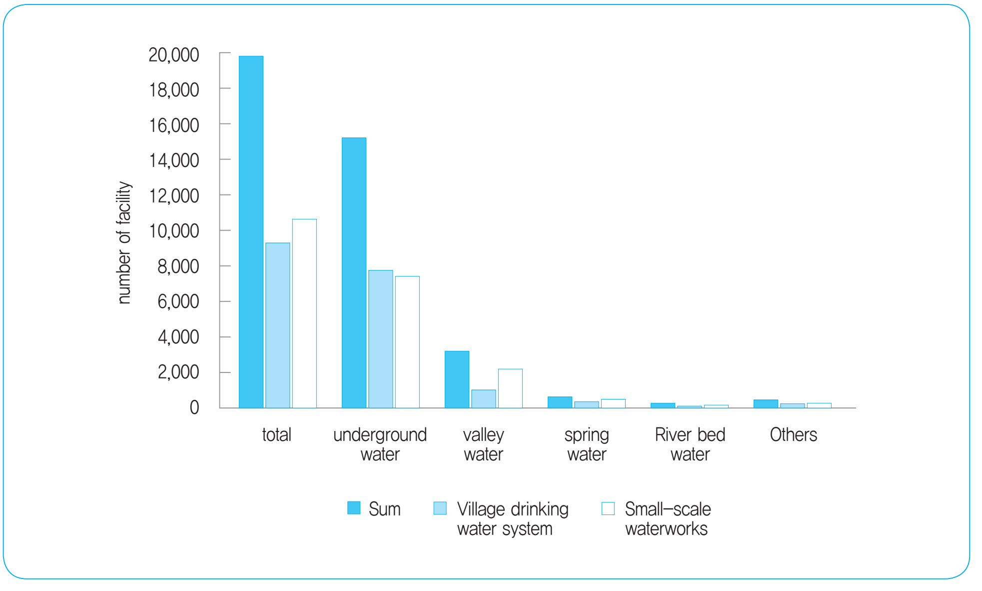
Table 2-4 | Number of Village Drinking Water Systems and Small Waterworks and the Population Using the Facilities, by Year

Division	Village drinking water system		Small waterworks	
	Population using the systems (unit: 1,000 people)	Number of systems	Population using the waterworks (unit: 1,000 people)	Number of waterworks
1995	3,645,951	25,882	-	-
1997	3,154,457	24,971	-	-
1999	2,153,468	11,250	744,920	12,944
2001	2,033,031	11,085	719,124	12,755
2003	1,872	10,905	687	12,647
2004	1,793	10,804	674	12,413
2005	1,698	10,554	652	12,095
2006	1,682	10,252	620	11,444
2007	1,572	10,221	601	11,609
2008	1,437	9,658	618	11,295
2009	1,331	9,415	636	11,202
2010	1,263	8,811	607	11,038

Source: www.index.go.kr

[Figure 2-3] shows the status of the small-scale water supply facilities by water source. As of the end of 2009, 76.6% of small-scale facilities that were being run were found to use underground water as their water source, followed by valley water, spring water and river bed water. Of the small-scale facilities, it was found that 83.3% of the village drinking water systems used underground water, while 70.7% of small waterworks used underground water, followed by valley water at 20.9% and spring water at 4.7%.

Figure 2-3 | Small-scale Water Supply Facilities by Water Source (2009)



Source: www.index.go.kr

3.2. Small-scale Waterworks Treatment Technology

3.2.1. Water Pollution Sources

The main pollution sources of village drinking water systems are bacteriomycota, turbidity and nitrate nitrogen. Bacteriomycota refers to a number of bacteria and coliform groups. While the majority of bacteria are harmless, if there are too many bacteria in water, there is a high possibility that it has been polluted by animal refuse, and so the water is not good to drink. Coliform groups exist in human excretion in large quantities. As a water-borne pathogen exists with coliform group, this is used as a pollution indicator.

Turbidity indicates the degree of cloudiness of water, and, at the same time, indicates the presence of suspended solids. Turbidity is caused by organics and inorganics, bacteria, microorganism, algae, and the likes flowing from earth and sand, and sewage and waste water. Water with a high turbidity not only has an unpleasant appearance but also may be polluted by waste water.

Nitrate nitrogen is the end product resulting from an aerobic decomposition of nitrogen compounds in organic matter. As sewage or treated wastewater flows into the river, its concentration increases, and the major pollution source is fertilizer and inorganic chemistry industrial waste. Nitrate nitrogen is reduced by microorganisms into nitrite nitrogen, which reacts with hemoglobin in the blood stream and damages some functions of the oxygen transfer system of the blood. In particular, the long-term consumption of water containing nitrate nitrogen will cause cyanosis in infants. In areas where high amounts of fertilizers are used, or where livestock wastewater flows into an underground water source, nitrate nitrogen is the major water pollution source.

3.2.2. The Status of the Treatment Technology

The water source of small-scale water supply facilities is mostly good quality underground water or valley water, which can be used without any special filtration. However, as there is a possibility that various pollutants will flow into the water from its surroundings, depending on characteristics of the water source, it can be used as drinking water or water for daily use after the treatment process. <Table 2-5> shows the general water treatment process for the water sources of small-scale water supply facilities.

Table 2-5 | Water Treatment Process for Various Water Sources of the Village Drinking Water System

Water source	Water treatment process
Spring water	Water intake → Disinfection
Underground water	Water intake → Iron and hardness removal → Disinfection → Slow filtration → Disinfection
Valley water	Water intake → Plain sedimentation → Slow filtration → Disinfection
Lake and reservoir water	Water intake → Chemical pre-treatment → Plain sedimentation → Slow filtration → Disinfection → Coagulation → Precipitation → Rapid filtration → Disinfection
Surface water	Water intake → Chemical pre-treatment → Coagulation → Precipitation → Rapid filtration → Disinfection → Hardness removal → Disinfection
River bed water	Slow development : Water intake → Plain sedimentation → Slow filtration → Disinfection Rapid development: Water intake → Chemical pre-treatment → Coagulation → Precipitation → Rapid filtration → Disinfection
Oxygen-poor surface water and reservoir water	Water intake → Aeration → Chemical pre-treatment → Coagulation → Precipitation → Rapid filtration → Disinfection
High-turbidity surface water	Water intake → Chemical pre-treatment → Coagulation → Precipitation → Rapid filtration → Disinfection → Grit chamber → Chemical pre-treatment → Coagulation → Precipitation → Rapid filtration → Disinfection

Table 2-6 | The Status of the Water Treatment of Small-scale Water Supply Facilities (as of the end of 2009)

Category	Total	Slow filtration	Rapid filtration	Membrane filtration	Activated carbon	Others	Untreated water
Total	18,680	514	62	189	1	170	17,744
Village drinking water system	8,015	225	39	101	0	77	7,573
Small waterworks	10,665	289	23	88	1	93	10,171

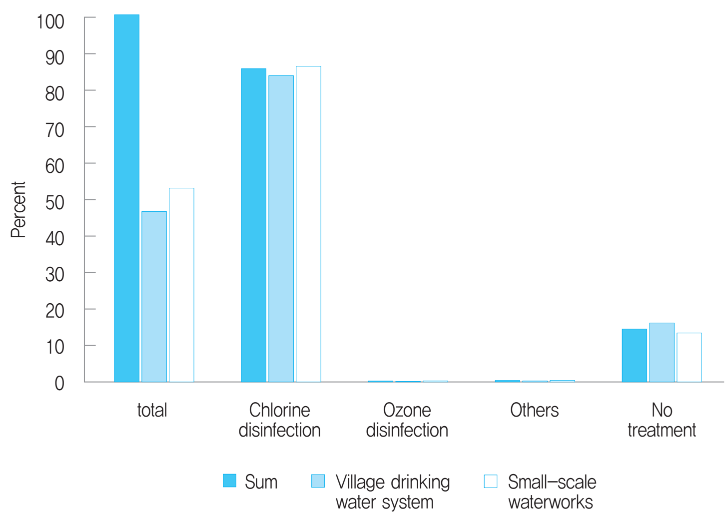
Source: www.index.go.kr

a. Disinfection System

Chlorine disinfection was first used in the USA in 1906. Korea is assumed to have used chlorine for disinfection since 1910. [Figure 2-4] shows the status of the disinfection systems for small-scale water supply facilities.

It was found that 85.3% of the small-scale water supply facilities supplied water after disinfection treatment and 14.7% supplied water only after storing it in the water tank. Looking at the types of disinfection used, the chlorine disinfection system was the most prevalent, at 99.6%. A chlorine disinfection system is easy to install and handle, and its initial cost is cheap. Looking at the village drinking water systems, it was found that 83.5% had a chlorine disinfection system installed and 0.26% used another type of disinfection system. Looking at the small waterworks, it was found that 86.3% of small waterworks used a chlorine disinfection system, while on the other hand 13.4% did not have any disinfection system.

Figure 2-4 | Status of Disinfection Systems (as of the end of 2009)



Source: www.index.go.kr

Liquified chlorine, calcium hypochlorite, sodium hypochlorite and chlorine dioxide were designated as standards for chlorine disinfectant. A method of disinfecting small scale water supply systems includes injecting sodium hypochlorite and input of solid calcium hypochlorite (See Appendix for details) (Ministry of Environment, 2002).

Table 2-7 | Characteristics of Chlorine Disinfectants by Type

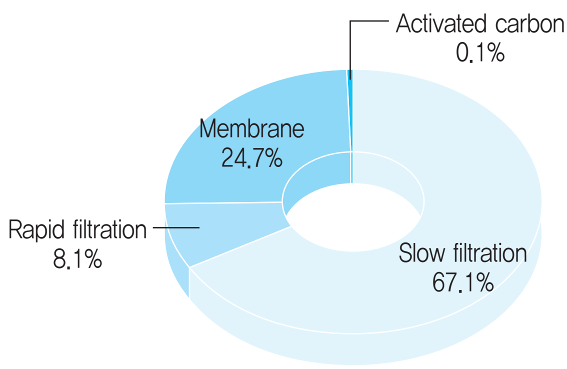
Division	Liquefied chlorine	Sodium hypochlorite	Calcium hypochlorite (Bleaching powder)
Phase	Liquid	Liquid	Solid
Available chlorine	100%	10-12%	60-70%
Preparation method	NaCl→Na+ + Cl- 2Cl→Cl2 +2e-	2NaOH +Cl2→ NaClO + NaCl +H2O	2Ca(OH)2 + 2Cl2→ Ca(OCl)2 +CaCl +2H2O
Use	Large sized filtration plant	Medium-small sized filtration plant Small-scale water supply system	Small-scale water supply system

Source: Ministry of Environment(2002)

b. Filtration Technology

Of the village drinking water systems and small waterworks, 5.1% were found to have a filtration process, and the majority of these (67.1%) were found to adopt slow filtration, followed by membrane filtration at 24.7%, rapid filtration at 8.1% and activated carbon at 0.1% (See Appendix for details).

Figure 2-5 | Status of Running Filtration Treatment by Process (as of the end of 2009)



Source: www.index.go.kr

c. Nitrate Removal Technology

If the water source of a small waterworks is underground water, it has a high possibility of being polluted by nitrate nitrogen ions. Water polluted by nitrate nitrogen ions can cause many health risks, particularly blue baby syndrome. Typical methods of removing nitrate nitrogen from water are the ion-exchange method, reverse osmosis, the electrodialysis method and the electrolytic method (See Appendix for details).

4. Drinking Water Quality Standard and Status

To secure the safety of quality of drinking water, a management authority, such as the water service provider, implements a water inspection system by classifying inspection items and inspection periods according to the type of the water supply facility. In addition to a legal inspection implemented by a general water service provider and an industrial water service provider, a joint verification inspection is performed twice a year through private-public cooperation (first half: Apr.1-May.31, Second half: Sep.1-Oct.31), so that if problems are found, the relevant authorities or local governments can take corrective action. Private-public joint inspection of water quality selects an object facility to be inspected according to the actual state of the region, but for village drinking water systems, relatively old facilities are generally inspected.

Table 2-8 | Status of Facilities to be Inspected by Private-public Cooperation for Water Quality (by half-year)

City/ Province (*Do*)	Number of object facilities to be inspected	Filtration plant			Faucet	Village drinking water system, etc.				Note
		Total	Local	Megalopolis		Total	Village drinking water system	Only for Water supply	Small waterworks	
Total	3,439	485	463	22	2,325	628	375	27	226	
Seoul	355	6	6	-	349	-	-	-	-	
Busan	183	4	4	-	175	4	3	-	1	
Daegu	125	5	5	-	110	10	5	-	5	
Incheon	94	7	7	-	70	17	9	-	8	
Gwangju	58	4	4	-	50	4	2	-	2	
Daejeon	57	3	3	-	50	4	-	-	4	
Ulsan	63	3	3	-	50	10	10	-	-	
Gyeonggi	365	39	39	-	192	134	74	22	38	
Gangwon	324	86	84	2	220	18	18	-	-	
Chungbuk	199	27	25	2	108	64	52	-	12	
Chungnam	177	21	17	4	84	72	35	2	35	
Jeonbuk	142	27	23	4	84	31	17	-	14	
Jeonnam	356	88	88	-	178	90	59	-	31	
Gyeongbuk	552	94	89	5	382	76	39	3	34	
Gyeongbuk	304	55	50	5	159	90	48	-	42	
Jeju	84	16	16	-	64	4	4	-	-	

*Target faucets to be inspected

1) 4 faucets per filtration plant in *Do* (city/county). (In consideration of workload, self-adjusting is allowed.)

2) For regional units larger than megalopolis, selection is based on a proportion of the population, excluding that of cities and counties

* Village drinking water system, etc.: Select more than about 2% of facilities in operation

Source: Ministry of Environment (2011b)

Water quality standards and inspection for small-scale water supply facilities were performed on 16 items of inspection (such as general bacteria, total coliform group, fecal coliform, or colon bacillus, ammonia nitrogen, nitrate nitrogen, smell, taste, chromaticity, turbidity, fluorine, Manganese, Aluminium, residual chlorine, boron and chlorine ion) which are microorganisms, harmful nonorganics, harmful organics, etc., at least once every quarter.

Since January 2008, 55 items such as general tap water have been inspected once a year. The inspection period and inspection items were partially revised, so that an item whose inspection result has been below 10% of the limit under the water quality standard for three years could be inspected only once every three years.

Under Article 2 of the regulation on water quality and inspection for drinking water, bromodichloromethane (0.03mg/L) and dibromochloromethane (0.1mg/L), which are disinfection by-products, were added to the water quality standard for drinking water in 2010, and 1.4-dioxane (0.05mg/L) as a trace hazardous chemical was also newly added in Jan 2011. With this, a total of 58 items for water quality standard have been inspected.

Table 2-9 | Items and Standard of Inspection for Drinking Water (as of 2011)

Type		Items of inspection
Filtration plant	Daily (6 items)	smell, taste, chromaticity, turbidity, hydrogen ion concentration, residual chlorine
	Every week 1) (8 items)	general bacteria, total coliform group, fecal coliform, or colon bacillus, ammonia nitrogen, nitrate nitrogen, potassium permanganate consumption, residues evaporated
	Every month 2) (52 items)	Excluding disinfectants and disinfection by-products
	Every quarter (6 items)	6 items of 8 disinfection by-products (residual chlorine, chloral hydrate, dibromoacetonitrile, dichloroacetonitrile, trichloroacetonitrile, haloacetic acid)
Faucets	Every month (5 items)	general bacteria, total coliform group, fecal coliform, or colon bacillus, residual chlorine
Water pipes Deteriorated areas Faucets	Every month (11 items)	general bacteria, total coliform group, fecal coliform, or colon bacillus, ammonia nitrogen, Fe, Cu, Zn, Mn, Chlorine ion, residual chlorine
By water service process Facilities	Every quarter (12 items)	general bacteria, total coliform group, fecal coliform, or colon bacillus, ammonia nitrogen, total trihalomethane, copper, pH, zinc, Fe, turbidity, residual chlorine
Village drinking water system Drinking water-only system Small waterworks	Every quarter 3) (16 items)	general bacteria, total coliform group, fecal coliform, or colon bacillus, ammonia nitrogen, nitrate nitrogen, smell, taste, chromaticity, turbidity, fluorine, manganese, aluminium, residual chlorine, boron and chlorine ion (seawater only)
	Yearly: all items (58 items)	All items of water quality standard for drinking water
Drinking water public facilities	Every quarter 4) (8 items)	general bacteria, total coliform group, fecal coliform, or colon bacillus, ammonia nitrogen, nitrate nitrogen, potassium permanganate consumption, residues evaporated
	Every year (49 items)	All items of water quality standard for drinking water (Excluding disinfectants and disinfection by-products)

1) Items of general bacteria, total coliform group and fecal coliform or colon bacillus must be checked at least once a week, and other items can be adjusted to be checked at least once a month, based on the result of the inspection for the last one year

2) Items of general bacteria, total coliform group, fecal coliform, or colon bacillus, ammonia nitrogen, nitrate nitrogen, potassium permanganate consumption, smell, taste, chromaticity, pH, chlorine ion, manganese, turbidity and aluminium must be checked at least once a month, and other items can be adjusted to be checked at least once every quarter according to the results of inspection for the last three years

3) Depending on the results of inspection for 3 years, inspection can be adjusted to at least once every 6 months.

4) During the third quarter of the year, inspection must be conducted every month

※ Under Article 4, Attached table 1 in the regulation on water quality and inspection for drinking water, for a village drinking water system, when yearly inspection for all items overlaps with quarterly inspection, the yearly inspection for overall items can replace the quarterly inspection. (Computer input essential)

Source: Ministry of Environment (2011c)

As the water quality standard for drinking water is set in consideration of the effect of water on the human body, water that meets the standard is safe and good to drink. <Table 2-10> shows the water quality standard for drinking water according to 58 items. On January 1 2011, the standard was changed from “0.05mg/L” to “0.01mg/L” for lead, from “0.05mg/L” to “0.01mg/L (spring water 0.05mg/L)” for arsenic, from “0.3mg/L (excluding spring water)” to “0.05mg/L (excluding spring water)” for manganese in tap water only and “hexavalent chrome” was changed to “chrome (0.05mg/L)” (Ministry of Environment, 2011c).

Table 2-10 | Water Quality Standards for Drinking Water

NO	Items	Water quality standard	NO	Items	Water quality standard
1	General bacteria	below 100 CFU/mL	30	Carbaryl	below 0.07mg/L
2	Total coliform group	Non-detection/100mL Non-detection/250mL (spring water, drinking spring water, drinking deep sea water)	31	1,2-dibromo-3-chloropropane	below 0.003mg/L
3	Fecal coliform	Non-detection/100mL	32	Residual chlorine	below 4.0mg/L
4	Colon bacillus	Non-detection/100mL	33	Total trihalomethane	below 0.1mg/L
5	Lead	below 0.01mg/L	34	Chloroform	below 0.08mg/L
6	Fluorine	below 1.5mg/L below 2.0mg/L (spring water, drinking spring water)	35	Chloral hydrate	below 0.03mg/L
7	Arsenic	below 0.01mg/L below 0.05mg/L (spring water)	36	Dibromoacetonitrile	below 0.1mg/L
8	Selenium	below 0.01mg/L	37	Dichloroacetonitrile	below 0.09mg/L
9	Mercury	below 0.001mg/L	38	Trichloroacetonitrile	below 0.004mg/L
10	Cyanogen	below 0.01mg/L	39	Haloacetic acid	below 0.1mg/L
11	Chrome	below 0.05mg/L	40	Hardness	below 300mg/L below 500mg/L (drinking spring water) below 1,200mg/L (drinking deep sea water, drinking underground water)
12	Ammonia nitrogen	below 0.5mg/L	41	Potassium permanganate consumption	below 10mg/L

NO	Items	Water quality standard	NO	Items	Water quality standard
13	Nitrate nitrogen	below 10mg/L	42	Smell	There must be no smell other than a smell caused by disinfection
14	Boron	below 1.0mg/L	43	Taste	There must be no taste other than a taste caused by disinfection
15	Cadmium	below 0.005mg/L	44	Copper (Cu)	below 1mg/L
16	Phenol	below 0.005mg/L	45	Chromaticity	below 5 degree
17	1,1,1- Trichloroethane	below 0.1mg/L	46	Detergent	below 0.5mg/L Non-detection (spring water, drinking spring water, drinking deep sea water)
18	Tetrachloroethylene	below 0.01mg/L	47	pH	5.8-8.5
19	Trichloroethylene	below 0.03mg/L	48	Zinc	below 3mg/L
20	Dichloromethane	below 0.02mg/L	49	Chlorine ion	below 250mg/L
21	Benzene	below 0.01mg/L	50	Residues evaporated	below 500mg/L
22	Toluene	below 0.7mg/L	51	Fe	below 0.3mg/L
23	Ethylbenzene	below 0.3mg/L	52	Mn	below 0.3mg/L below 0.05mg/L (tap water)
24	Xylene	below 0.5mg/L	53	Turbidity	below 1NTU below 0.5NTU (tap water)
25	1,1-Dichloroethylene	below 0.03mg/L	54	Sulfate ion	below 200mg/L
26	Carbon tetrachloride	below 0.002mg/L	55	Aluminium	below 0.2mg/L
27	Diazinone	below 0.02mg/L	56	Bromodichloromethane	below 0.03mg/L
28	Parathion	below 0.06mg/L	57	Dibromochloromethane	below 0.1mg/L
29	Fenitrothion	below 0.04mg/L	58	1,4-dioxane	below 0.05mg/L

Source: Ministry of Environment (2011c)

<Table 2-11> shows the results of water quality inspections jointly implemented by private and public cooperation on a total of 3,456 facilities, including filtration plants, faucets, village drinking water systems, etc., in the first half of 2010. The inspections implemented in the second half of 2009 showed a high rate of facilities that did not meet the water quality standard, at 8.1%. However, from the results in 2010, it was found that only 9 facilities

(1.4%) of the total 628 small-scale water supply facilities, including village drinking water systems and small waterworks, did not meet the water quality standard for drinking water.

Table 2-11 | The Results of Inspection on Water Quality Jointly Implemented by Private - Public Cooperation (2005-2010)

Inspection time	Category	Results of Inspection			
		Total number of inspections	Conformity	Non-conformity	Ratio that did not meet the standard (%)
The first half of 2005	Total	3,263	3,244	19	0.6
	Filtration plant	529	528	1	0.2
	Faucet	2,111	2,108	3	0.1
	Small-scale water supply system, etc.	310	295	15	4.8
	Storage tank	313	313	0	0.0
The first half of 2006	Total	6,568	6,476	92	1.4
	Filtration plant	1,032	1,031	1	0.1
	Faucet	4,194	4,193	1	0.02
	Small-scale water supply system, etc.	711	621	90	12.7
	Storage tank	631	631	0	0
The second half of 2006	Total	3,266	3,216	50	1.6
	Filtration plant	510	510	0	0
	Faucet	2,085	2,084	1	0.05
	Small-scale water supply system, etc.	356	307	49	12.8
	Storage tank	315	315	0	0
2007	Total	137,846	135,185	2,661	1.93
	Filtration plant	5,740	5,736	4	0.07
	Faucet	60,952	60,934	18	0.03
	Village drinking water system, etc.	71,157	68,518	2,639	3.7

Inspection time	Category	Results of Inspection			
		Total number of inspections	Conformity	Non-conformity	Ratio that did not meet the standard (%)
2008	Total	160,181	157,654	2,527	1.58
	Filtration plant	5,841	5,838	3	0.05
	Faucet	69,733	69,732	1	0.001
	Village drinking water system, etc.	84,607	82,084	2,523	3.0
The first half of 2009	Total	3,404	3,388	16	0.5
	Filtration plant	486	486	0	0
	Faucet	2,324	2,324	0	0
	Village drinking water system, etc.	594	578	16	2.7
The second half of 2009	Total	3,390	3,342	48	1.4
	Filtration plant	485	485	0	0
	Faucet	2,325	2,324	1	0.04
	Village drinking water system, etc.	580	533	47	8.1
The first half of 2010	Total	3,456	3,447	9	0.3
	Filtration plant	484	484	0	0
	Faucet	2,344	2,344	0	0
	Village drinking water system, etc.	628	619	9	1.4

Source: Ministry of Environment (2010b)

Chapter 3

Small-scale Sewerage System

Small-scale Sewerage System

1. Background

1.1. Background and Rationale

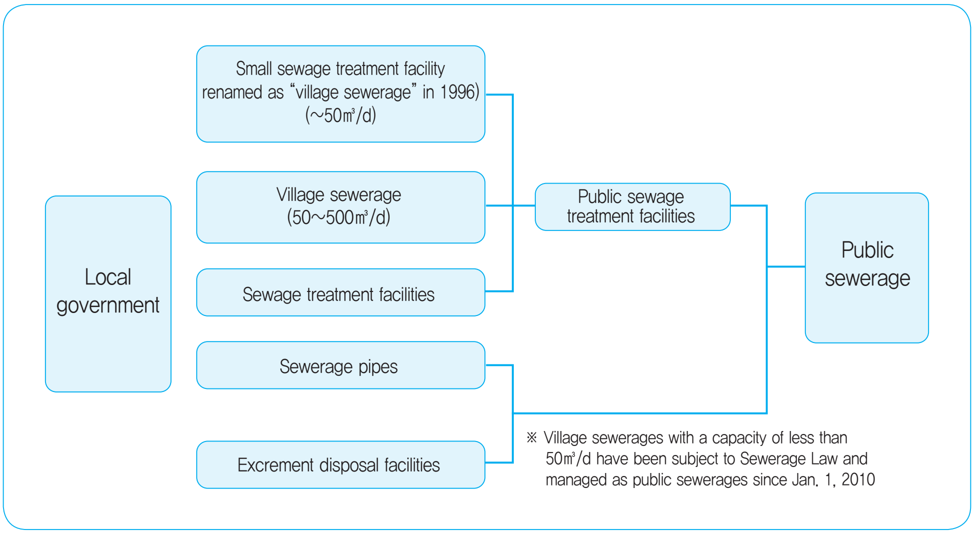
Sewerage is usually considered an urban infrastructure, and the government started to reorganize sewerage with the construction of sewage treatment plants in urban areas in the 1980s. However, as standards of living improved, stock farmers increased and flush toilets propagated with the supply of waterworks in rural areas; the pollution load greatly increased. Water became polluted, securing good water resources became a difficult task and bad smells and flies were present, and all of these issues greatly threatened the living environment in rural areas. To prevent the pollution of public waters and to contribute to the sound development and improvement of public health in rural areas by ensuring a sound environment, the Korean government began supplying village sewerage and small-scale sewage treatment facilities (hereinafter small-scale sewerage system), which had previously only been found in large cities. The small-scale sewerage project started with adding village sewage treatment facilities to the redevelopment planning in rural farm areas that had been run since 1976 and constructing 91 village sewerages on a trial basis from 1991 to 1994. Then, to resolve the depressed atmosphere of rural villages that had been caused by the result of the Uruguay Round Negotiations, the government planned political investment, and based on a special tax for rural areas for investment in rural villages that was established in 1995, started to drive the project. In the agricultural special tax project, based on the program to improve rural living conditions, the sewerage project focused on *myeon* or villages and was run for 10 years from 1995 to 2004 (KWWA: Korea water & wastewater works association, 1998).

1.2. Definition and Roles of the Small-scale Sewerage System

1.2.1. Definition and Purpose of the Small-scale Sewerage System

Under the 4th clause of article 2 in the Sewerage Law, a small-scale sewerage system is defined as a public sewage treatment facility with a sewage treatment capacity of less than 500 tons a day. Before the Sewerage Law was revised in September 2007 (Promulgation on Sep 27, 2006; Enforcement on Sep 28, 2007), small sewage systems had been called village sewage facilities. Small sewage treatment facilities with a capacity of less than 50 tons a day that had been illegal facilities and installed according to the Act on Rearrangement of Rural Villages and Act on the Promotion of Amelioration of Housing in Rural villages were renamed village sewerages and became legal facilities in 1996. Since 2010, these have been managed as public sewerages under the Sewerage Law.

Figure 3-1 | Classification of the Public Sewerage



Source: Lee, Ho-sik (2008)

[Figure 3-2] shows village sewerage; the image on the right shows a facility placed underground.

Figure 3-2 | Small-scale Sewerage System

The purpose of constructing the village sewerage is to invest reasonable construction costs and maintenance fees and to create a living environment adapted to rural areas, protecting water sources and preserving the water quality of public waters. <Table 3-1> is a comparative chart showing the differences between the village sewerage and the urban sewerage.

Table 3-1 | A Comparative Chart of Maintenance Systems in the Village and the Urban Sewerages

Division	Village sewerage	Urban sewerage	Note
1. Method of excluding sewage	Incomplete separate sewer system *1	Combined sewer system, separate sewer system	*1 In an incomplete separate sewer system, wastewater is collected through a watertight culvert, but rainwater through the existing drainway if possible. Laying of storm sewer should be minimized. *2 Included in the small-scale sewerage
2. Sewage treatment system	Small scale distributed treatment	Large scale centralized treatment	
3. Sludge disposal	Green belt and farm restoration is possible. (compost, soil conditioner)	Difficulties in Green belt and farm restoration (Reclamation, incineration, etc)	
4. Unit of administration	Ri*2 (Unit of rural area)	Cities (including metropolitan cities and megalopolises) Small cities (*Eup, Myeon**2)	
5. Relevant laws	Act on the Promotion of Amelioration of Housing in Rural villages (Ministry of Environment since 2007) Act on Rearrangement of Rural Villages (Ministry of Agriculture and Forestry) Sewerage Act (Ministry of Environment)	Sewerage Act (Enforced in August 1966)	

Source: Kim, Eung-ho (2002)

1.2.2. Role of the Small-scale Sewerage System[2]

The small-scale sewerage system should play the basic role of a sewerage facility by improving the living environment and preventing flooding and water pollution of the public waters, and also play an auxiliary role in collecting organic waste resources according to the particular situation of the rural area.

2. Kim, Eung-ho (1998) Characteristics of construction of village sewerage and effective management, Sewerage research society.

a. Easy Conveyance of Rainwater and Wastewater

The village sewerage, as a facility to improve the living environment, must be able to smoothly convey rainwater and wastewater away from the village. For the conveyance of rainwater in rural areas, natural drainage is used to the greatest extent possible, but if storm sewers are required, a U-shaped gutter or a storm sewer should be planned so that flooding does not occur. Since the majority of wastewater in rural areas is related to livestock waste, as village sewerage is constructed, people will be able to convey wastewater through a watertight wastewater pipe line. This will eliminate the need for ditches in the village, improving the living environment.

b. Preventing Water Pollution at an Early Stage in the Rural Area

The main purpose of the village sewerage as a facility that properly treats all sorts of wastewater produced from the village is to prevent water pollution at its earliest stage. In this way, it is expected that polluted water in rural streams can be purified. Also, the construction of this system could contribute to protecting water quality and conserving the ecosystem of rural streams.

c. Collection and Use of Organic Waste Resources

As the wastewater handled by a village sewerage differs from that handled by urban facilities (as it does not contain harmful substances such as heavy metal, etc., caused by industrialization), sludges produced by a village sewerage could be collected and converted into resources through the process of stabilizing and composting.

2. Framework of Small-scale Sewerage System

2.1. Changes in the Relevant Law

To contribute to the sound development of cities and improve public health, the Sewerage Law, consisting of 44 articles and supplementary regulations, was established on August 3, 1966. In its 1st revision in 1973, contents related to the collection of a sewer charge and restrictions on alternate uses were revised. In December 1982, through the 2nd reform, a foundation for planning sewerage construction projects was prepared. In the 4th reform in August 1994, based on a policy of unifying water management, work on sewerages was transferred from the Ministry of Construction to the Ministry of Environment, and the basic plan for constructing sewerage changed so that it could be planned every five years.

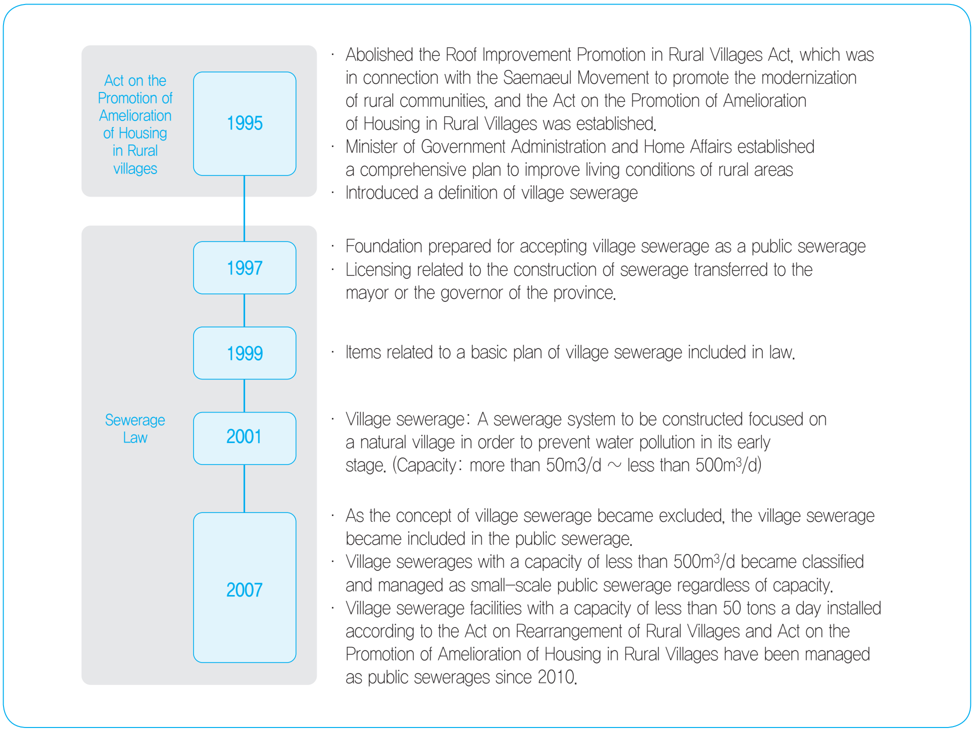
Village sewage treatment systems had previously been managed as illegal facilities without the observation of certain facility standards, and in 1966, small-scale sewage treatment facilities were renamed village sewerages and became legal facilities. In Korea's positive laws, the concept of the village sewerage appeared for the first time in Article 2 (Definition) of the Act on the Promotion of Amelioration of Housing in Villages. This article says that public sewerage should be constructed focusing on a natural village in order to prevent water pollution in the rural areas in an early stage.

The Act on the Promotion of Amelioration of Housing in Rural villages was established as Law No. 1891 on February 28, 1967, and its purpose was to promote the modernization of rural communities by improving the rural living environment in connection with the Saemaeul Movement. Subsequently, in accordance with the revision of Law No. 2385 in Dec 26, 1972, with a development project for rural community run by the Ministry of Home Affairs and the roof improvement promotion Act run by the Ministry of Agriculture and Forestry, the Ministry of Environment was newly organized and a project for village sewerages began to be managed and implemented by each government department.

In the 5^{th} revision of the Sewerage Law in March 1997, the village sewerage was included in the Sewerage Law for the first time. With this, a foundation on which the village sewerage could be accepted as a public sewerage was prepared, and the licensing related to the construction of sewerage was transferred to the mayor or the governor of the province. In the 6^{th} reform in February 1999, details on a basic planning for the village sewerage became included in the law.

Under the Sewerage Law in 2001, a village sewerage is a sewerage facility with a capacity of less than $50m^3/d$-$500m^3/d$ which was constructed focusing on a natural village in order to prevent water pollution in its early stage. However, with the revision of the Sewerage Law in 2006 (promulgation on September 27, 2006; enforcement on September 28, 2007), the concept of a village sewerage was excluded from the Sewerage Law and became included in the definition of "public sewerage" as of 2007; village sewerages with a capacity of less than 500 m^3/d became classified as "small-scale public sewerages" and were managed regardless of their capacities (Ministry of Environment, 2009). In addition, village sewerages with a capacity of less than 50 tons a day that were installed according to the Act on Rearrangement of Rural Villages and Act on the Promotion of Amelioration of Housing in Rural Villages have been managed as public sewerages since 2010.

Figure 3-3 | Changes in Law Related to the Small-scale Sewerage System



2.2. Operation Management System

2.2.1. Authorities in Charge and Project Area

In the early stage, the village sewerage project was implemented without a specific standard for facilities or method of management, according to the direction of government departments such as the Ministry of Home Affairs, the Ministry of Agriculture and Forestry and the Ministry of Environment. The Ministry of Home Affairs, based on the Act on the Promotion of Amelioration of Housing in Rural Villages and A Guideline for Agricultural Special Tax Projects, ran a small-scale sewerage project, and the Ministry of Agriculture and Forestry ran the project as part of the culture village creation project based on the Act on the Rearrangement of Rural Villages and the Act on the Special Measures for the Development of Rural Villages.

The Ministry of Environment ran a small-scale sewerage project focused on Myeon units in accordance with the guidelines for the Sewerage Law and the agricultural special tax project. In December 1997, with the aim of improving the efficiency of business consultation, project promotion and management among the three departments, the ‘integrated guidelines for village sewerage project’ were established to define project planning, implementing running, managing, etc., related to the village sewerage.

Based on those guidelines, village sewerages would be independently constructed by government departments, but their management after completion was unified under the Ministry of Environment. However, the support project of the Ministry of Government Administration and Home Affairs (Ministry of Home Affairs) was unified under the Ministry of Environment in accordance with a measure on the division of roles for finance support project for rural areas in 2006, and a project for constructing the village sewerage in rural areas began to be operated based on environmental improvement special accounts in 2007. Thus, according to the integrated guideline for small-scale sewerage projects established in 2007, based on the Act on the Promotion of Amelioration of Housing in Rural Villages, the project for improvement of the rural housing environment of the Ministry of Government Administration and Home Affairs was transferred to the Ministry of Environment. Currently, small-scale sewerage projects are run by the Ministry of Environment and the Ministry of Agriculture and Forestry.

Table 3-2 | Promotion, Management and Relevant Authorities for Small-scale Sewerage Projects

Division	Name of the project	Project to improve the rural housing environment	Project to improve the rural living environment	Sewerage project
Existing	Relevant authority	Ministry of Agriculture and Forestry	Ministry of Government Administration and Home Affairs	Ministry of Environment
	Applicable Act	Rearrangement of Rural Villages Act	Act on the Promotion of Amelioration of Housing in Rural Villages	Sewerage Law
	Details of the project	o Implementing the projects to rearrange an existing or a new village in order to improve the rural living environment.	o Implementing the projects to improve living environment after designating rural environment improvement area focused on natural village.	o Implementing a project of constructing small-scale public sewerage facilities for final treatment of wastewater produced in rural areas. o Implementing a project of small-scale public sewerage according to the Act on the Promotion of Amelioration of Housing in Rural Villages.
	Details of the village sewerage project	o Implemented as part of a project to improve the rural living environment. Facilities with a capacity range of 50 to 500 tons a day	o Implemented as part of a project to improve the rural residential environment. Facilities with a capacity range of 50 to 500 tons a day	o Implemented as part of a project to improve water quality. Facilities with a capacity range of 50 to 500 tons a day
Since 2007	Relevant authority	Ministry of Agriculture and Forestry.	Ministry of Environment	
	Applicable Act	Rearrangement of Rural Villages Act	Sewerage Law	
	Details of the project	o Implementing the projects to rearrange existing or new villages in order to improve the rural living environment.	o Implementing a project to construct small-scale public sewerage facilities for final treatment of wastewater produced in rural areas. o Implementing a project of small-scale public sewerage according to the Act on the Promotion of Amelioration of Housing in Rural Villages	

Source: Ministry of Agriculture and Forestry / Ministry of Environment (2007)

The target area of the small-scale sewerage project is selected based on the relevant regulations (Act on the Promotion of Amelioration of Housing in Rural Villages and Rearrangement of Rural Villages Act), but in order to improve the effectiveness of the small-scale sewerage project, the following areas are preferentially selected:

1. Certain farming or fishing areas where water pollution prevention programs are urgently needed (Areas that affects water sources such as a water source reserve and areas where agricultural water may be polluted by domestic sewage).
2. An area where water pollution can be significantly prevented (Village with a cluster of livestock farms, area near tourist attractions, etc.).
3. An area with large ripple effects of improving the living environment.
4. An area with a large pollutant load and discharge load.
5. A natural village with more than 20 households clustered within 300m, with wastewater flow of less than 500 tons/d (10 people/0.01km^2).

2.2.2. Planning and Running a Small-scale Sewerage Project

As Article 11 of the Sewerage Law says that the head of the local government should construct the public sewerage system according to the basic planning for the sewerage construction, small-scale sewerage projects should be targeted at areas designated as small-scale sewerage treatment areas in the basic planning for the sewerage construction. Through comprehensive consideration of the type of project, wastewater flow, economic feasibility and maintenance convenience, construction of one small-scale sewerage system separately for one village, or an integrated one for a few villages, should be selected. The small-scale sewerage project should include the following items: (Ministry of Agriculture and Forestry·Ministry of Environment, 2007)

1. Target year
2. Projected population and the population using sewerage
   - Estimated projected population by surveying the resident registration population and the actual resident population, comparing with past population movement and analyzing it.
3. Drainage region and sewage treatment area
   - Layout plan: Indicated on the layout plan of sewerage facilities of the existing basic plan for sewerage construction
   - Ground plan of the sewerage treatment area (1/5,000-1/10,000)

4. Design volume of sewage and design water quality
   - Estimated units of sewage flow and pollution load and deciding sewage inflow rate, inflow water of sewage and discharge water of sewage
   - Estimated the sewage flow based on home foul water in consideration of the fact that the project area is focused on a natural village

5. Sewerage pipes planning
   - Method of conveying sewage: Selecting the separate sewer system for conveying rainwater and wastewater and marking the condition of sewage discharge point on the floor plan.
   - Sewerage pipe construction planning: Sewerage pipes, in principle, should be planned for a structure for nonpressure flow, but a measure of introducing a pressure sewer pipe needs to be considered. In particular, if the depth at which sewer pipes are laid is more than 5m underground, vacuum or pressure type sewer pipes should be planned to lower the depth as much as possible.

6. Plan for wastewater sludge treatment and disposal
   - No dehydration facility for treatment of wastewater sludge generated from a small-scale sewerage pipes should be installed, but rather, a retaining facility to store sludges for a certain period of time is needed so that neighboring public sewage treatment facilities could collect and dehydrate the sludges.

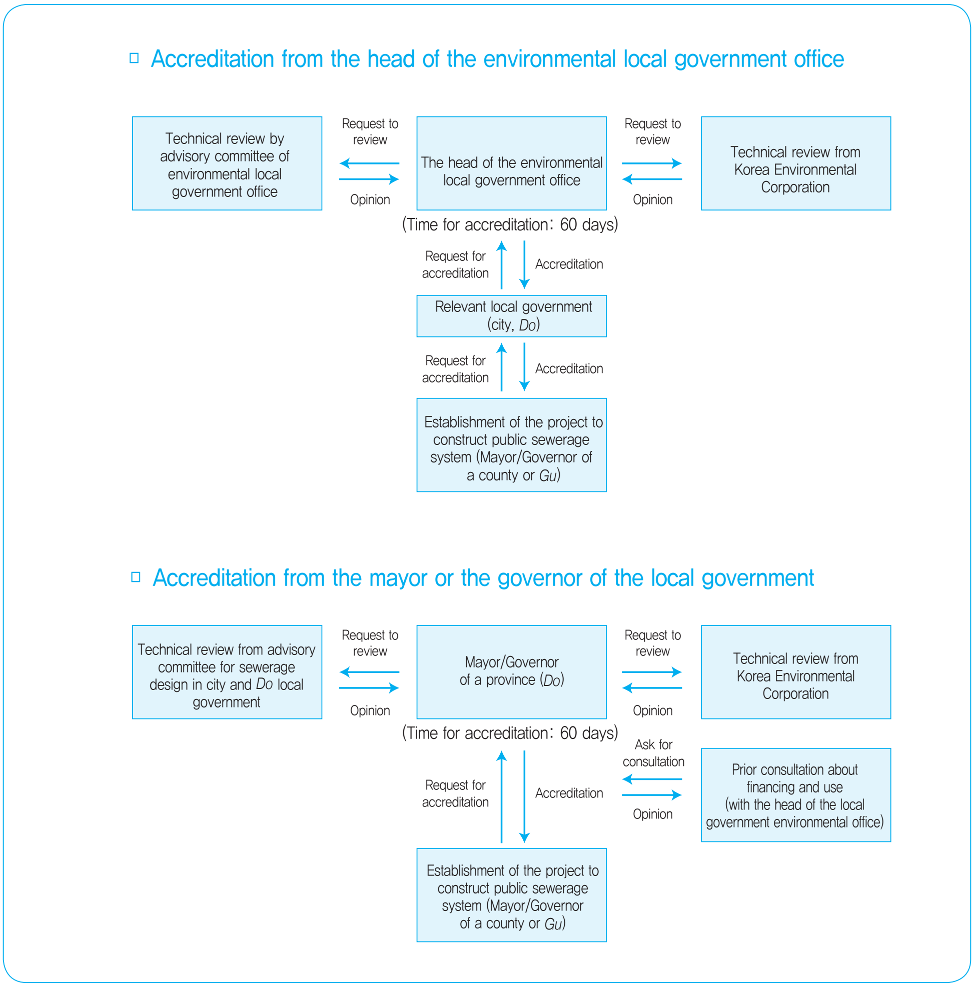
7. Plan for operation, maintenance and management
   - It is planned that a small-scale sewerage system be managed by neighboring public sewage treatment facilities on an integrated management basis, and in consideration of the lack of professional manpower, a degree of privatization of facility management should be positively considered.

8. Project cost and financing plan

When small-scale sewage treatment facilities are planned, the public sewerage management office performs a working design, complementing the results of a consultation from the Korea Environmental Corporation or an environmental advisory committee of the local government office and from the construction technology review committee, and then applies for accreditation.

If the public sewerage management office attempts to change (excluding petty matters) or abolish the accredited project, accreditation for changes or abolition should be received from the head of the environmental local government office or the mayor or the governor of the local government. For small-scale sewerage constructed with government subsidy, when the mayor or the governor of the local government notifies or permits it, prior consultation with the head of the environmental local government office about financing and use should be required. [Figure 3-4] shows a flow chart on the construction, change and abolition of the public sewerage facilities.

Figure 3-4 | Flow Chart on the Construction, Change and Abolition of Public Dewerage Facilities



Source: Ministry of Environment (2010b)

Since the small-scale sewerage facilities are regulated to operate with the unmanned integrated management system at nearby final sewage treatment facilities under the integrated guidelines for small-scale sewerage projects (Ministry of Agriculture and Forestry·Ministry of Environment, 2007), the small-scale sewerage facilities, unlike urban sewage treatment plants, are managed with a circulatory management system along with unmanned operation.

As the guidelines on the construction of the treatment facilities do not recommend a management building or laboratory, no additional facilities for stay of workers are prepared, except for treatment facilities. Therefore, while there are local government employees who are in charge of maintenance and management of the small facilities, nobody stays at the facilities on-site, and they are all operated under circulatory management. Furthermore, in consideration of the lack of professional manpower, a measure of privatization of facility management is recommended. According to the operation method, the small-scale sewage treatment facilities are divided into facilities managed by a professional service company, and those directly managed by the relevant department in the local government. <Table 3-3> shows the percentage of management on commission. The rate of management on commission was found to be about 46.7%, while the rate of direct management by local government was about 31.9%. In terms of the status of management on commission by region, Gyeonggi-do showed the highest rate at 78.9%, while Jeonbuk had the lowest rate at 12.8%. Chungbuk and Chungnam were in the range of 50-59%.

Table 3-3 | Management on Commission of Small-scale Sewage Treatment Facilities (as of 2010)

Administrative district	Total (number of facilities)	Local government (number of facilities)	Private (number of facilities)	Other (number of facilities)
Total	3,064	978	1,431	655
City of Seoul	4	2	2	-
City of Incheon	12	-	6	6
City of Busan	27	4	14	9
City of Daegu	16	-	-	16
City of Daejeon	2	-	-	2
City of Ulsan	10	3	7	-
City of Gwangju	9	7	-	2
Gyeonggi Do	303	34	239	30
Gangwon Do	319	124	149	46
Chungcheongbuk Do	223	73	113	37
Chungcheongnam Do	318	92	188	38
Jeollabuk Do	397	187	87	123
Jeollanam Do	731	302	347	82
Gyeongsangbuk Do	268	52	85	131
Gyeongsangnam Do	389	62	194	133
Jeju Do	36	36	-	-

Source: Ministry of Environment (2011d)

<Table 3-4> is a chart that compares the merits and demerits of privately-commissioned management and direct management by local government. The merits of privately-commissioned management are that it enables cost reduction and greater operating efficiency by introducing an effective operational method and flexibility of operation organization. However, due to the private sector's pursuit of profit, low-grade engineers with low labor costs might be supplied, which might result in poor management of facilities and reduced treatment efficiency. For this reason, solving the personnel problem is the most significant issue for the existing facilities.

Table 3-4 | A Comparative Chart of the Verits and Demerits of Public /Private Sector Management

Division	Direct management by local government	Privately commissioned management
Merits	- No concern about cessation of work due to bankruptcy or walkout - Since their purpose is not to make profits, facility maintenance will be properly performed. Contributes to water quality control by adjusting the water quality as low as possible. - If existing employees continue to work, there will be no personnel problems as facility maintenance becomes available.	- Securing cost reduction and operational efficiency by introducing efficient operation methods and organizational flexibility. - In the event of improper operation, sanctions could be applied by local government in its supervisory capacity. - Private company's laborers are available to repair facilities. - Promoting integrated management on environmental foundation facilities
Demerits	- Frequent reshuffling could result in a lack of specialization and responsibility. - Separate operation of environmental foundation facilities could cause excessive operation costs. - Simultaneously acting as operator and director could result in a decline in function of superintendent. - Window dressing could result in excessive administrative costs and the organization's rigidity could reduce operational efficiency.	- Concern about cessation of work due to bankruptcy or walkout - Due to the pursuit of profit, less-qualified engineers with low labor costs might be supplied, which might result in poor management and reduced treatment efficiency. - Concerns about repair costs being passed on from commissioned company to local government. - If a small company is selected, it may have poor operation and management. - For existing facilities, there will be difficulty solving the surplus personnel problem.

Source: Choi, Yong-chul (2003)

2.3. Financial Support

To finance village sewerage projects, the Korean government used a special tax for rural development and the agricultural structure improvement special account (national treasury) and promoted a program to improve rural living conditions. The Ministry of Environment would provide 70% of project costs as a local transfer fund from the special tax for rural development, while the Ministry of Home Affairs would fully fund some projects through a local transfer fund from the special tax for rural development, and after 1996 would support 80% of project cost. The Ministry of Agriculture and Forestry would fully fund certain projects from the agricultural structure improvement special account (national treasury).

With the abolition of the local transfer fund, the financing for sewerage projects is currently composed of the environmental improvement special account, the balanced national development special account and the agricultural structure improvement special account. Also, sewerage projects focused on the *Myeon*, which from 1995 to 2004 were run with part of the special tax for rural development as a local transfer fund, were changed to a special account subsidy program of the special tax management for rural areas in 2005, due to the abolition of local transfer funds, and were changed again to the agricultural structure improvement special account in 2007.

Table 3-5 | Financing System for Rural Sewerage Project

	Ministry of Environment	Ministry of Public Administration and Security	Ministry for Food, Agriculture, Forestry and Fisheries
Finances	1995-2004 : Special tax for rural development (Local transfer fund) 2005-2006 : Special account subsidy program of the special tax management for rural areas 2007- : Special account for environmental improvement and special account for the balanced national development (Construction of sewerage in rural areas) Agricultural structure improvement special account (Sewerage treatment facilities focused on *Myeon*)	1995-2004 : Special tax for rural development (Local transfer funds) 2005-2006 : Special account subsidy program of the special tax management for rural areas 2007- : Ministry of Environment	1995-2004 : Agricultural structure improvement special account (National funds) 2005-2009 : Special account for balanced national development 2010- : Special account for regional development
Project cost support	70%	Total project cost → 80%(1996) → Ministry of Environment (2007)	Total project cost (special account) → 80% (special account) → 70% (special account)

3. Small-scale Sewerage Facility and Treatment Technology

3.1. Current Status of the Small-scale Sewerage Facility Installation

As of the end of 2010, there are a total of 3,064 sewage treatment facilities in Korea. Of these, there are 1,308 facilities treating less than 50m³/d of sewage and 1,286 facilities with treatment capacity of 50-500m³/d. Looking at the number of small facilities by region with a treatment capacity of less than 500m³/d, Jeollanam-do Province has the highest number of facilities with 673, while Jeollabuk-do has 353 facilities, Gyeongsangnam-do has 341 facilities, Chungcheongnam-do has 271 facilities and Gangwon-do has 282 facilities.

Table 3-6 | Current Status of Small-scale Sewerage Facilities by Region and Scale of the Sewage Treatment Facilities (2010)

Region	# of facilities	Sewage treatment facility scale		
		less than 50 m³/d (#)	50-500 m³/d (#)	more than 500m³/d (#)
Total	3,064	1,308	1,286	470
Seoul	4	-	-	4
Incheon	12	-	2	10
Busan	27	-	16	11
Daegu	16	2	7	7
Daejeon	2	-	-	2
Ulsan	10	-	5	5
Gwangju	9	4	3	2
Gyeonggi-do	303	51	135	117
Gangwon-do	319	106	176	37
Chungcheongbuk-do	223	92	103	28
Chungcheongnam-do	318	158	113	47
Jeollabuk-do	397	210	143	44
Jeollanam-do	731	399	274	58
Gyeongsangbuk-do	268	142	84	42
Gyeongsangnam-do	389	128	213	48

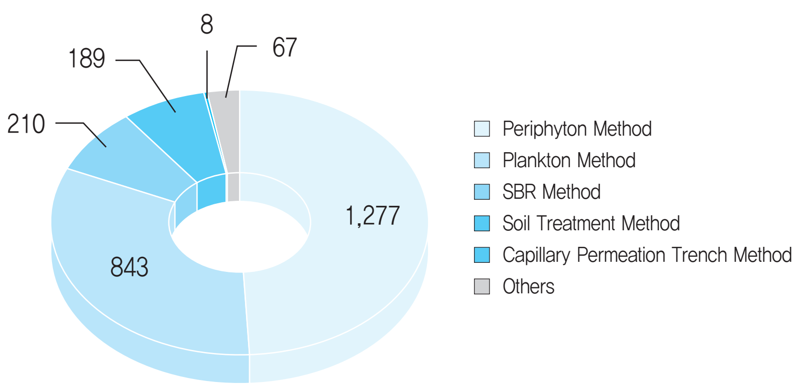
Source: Ministry of Environment (2011d)

3.2. Small-scale Sewerage Facility Treatment Technology and Status

Unlike medium- and large-scale public facilities, various treatment methods have been applied to the small sewage treatment facilities in the rural communities. These can be roughly divided into the Suspended growth method, SBR (Sequencing batch reactor), Attached growth method and Soil treatment method. The Suspended growth method includes Activated sludge process, Extended aeration and Oxidation ditch method. The Attached growth method includes Rotating biological contactor, Contact oxidation method and Trickling filter process. Finally, the Contact oxidation method topped soil and Capillary permeation trench method are included in the Soil treatment method (National institute of Environmental Research, 2001). Treatment technologies applied to the small sewage treatment facility are briefly described in the Appendix.

[Figure 3-5] presents the current status of small sewage treatment facilities by treatment method. The most highly applied method is the Attached growth method with 1,277 facilities (49.2%), and other Suspended growth methods are applied to 843 facilities (32.5%). 210 facilities (8.1%) using SBR and 189 facilities (7.3%) using the Soil treatment method follow. Only the number of facilities using the Capillary permeation trench method was decreased, from 47 in 2007 to 8 as of the end of 2010.

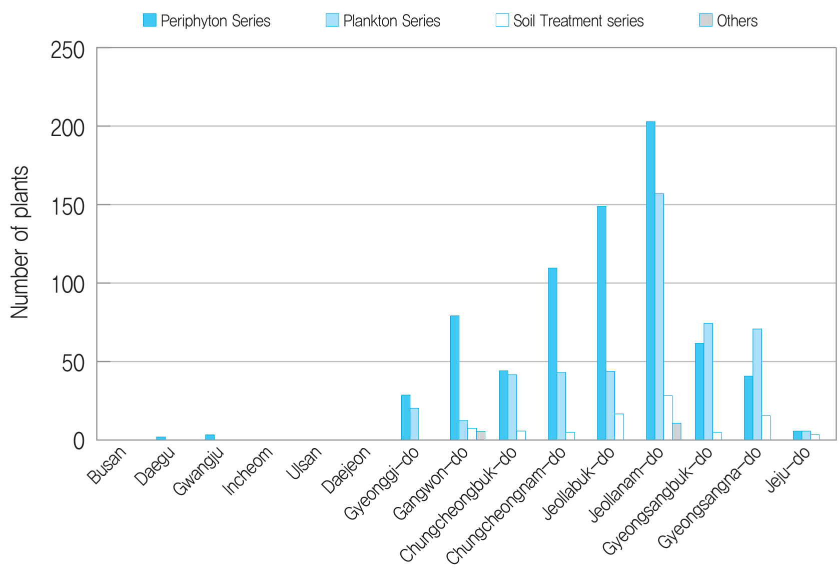
Figure 3-5 | Small Sewage Treatment Facility by Treatment Method



Source: Ministry of Environment (2011d)

The distribution by treatment method and region of small sewage treatment facilities treating less than 50m³/d of sewage is shown in [Figure 3-6] and <Table 3-7>. It was found that 728 facilities use the Attached growth method, with the next-most-common methods being the Suspended growth method (398) and the Soil treatment method (85). Breaking down the data by region, the Attached growth and Suspended growth methods are widely used in Jeolla-do and in Gyeongsangnam-do Provinces, and the Suspended growth method is more applied to facilities than the Attached growth method. On the other hand, the SBR method is more frequently used in Chungcheongbuk-do and Gyeongsangbuk-do provinces than in the other provinces.

Figure 3-6 | Number of Small Sewage Treatment Facilities with Treatment Capacity less than 50m³/d, by Treatment Method and Region



Source: Ministry of Environment (2011d)

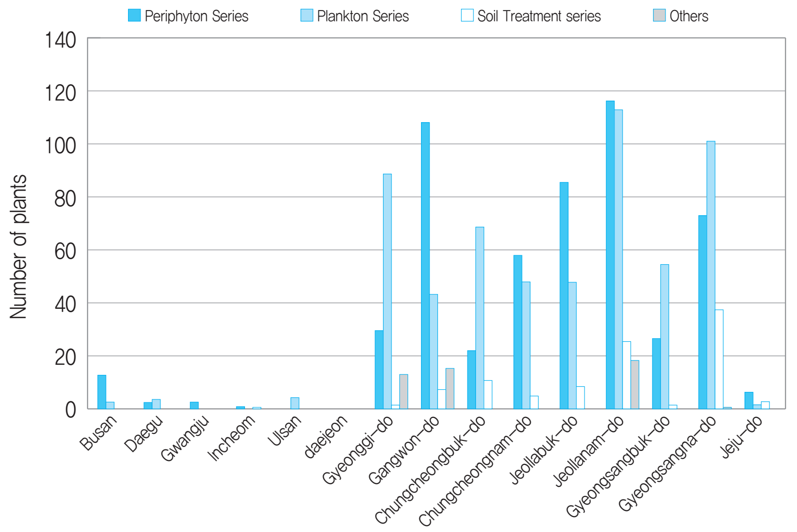
Table 3-7 | Distribution of Small Sewage Treatment Facilities with less than 50m^3/d Treatment Capacity by Treatment Method and Region

Method / Region	Total	Peryphy ton	Suspended growth			Soil treatment			Others
		Peryphyton method	Sub-total	Suspended growth method	SBR	Sub-total	Soil treatment method	Capillary permeation trench method	
Total	1,308	728	472	398	74	91	85	6	17
Busan	-	-	-	-	-	-	-	-	-
Daegu	2	2	-	-	-	-	-	-	-
Gwangju	4	4	-	-	-	-	-	-	-
Incheon	-	-	-	-	-	-	-	-	-
Ulsan	-	-	-	-	-	-	-	-	-
Daejeon	-	-	-	-	-	-	-	-	-
Gyeonggi-do	51	29	21	15	6	1	-	1	-
Gangwon-do	106	79	13	11	2	8	6	2	6
Chungcheongbuk-do	92	44	42	26	16	6	6	-	-
Chungcheongnam-do	158	110	43	40	3	5	5	-	-
Jeollabuk-do	210	149	44	32	12	17	16	1	-
Jeollanam-do	399	202	157	143	14	29	29	-	11
Gyeongsangbuk-do	142	62	75	58	17	5	3	2	-
Gyeongsangnam-do	128	41	71	67	4	16	16	-	-
Jeju-do	16	6	6	6	-	4	4	-	-

Source: Ministry of Environment (2011d)

[Figure 3-7] and <Table 3-8> show the distribution of the small sewage treatment facilities, with 50-500 m^3/d facility capacity, by treatment method and region. According to the number of facilities that applied the Attached growth method, there are 116 facilities in Jeollanam-do, 108 facilities in Gangwon-do, 86 facilities in Jeollabuk-do and 73 facilities in Gyeongsangnam-do provinces. The Suspended growth method is also widely applied to facilities in Jeollanam-do (113), Gyeongsangnam-do (101), Gyeonggi-do (89) and Chungcheongbuk-do (69). Of the Suspended growth methods, the SBR method is most used in Gyeonggi-do, Chungcheongbuk-do and Jeollabuk-do. Meanwhile, the Soil treatment method is mostly used in Gyeongsangnam-do and Jeollanam-do provinces.

Figure 3-7 | Number of Small Sewage Treatment Facilities, with 50-500m³/d Treatment Capacity, by Treatment Method and Region



Source: Ministry of Environment (2011d)

Table 3-8 | Distribution of Small Sewage Treatment Facilities, with 50-500m³/d Treatment Capacity, by Treatment Method and Region

Method / Region	Total	Attached growth	Suspended growth			Soil treatment			Others
		Attached growth method	Sub-total	Suspended growth method	SBR	Sub-total	Soil treatment method	Capillary permeation trench method	
Total	1,286	549	581	445	136	106	104	2	50
Busan	16	13	3	3	-	-	-	-	-
Daegu	7	3	4	4	-	-	-	-	-
Gwangju	3	3	-	-	-	-	-	-	-
Incheon	2	1	-	-	-	1	1	-	-
Ulsan	5	-	5	5	-	-	-	-	-
Daejeon	-	-	-	-	-	-	-	-	-
Gyeonggi-do	135	30	89	55	34	2	2	-	14

Region \ Method	Total	Attached growth	Suspended growth			Soil treatment			Others
		Attached growth method	Sub-total	Suspended growth method	SBR	Sub-total	Soil treatment method	Capillary permeation trench method	
Gangwon-do	176	108	44	26	18	8	7	1	16
Chungcheongbuk-do	103	23	69	43	26	11	11	-	-
Chungcheongnam-do	113	59	48	41	7	6	6	-	-
Jeollabuk-do	143	86	48	28	20	9	9	-	-
Jeollanam-do	274	116	113	107	6	26	25	1	19
Gyeongsangbuk-do	84	27	55	42	13	2	2	-	-
Gyeongsangnam-do	213	73	101	89	12	38	38	-	1
Jeju-do	12	7	2	2	-	3	3	-	-

Source: Ministry of Environment (2011d)

4. Water Quality Standards and Status of Small-scale Sewerage Effluent

4.1. Water Quality Standard Changes of Small-scale Sewerage Facility

As the Village sewerage was stipulated in 1996, the very first water quality standard of the village sewerage was defined as in <Table 3-9> below. Facilities were divided into Intensive and On-site treatment facilities, and BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), SS (Suspended Solids), T-N (Total Nitrogen) and T-P (Total Phosphorus) are included in the regulation category.

Table 3-9 | Water Quality Standard of Village Sewerages (1996)

Category	BOD (mg/L)	CODMn (mg/L)	SS (mg/L)	Others
Intensive treatment facility	less than 20	less than 40	less than 20	T-N: less than 60 T-P: less than 8
On-site treatment facility	less than 30	less than 40	less than 30	

Intensive treatment facility: more than a certain scale of treatment facility, as the larger the treatment facility, the more economical and easier the maintenance

On-site treatment facility: applied for treatment of sewage from a place of small independent business

Source: Ministry of Environment (2011d)

In 2001, there were 6 categories in total related to water quality standards of effluence of village sewerage, including coliform count, and these were separately applied to special areas and other areas until 2007 (refer to <Table 3-10>). The water quality standard value for special areas was applied to all areas as of Jan. 1st, 2008.

Table 3-10 | Water Quality Standards for Village Sewerage (2001)

Category	BOD (mg/L)	CODMn (mg/L)	SS (mg/L)	T-N (mg/L)	T-P (mg/L)	Coliform count (#/mL)
Special area	less than 10	less than 40	less than 10	less than 20	less than 2	less than 3,000 (less than 1,000)
Other area	less than 20	less than 40	less than 20	less than 60	less than 8	

Special areas:
- from Jan. 1, 2002: Paldang Lake Water Supply Protection Special Area, Jamsil water barrage region
- from Jan. 1, 2004: Hangang, Nakdonggang, Geumgang, Yeongsangang, Seomjingang regions
- from Jan. 1, 2008: the entire area

  Areas applied below 1000 #/mL of coliform count
- Clear zone specified under the Water Quality Conservation Act
- Water supply source protection area and within 10km of the upper region from its boundary
- Within 15km of the upper region from water intake facility

Source: Ministry of Environment (2011d)

Through an amendment to the Sewerage Act (Nov. 13, 2008), the water quality standard of effluence of public sewage treatment facilities was divided into two standards for two categories: sewage treatment capacity above and sewage treatment capacity below 50 tons per day, and 6 water quality constituents are regulated separately as of Jan. 1, 2009. Furthermore, ecotoxicity has been included in the water quality constituents since 2011.

Table 3-11 | Water Quality Standards in 2010 and 2011

Classification	BOD (mg/L)	CODMn (mg/L)	SS (mg/L)	TN1 (mg/L)	TP2 (mg/L)	Coliform count (#/mL)	Ecotoxicity3 (TU)
Sewage treatment capacity more than 50 tons/d	less than 10	less than 40	less than 10	less than 20	less than 2	less than 3,000 (less than 1,000)	less than 1
Sewage treatment capacity less than 50 tons/d	less than 10	less than 40	less than 10	less than 40	less than 4		

1, 2: the effluence water quality standard of T-N and T-P are less than 60mg/L and 8mg/L each in winter (applied from Dec. 1st to Mar. 31st)

3: applied from 2011

Source: Ministry of Environment (2011d)

Looking at the changes in the water quality standard for village sewerage as shown above, there was no separate standard established which considered the features of the village sewerage, but the existing standard for public sewage treatment facilities was applied as is. Since Jan. 1st, 2012, however, public wastewater terminal disposal facilities with a treatment capacity of more than 500 ton/d has had separate discharge standards applied according to 3 medium areas related to basin characteristics, such as water intake from water supply and water utilization of downstream areas, while the existing water quality standard has been applied to small public sewage treatment facilities with a treatment capacity of less than 500 ton/d.

Table 3-12 | Effluence Water Quality Standard for Public Sewage Treatment Facilities

Classification		Biochemical oxygen demand (BOD) (mg/L)	Chemical oxygen demand (COD) (mg/L)	Suspended solids (SS) (mg/L)	Total nitrogen (T-N) (mg/L)	Total phosphorus (T-P) (mg/L)	Total coliform count (#/ml)	Ecotoxicity (TU)
Sewage treatment capacity (more than 500 m³/d)	Zone I	less than 5	less than 20	less than 10	less than 20	less than 0.2	less than 1,000	less than 1
	Zone II	less than 5	less than 20	less than 10	less than 20	less than 0.3	less than 3,000	
	Zone III	less than 10	less than 40	less than 10	less than 20	less than 0.5		
	Zone IV	less than 10	less than 40	less than 10	less than 20	less than 2		
Sewage treatment capacity (50-500 m³/d)		less than 10	less than 40	less than 10	less than 20	less than 2		
Sewage treatment capacity (less than 50 m³/d)		less than 10	less than 40	less than 10	less than 40	less than 4		

1. Water quality of effluence applied to contaminants of public sewage treatment facilities, such as phenols, is announced by the Minister of Environment with a request from an operator of the treatment facility within the effluence equality standard applied to special area in accordance with Water Quality and Hydroecology Conservation Act Enforcement Regulation 13, Section 2
2. Water quality standard of effluence for Total Nitrogen and Total Phosphorus of a public sewage treatment facility with facility capacity under 500m³/d of in winter (from December 1st to March 31st) applies values under 60mg/L and under 8mg/L each until 31st of December, 2014
3. Water quality standard of effluence of the public sewage treatment facility in regions hereunder applies value under 1000 units/ml of total coliform count
   A. Clear zone designated by Water Quality and Hydroecology Conservation Act Enforcement Regulation 13
   B. Regions within 10km of a Water supply source protection area and its boundary to the upper stream in accordance with Water Supply and Waterworks Installation Act Article 7
   C. Regions within 15km of a Water intake facility to the upper stream in accordance with Water Supply and Waterworks Installation Act Article 7, Section 17
4. Water quality standard of effluence for facilities with a capacity above 50 m³/d is applied to public sewage treatment facilities installed at waterside
5. Water quality standard for ecotoxicity is based on an acute toxicity test related to water fleas, and is applied to public sewage treatment facilities meeting the requirements hereunder
   A. Wastewater should flow in from a wastewater discharge facility corresponding to Water Quality and Hydroecology Conservation Act Enforcement Regulation 4, Sections 2, 3, 12, 14, 17-20, 23, 26, 27, 30, 31, 33-40, 46, 48-50, 54, 55, 57-60, 63, 67, 74, 75, and 80
   B. Facility capacity should be over 500m³ per day

Source: Ministry of Environment (2011d)

4.2. Current Status of Water Quality Standards for Small-scale Sewerage Facilities

Under the enforcement ordinance of article 15 of the Sewerage Act, water examination of influent water and effluence of the small sewage treatment facilities must be done at least once daily for public sewage treatment facilities with a treatment capacity above 500m^3/d, at least once weekly for public sewage treatment facilities with a treatment capacity of 50-500m^3/d, and at least once monthly for small sewage treatment facilities with a treatment capacity below 50m^3/d. Only the ecotoxicity has to be examined at least once monthly.

The rate of sewage treatment facilities that did not meet the water quality standard of effluence by facility capacity as of 2010 was counted based on sewerage statistical data of the Ministry of Environment (2011). The number of facilities in which the effluence was higher than the BOD standard (10.0 mg/L) and the rate are shown in <Table 3-13> classified according to the facility capacity: under 50m^3/d and between 50-500m^3/d. 6.65% of sewage treatment facilities with a facility capacity under 50m^3/d and 2.05% of facilities with facility capacity of 50-500m^3/d had BOD levels that were higher than the standard for effluence. 77.0% of all small sewage treatment facilities had levels exceeding the standard for BOD.

Table 3-13 | Number of Facilities with BOD Levels Higher than the Standard, and Rate According to Facility Capacity

Classification	# of facilities	Facilities with effluence that does not meet minimum standards		Rate for facility excess of standard (%)
		# of facilities	Rate (%)	
Total	2,594	113	4.36	100
less than 50m^3/d	1,308	87	6.65	77.0
50-500m^3/d	1,286	26	2.05	23.0

Source: Ministry of Environment (2011d)

<Table 3-14> shows the number of facilities that had BOD levels higher than the standard for effluence by facility capacity and treatment method, and subdivided into Attached growth, Suspended growth and Soil treatment series. Of facilities using the Attached growth method, around 80.5% had BOD levels in excess of the standard, while this was true for only 18.5% of facilities using the Suspended growth method. Generally, the Attached growth method shows a higher BOD excess rate than other methods.

Table 3-14 | Number of Facilities with BOD Levels above the Standard, by Treatment Method and Facility Capacity

Classification		Treatment capacity		
		Total	less than 50m³/d	50-500m³/d
Total number of facilities		113	87	26
Attached growth system	Attached growth method	91	70	21
Suspended growth system	Subtotal	21	16	5
	Suspended growth method	16	12	4
	SBR	5	4	1
Soil treatment	Subtotal	1	1	-
	Soil treatment method	-	-	-
	Capillary permeation trench method	1	1	-

Source: Ministry of Environment (2011d)

For the COD standard (40 mg/L), 0.12% of all treatment facilities had levels higher than the standard, as shown in <Table 3-15>, while 100% of facilities with a capacity less than 50m³/d had levels higher than the standard.

Table 3-15 | Number of Facilities with COD Levels Higher than the Standard, and Rate by Facility Capacity

Classification	# of facilities	Facility capacity		Rate for facility excess of standard (%)
		# of facilities	Rate (%)	
Total	2,594	3	0.12	100
less than 50m³/d	1,308	3	0.23	100
50-500m³/d	1,286	-	-	-

Source: Ministry of Environment (2011d)

As shown in <Table 3-16>, 4.11% of all treatment facilities had levels higher than the SS standard (10 mg/L), and the highest number of facilities is the facilities with under 50m³/d of facility capacity with 6.80% among others. Meanwhile, 70.6% of facilities with capacity under 50m³/d had levels higher than the SS standard, compared to 28.8% of others.

Table 3-16 | Number of Facilities Exceeding SS Standard, and Rate by Facility Capacity

Classification	# of facilities	Facility capacity		Rate for facility excess of standard (%)
		# of facilities	Rate (%)	
Total	2,594	125	4.82	100
under $50m^3/d$	1,308	89	6.80	71.2
$50\text{-}500m^3/d$	1,286	36	2.80	28.8

Source: Ministry of Environment (2011d)

<Table 3-17> shows the number of facilities with T-N in excess of the standard. Of all facilities, 1.85% had T-N in excess of the standard. 3.42% of facilities with capacity of 50-500 m^3/d had T-N in excess of the standard, representing 91.67% of the group exceeding the standard.

Table 3-17 | Number of Facilities with T-N in Excess of the Standard, and Rate by Facility Capacity

Classification	# of facilities	Facility capacity		Rate of facilities in excess of standard (%)
		# of facilities	Rate (%)	
Total	2,594	48	1.85	100
less than $50m^3/d$	1,308	4	0.31	8.33
$50\text{-}500m^3/d$	1,286	44	3.42	91.67

Source: Ministry of Environment (2011d)

<Table 3-18> shows the number of facilities with T-N in excess of the standard for effleunce by facility capacity and treatment method, and is subdivided as follows: Attached growth, Suspended growth and Soil treatment systems. 41.7% of facilities with T-N in excess of the standard used the Attached growth method, while 37.5% used the Suspended growth method and 20.8% used the Soil treatment method.

Table 3-18 | Number of Facilities with T-N in Excess of Standard, by Treatment Method and Facility Capacity

Classification		Treatment capacity		
		Total	less than 50m³/d	50-500m³/d
Total		48	4	44
Attached growth system	Attached growth method	20	1	19
Suspended growth system	Subtotal	18	3	15
	Suspended growth method	18	3	15
	SBR	-	-	-
Soil treatment	Subtotal	10	-	10
	Soil treatment method	6	-	6
	Capillary permeation trench method	4	-	4

Source: Ministry of Environment (2011d)

<Table 3-19> describes the number of facilities with T-P in excess of the standard and the rate. 8 facilities out of 1,308 (0.6%) with a facility capacity under 50m³/d had T-P in excess of the standard, and 64 facilities out of 1,286 (5.0%) with capacity of 50-500m³/d had T-P in excess of the standard. The total excess rate is around 2.8%. Meanwhile, the highest rate for facilities in excess of the standard, 88.9%, was the facilities with a capacity of 50-500 m³/d.

Table 3-19 | Number of Facilities with T-P in Excess of Standard, and Rate by Facility Capacity

Classification	# of facilities	Facility capacity		Rate for facility excess of standard (%)
		# of facilities	Rate (%)	
Total	2,594	72	2.78	100
less than 50m³/d	1,308	8	0.61	11.11
50-500m³/d	1,286	64	4.98	88.89

Source: Ministry of Environment (2011d)

<Table 3-20> describes the number of facilities with T-P in excess of the standard, by treatment method and facility capacity. Of all of them, facilities using the Attached growth method represent 47.2%, while 43.1% used the Suspended growth method and 9.7% used the Soil treatment method.

Table 3-20 | Number of Facilities with T-P in Excess of Standard, by Treatment Method and Facility Capacity

Classification		Treatment capacity		
		Total	less than 50m³/d	50-500m³/d
Total		72	8	64
Attached growth system	Attached growth method	34	4	30
Suspended growth system	Subtotal	31	4	27
	Suspended growth method	25	3	22
	SBR	6	1	5
Soil treatment	Subtotal	7	-	7
	Soil treatment method	7	-	7
	Capillary permeation trench method	-	-	-

Source: Ministry of Environment (2011d)

Chapter 4

Evaluation of Small-scale Water Supply and Sewerage Systems

Evaluation of Small-scale Water Supply and Sewerage Systems

1. Improvement of Small-scale Water Supply and Sewage Service Distribution Rates in Rural Areas, and Enhancement of Health Hygiene

1.1. Small-scale Water Supply

The distribution of water supplies and sewage systems in rural areas, which, along with telecommunications and the spread of the traffic network, is one of the most important factors in improving the living environment and modernizing rural areas, is an element of the current urban-rural quality-of-life disparity.

As shown in <Table 4-1>, the distribution rate of water supply has increased gradually, reaching 97.7% in 2010. In *Eup* and *Myeon* (towns), the distribution rates of the water supply are 89.9% and 55.9%, respectively, which are low compared to Metropolitan City or City areas. However, if the small-scale water supply facilities implemented to improve the quality of life in rural areas are counted, then the rates would be increased to 94.7% for *Eup* and 85.4% for *Myeon*. Through these village water supplies and the small water supply facilities, the distribution of the water supply in rural areas and public health can be improved.

Table 4-1 | Distribution of Water Supply by Year

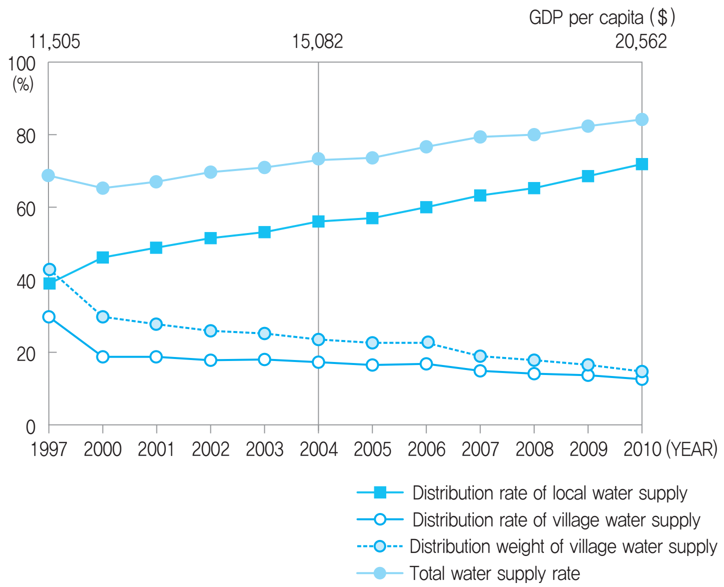
Category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Nationwide	87.8	88.7	89.4	90.1	90.7	91.3	92.1	92.7	93.5	94.1
						(92.2)	(93.2)	(94.1)	(94.8)	(97.7)
Metropolitan City	98.4	98.5	98.7	98.8	98.9	99.1	99.1	99.3	99.4	99.5
						(99.1)	(99.3)	(99.5)	(99.5)	(99.9)
City	96.5	97.0	97.0	97.3	97.5	97.5	97.6	98.3	98.6	98.7
						(97.6)	(97.8)	(98.4)	(98.7)	(99.0)
Town (*Eup*)	77.4	80.1	80.8	82.5	82.6	84.3	86.2	87.4	88.8	89.8
						(86.0)	(87.8)	(89.3)	(90.7)	(94.7)
Town (*Myeon*)	29.0	31.1	33.0	35.2	37.7	41.1	45.2	47.4	51.0	56.1
						(48.4)	(53.9)	(58.1)	(61.6)	(85.4)

Annotation: ( ) including small water supply

Source: Statistical water supply data from the Ministry of Environment (2001-2010)

Furthermore, [Figure 4-1] shows that the drinking water supply has been gradually shifted from small village water supply systems to systems managed by local governments as the standard of living and the economy has been improving. Distribution weight of the village water supply in rural areas (*Gun*) - population of the village water supplies divided by total population - was 42.8% in 1997. However, this was decreased to 23.4% in 2004, the year when GDP per capita was more than 15,000 dollars, while the water supply rate of 76.6% indicates what was provided by the local water supply. In 2010, the GDP per capita was over 20,000 dollars, the water supply rate of rural areas was 84.1% and only 14.6% of this was provided by the village water supply, while the local water supply system, which was managed more systematically by the local government, provided the other 85.4%.

Figure 4-1 | Distribution Rate of Water Supply in Rural Areas (unit: Gun) by Year



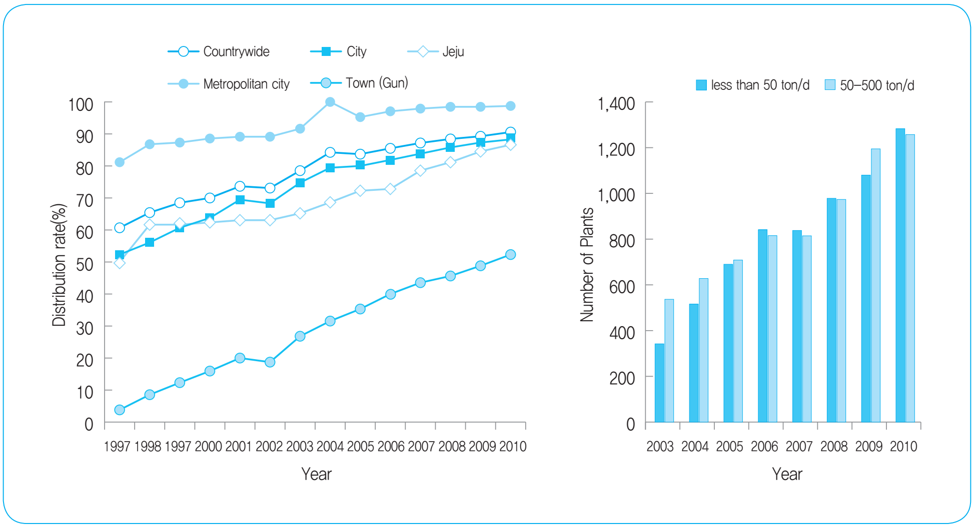
Source: www.index.go.kr

1.2. Small-scale Sewerage

As most of the Sewerage construction projects prioritized efficiency of facility capacity and the city area before any other aspects, rural areas have been excluded from receiving the benefits of sewerage service since the projects have mostly been large-scale public sewage treatment facility constructions. But the project to boost farmers' incomes through farming improvement and the green revolution, part of the Saemaeul Movement promoted in 1971, caused an increase of contaminant discharge and water pollution due to the increased use of fertilizer and agricultural chemicals. This raised the issue of fundamental water improvement as a necessary means of protection of the water supply source. To solve this problem, the government has promoted the distribution of village sewerage systems in rural areas by investing political sources of revenue such as a Special Rural Development Tax, Rural Structure Improvement Special Account, Environmental Improvement Special Account and Regional/Local Development Special Account. As seen in [Figure 4-2], the distribution rate of sewerage in rural areas (Gun) was steadily increased, from 4.9% (1997) to 52.7% (2010).

However, when looking at the distribution rate of sewerage facilities in all parts of the country, 90.1%, 98.8% and 88.3% of the sewerage system were supplied in each Metropolitan city and City area as of 2010, but there is still a distribution gap in sewerage between cities and rural areas. For this reason, the government has been consistently investing every year to achieve a 75% distribution rate of the sewerage system in rural areas by 2015.

Figure 4-2 | Distribution of Small Sewerages by Year



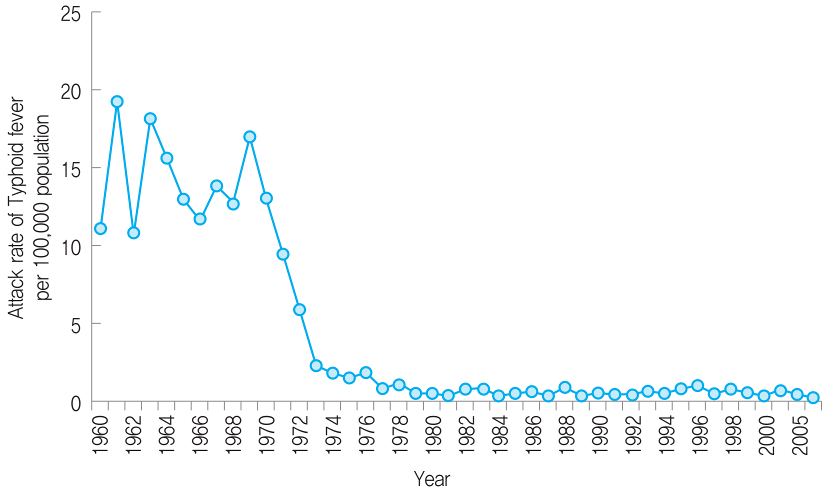
Source: Statistical data of Sewerage from the Ministry of Environment (1998-2011)

1.3. Health Hygiene

Improvements in the distribution rate of the water supply and sewerage in rural areas has prevented water-borne diseases and other illnesses, thus contributing to an improvement in health hygiene and public health in rural areas, and the development of a pleasant living environment as well.

With the Saemaeul Movement, the rate of Typhoid fever attacks started to decrease dramatically in 1970, the year in which the distribution of the water supply in rural areas was pursued in earnest, and dropped to 0.83 per 100,000 people by 1977. Since then, it has remained at a consistently low level.

Figure 4-3 | Changes in the Rate of Typhoid Fever by Year



Source: Ministry of Health and Welfare (1992; 2002), Statistics Korea (www.index.go.kr)

2. Problems of Operating Small Water Supplies and Sewerage Facilities, and Means of Improvement

2.1. Small-scale Water Supplies

Drinkable water is directly related to people's health and life, so it is reasonable for it to be managed by administrative agencies or specialized agencies. But the reality is that when a village representative, who has no expertise in facility operation, is given the responsibility of being the main manager of a facility, problems may arise such as over- and/or under-supply of disinfectant, and substantial management may not be done properly. Furthermore, most of the existing facilities are decrepit since they were built in the early or late 1970s.

Therefore, the Ministry of Environment evaluated the actual conditions of village water supplies from 2005 to 2007 to maximize the improvement of village water supply management, and some problems were pointed out, such as deterioration of facilities and poor operation management. This led to the positive participation and interest of local governments. The aim of evaluating the actual condition is to protect the health of residents who live in a weak water supply area such as a rural area, and to contribute to improvements in quality of life through various effects such as facility construction, water quality inspection and promotion targeting residents. The evaluation group participated in the entire process of evaluation - submission of data verification, on-site evaluation and writing a report. In a written evaluation, there are 8 categories – including water quality management, execution of the budget, operation management, facility improvement - with a score of 60 in total. In an on-site evaluation, there are 6 categories – including management of water intake source, water treatment facility, sewerage facility – with a score of 40 in total. Facility construction expenses and a reward for the village water supply facilities were given to local governments that had excellent results in the overall evaluation by enacting relevant execution policies within the year's set budget. Local governments are supposed to spend 80% of the received budget on improving facilities, while up to 20% should be spent on the ongoing systematic management of the village water supply and efforts to improve facilities.

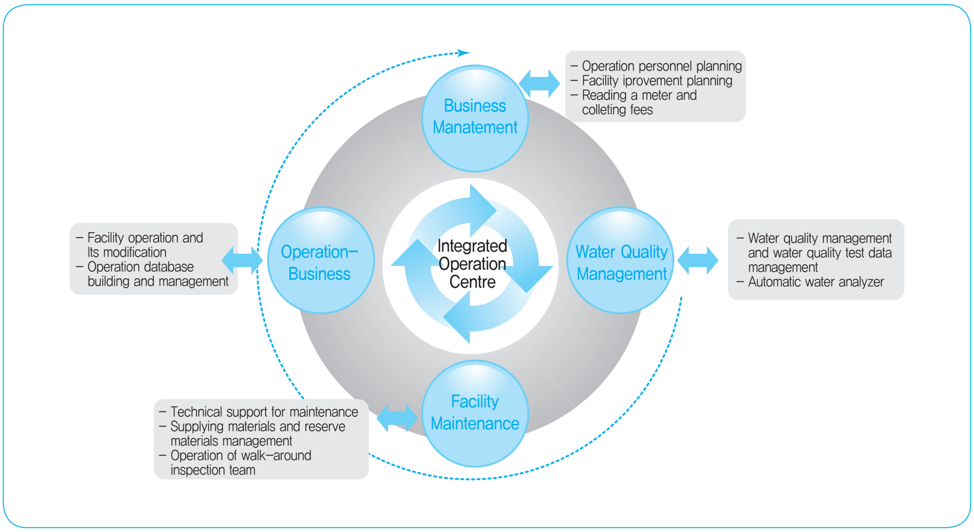
Since 2008, public funds have contributed 70% of the budget used in improvement projects for superannuated small water supplies (the estimated number is 15,148 as of 2014). Furthermore, the inspection standard of water quality has been increased to 16 water quality categories for quarterly inspections and 58 water quality categories for annual inspections in order to manage the water quality more strictly. Public and private joint inspection of the water quality is also performed, involving a sampling and analysis process twice a year.

To improve the management of the small water supply facilities by non-expert village representatives, the government has promoted a policy of supporting specialized maintenance through consigned management and education of workers in charge. The government also has established the project for small facility management on consignment by cities and counties, and tried to make a contract with consigning enterprises. After entrusting the management of 42 village water supplies and 50 small water supply facilities to a private enterprise (60 million won/year, around 70,000 won/month/facility), it became possible to supply water that met the drinking water quality standards. And, the trust of the inspection agency and local residents was gained through the maintenance of a stable water quality, with a 100% automatic disinfection feeding operation and the improvement of the facility environment. Plus, through the long-term use of facilities, expenses for additions or supplementations and the waste of chemicals can be reduced. Also, the prevention of damage by mishandling was remarkably reduced. Prompt action can also be taken in the event of a problem with subsidiary facilities such as water intake facility and water tank; this has been put to the test when changes in the surrounding environment were noticed at an early stage so that timely measures could be taken. In 2004, the Ministry of Environment spent 2.2 billion won to build 2 new small-scale water supplies and improve 13 facilities. Also, it has collected 3,000-5,000 won in fees from each household to use for facility maintenance and improvement expenses.

In the city of Andong, to solve the facility maintenance problems related to the lack of specialized knowledge and the aging of the local population, the Village Water Supply Maneuver was established and operated to increase the expertise of operation managers to ensure a stable water supply through the prompt handling of civil complaints.

Recently, areas that had been supplied water from existing village water facilities have been shifted to receiving water from sources managed by the local and regional governments. For some areas in which it has been impossible to supply water due to geographical reasons, the integrated operating system introduction policy has been carried forward to increase the efficiency of operation management (Ministry of Environment, 2007). Also, there have been education programs for related officers of the local government to improve their expertise, and the water quality data is available to the public, which in turn promotes the efficient management of facilities. Furthermore, to resolve the problem of waste of personnel and ensure efficient operation management for facilities, the remote integrated management system has also been built. This means that all conditions, such as water level in the tank of the village water supply, chemical levels, and motor operating condition, are sent to the person in charge in text and graph form through the Internet, in real time. Therefore, not only village representatives but also people in the office can check any problems in facility operation without visiting the sites, so that water quality-related accidents and civil complaints can be prevented and the village water supplies can also be operated systematically, maximizing the satisfaction of local residents and improving administrative services.

Figure 4-4 | Integrated Operating System for the Village Water Supply



Source: Ministry of Environment (2007)

2.2. Small-scale Sewerage

As mentioned above, small-scale sewerage facilities have been promoted since 1995 and have contributed to sound development and public health. However, as with the small water supply, some operational problems have manifested due to a lack of facility operation and maintenance technology. A number of policies have been pursued to improve this situation.

1) Small-scale sewerage department of government ministry and local government

Initially, village sewerage was carried out through separate programs, including the 'Residential Improvement Project' of the Ministry of Home Affairs, the 'Rural Environment Improvement Project' of the Ministry of Agriculture, Forestry and Fisheries and the 'Support Project for Small Sewage Treatment Facility Installation' of the Ministry of Environment. As a result, some problems had continuously arisen, such as the need for comprehensive review across the agencies, consistency deficit of projects and inefficiency due to project redundancy. Furthermore, facility planning and construction were under the jurisdiction of the housing management division, and the water supply and sewerage-related division took charge of facility operation and maintenance so that there was no consistency in facility maintenance and it was difficult to reflect the improved effect.

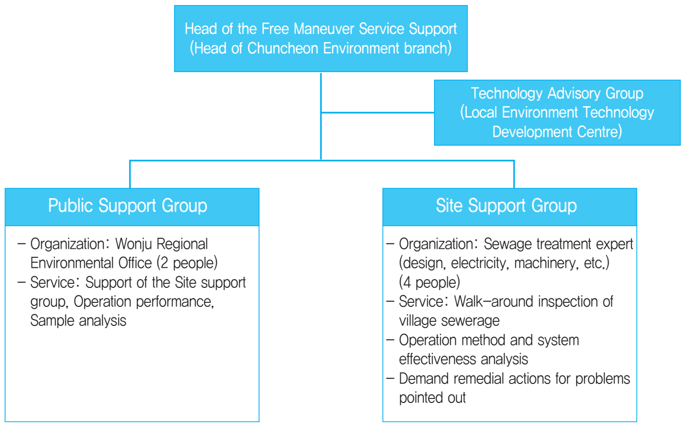
Thereafter, as the village sewerage was managed as a small public sewerage, the project by the Ministry of Government Affairs and Home Affairs was transferred to the Ministry of Environment in 2007. While the small-scale sewerage project is superintended by the Ministry of Environment, it still has to be promoted after consultation with the Ministry of Agriculture and Forestry according to the regulations of the relevant Act. To improve expertise and unify the small-scale sewerage-related divisions of the local governments so as to resolve inefficiency due to the dualized responsibility, it was prescribed that all the processes, from the basic initial planning of the small-scale sewerage facilities to their construction and its maintenance, should be integrated and managed by the sewerage-related division. However, it can be done in cooperation with the division related to the improvement of the living environment in rural areas (Ministry of Agriculture and Forestry, Ministry of Environment 2007).

2) Compliance with the water quality standard for effluence

The water quality standard for T-N and T-P levels in effluence from public sewage treatment facilities has been separately applied to facilities with capacities of both under and above 50ton/d since 2009. As mentioned above, most of the small-scale sewerage facilities in rural areas use the Attached growth method, the Suspended growth method or the SBR method, and their excess rates of BOD/COD/SS are high. On the other hand, the excess rates of T-N/T-P appear to be high at facilities with a capacity of 50-500ton/d to which a relatively enhanced water quality standard is applied. Therefore, levels of T-N and T-P for the facilities without advanced treatment system or of poor quality need to be reduced to meet the standard.

In terms of countermeasures, if the existing small-scale sewerage does not meet the water quality standard of effluence or other facility standards, affected cities and counties figure out the cause with technical support or inspection from the related special agencies. When it is judged that there needs to be a facility improvement, they improve the facilities with the necessary budget. The Free Maneuver Service operation for the small-scale sewerage at Bukhangang is an example of this. There are small-scale sewerages scattered in the large area of Bukhangang basin, but most were operated poorly due to a lack of operating personnel and funds. Their rate of exceeding the acceptable levels for the water quality standards reached 38% in 2006. Hence, the local government operated the Free Manuever Service support team for the village sewerage, which led to a reduction in the rate exceeding acceptable levels to 25% in 2007.

Figure 4-5 | Free Maneuver Service Support Group and its Main Services for Small-scale Sewerages



Support vehicles for Free Maneuver Service | Activity of Free Maneuver Service | Activity of Free Maneuver Service

Source: www.koetic.or.kr

3) Number of personnel in charge of the small-scale sewerage and their expertise

The number of personnel in charge of the small-scale sewerage maintenance was 1 person from the division related to housing, environment and the water supply and sewerage, regardless of how many village sewerage facilities there were. This resulted in poor facility management because it was a heavy workload for 1 person and there were frequent personnel appointments. Since it was hard to continue accumulating operating experience, it was natural for the person in charge to lack specialized knowledge about the sewage treatment system. Looking into the operation personnel by region, it appeared that approximately 1 or 2 people managed all facilities within a region, and among them, there were regions with 20 facilities and/or under 5 facilities that the local government was in charge of. Maintenance personnel were not assigned proportionally to the number of facilities. Meanwhile, there were wide variations in village sewerage maintenance expenses between regions. The maintenance expense tended to be low in Gangwon-do, Chungcheongbuk-do and Jeollanam-do provinces where the small facilities were scattered, while on the other hand, Metropolitan cities appropriated more funds in comparison to other neighboring facilities.

Thus, for more efficient operation management of the village sewerages scattered throughout rural areas, the Integrated Operation Management system, which integrates and manages all kinds of sewage treatment system around basins, has been introduced from the upper basin of dams. That is, several local governments are included in this system, and it builds an integrated operation management system excluding administrative districts from the project to operate and manage many small-scale sewerage facilities efficiently, so that economies of scale can be achieved by managing many facilities with less specialized personnel (Ahn Chung-hee, Lee Gwan-yong, 2011; Park Gyu-hong, et al., 2011). In November 2002, the Ministry of Environment determined to execute a project plan adopting the basin integrated management method, and carried it forward stage by stage as shown below.

Nov, 2002: Selected project plan adopting the integrated management method of basin (Ministry of Environment)
(Built the integrated management system combined with ET and IT)

Jan-Aug, 2003: Made an agreement for the private investment business (Ministry of Environment, local government, Korea Environment Corporation)

Mar, 2003-June, 2005: Feasibility study and Establishment of Master Plan (Korea Environment Corporation)

Mar, 11, 2005 : Private investment business changed to Fiscal business (Ministry of Environment)

※ Changed the method of business based on the result of an audit, "Operational realities of SOC private investment system" from the Board of Audit and Inspection

Apr-June, 2005: Consignment agreement stipulating the integrated operation principle (Ministry of Environment, Local government, Korea Environment Corporation)

Sep-Oct, 2006: Regional construction contract and beginning of project

Dec, 2009: Development of integrated operation management program through technology standardization

(Remote monitoring control, operation management, facility management, integrated messaging)

Sep-Dec, 2011: Completion of regional construction and agreement for the integrated management of basin

Jan, 2012: Started the integrated management of basin

Thus, the operation method has been changed from one of separate monitoring and control of small-scale sewerage facilities scattered throughout the upper region of dam to integrated automatic monitoring and control from the central treatment facility and the automatic operation of the small sewage treatment facilities. Furthermore, the problems related to direct operation management from the local government - the decline in the efficiency of operation management, rigidity, and insufficiency of specialized technology accumulation because of frequent reshuffling - could be solved by consigning to a private enterprise.

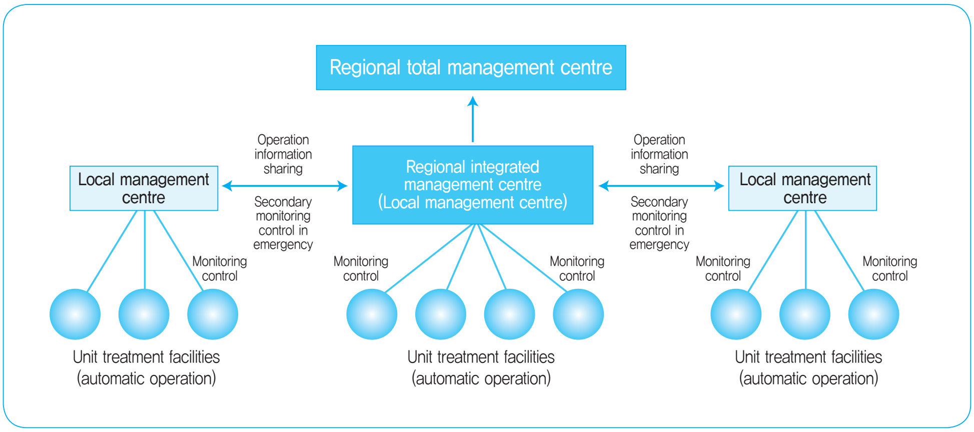
Table 4-2 | Orientation of Integrated Operating System

Classification	Existing system	Integrated operating system
Operating system	Separate monitoring control operation for each treatment facility - decline in the efficiency of operation management due to direct operation management by the local government - inflexibility of operation management and difficulty in accumulating technology	Regional integrated management - integrated automatic monitoring control from the central treatment facility - automatic operation of small treatment facilities Consigned operation and management by private agencies

Source: Ministry of Environment (2003)

The system configuration consists of the central sewage treatment facility, the medium and small treatment facility, and the village sewerage facility, as shown in [Figure 4-6]. First, the central sewage treatment facility builds the system for central remote monitoring and control of the sewage treatment facility within the same basin by using facility automation. Then, a system which can be automatically monitored and controlled from the central treatment facility is installed at the medium and small facility so that minimal manpower is required for operation. Finally, the village sewerage facility is monitored from the central treatment facility by the facility automation control, and walk-around inspections shall occur regularly.

Figure 4-6 | Diagram of the Integrated Operating System



Source: Korea Environment Corporation (2010)

In particular, the integrated operation management system features the automatic control system, which is included not only for the system integration of the environmental infrastructure but also to improve the treatment efficiency in accordance with facility automation using the remote control. Refer to <Table 4-3> for the main roles and functions of the integrated operation management facilities.

Table 4-3 | Main Roles and Functions of the Integrated Operation Management Facilities

Category	Main roles and functions
Regional total management centre	Total management of sewerage facilities at the upper region of dam (standardization of facility and operation management through statistical analysis) Maintenance of integrated operation management system and program standardization Enhancement of function and technical support for the integrated operation management system
Regional integrated management centre	General responsibility for facility operation and process management of jurisdiction Remote monitoring and control for sewerage facilities in jurisdiction (functions as local management centre) Data production for policy support for sewerage in the jurisdiction
Local management centre	Remote monitoring and control for sewerage facilities in the jurisdiction Operation information analysis, establishment of efficiency improvement plan and data management
Unit treatment facility	Remote command execution through the automatic operation of environmental infrastructure and data transmission with the local management centre Operation of data transmission to the local and regional integrated management centers

Source: Korea Environment Corporation (2010)

Looking at the organizational structure and the division of duties of the integrated management centre and the local management centre for the integrated operation management system of the sewerage facility as shown in <Table 4-4>, the integrated management centre and the local management centre have an operation management team, a water quality analysis team and a walk-around inspection team in common. In addition, they each have an integrated management team and a local management team for remote monitoring control and integrated operation management of the small unit facilities.

Table 4-4 | Division of Duties of the Integrated Operating Management Organization [Example]

Organization	Services		Division of duties
Regional integrated management centre (functions as Local management centre as well)	Integrated Management Team	Management and support	- Budget planning and execution management - Manpower supply and demand, and general office work such as goods supply
		System management	- Operation management and maintenance of the integrated/local management system - Data receipt from unit treatment facilities and local management centre, and data management - Technical support for system management of the local management centre
		Facility management	- Cause analysis of facility malfunction and support for countermeasures - Technical support for operation management of the local management centre - Facility maintenance status check
		Water quality and process management	- Water quality management and process analysis, sewerage policy data and annual report preparation - Status analysis of the flow rate of treatment facility and the water quality management - Technical support for process management of the local management centre
		Facility management	- Cause analysis of facility malfunction and support for countermeasures - Technical support for operation management of the local management centre - Facility maintenance status check
		Water quality and process management	- Water quality management and process analysis, sewerage policy data and annual report preparation - Status analysis of flow rate of treatment facility and water quality management - Technical support for process management of the local management centre

Organization	Services		Division of duties
Local management centre	Local Management Team	Facility management	- Cause analysis of facility malfunction and support for countermeasures - Facility maintenance status check - Business cooperation with the integrated management centre (the local government) related to administration and system - Basic information input about the environmental infrastructure - Operational data collection and transfer to the regional integrated management centre
		Water quality and process management	- Water quality management and process analysis, sewerage policy data and annual report preparation - Forming an improvement plan for process analysis
Integrated management centre, Local management centre (Central treatment facility)	Operation Management Team		- Operation management of the unit facility and its maintenance - Maintenance status analysis of machinery and electric facilities - Cause analysis of facility malfunction and support for countermeasures
	Water Quality Analysis Team		- Water quality data analysis and input - Status analysis of flow rate of unit treatment facilities and water quality
	Walk-around Inspection Team		- General inspection and management of the unit treatment facilities and the smallssewerage - Sampling and water quality management of the small sewerage - Sewage collection and treatment - Sewerage pipes and mediation pumping station inspection/management

Source: Chung-hee Ahn, Gwan-yong Lee (2011)

<Table 4-5> describes the method of operating the integrated sewerage facility recommended by the Ministry of Environment. The government promotes the operation management system after integration in various ways - outsourcing, public cooperation and intersourcing between public and private enterprises – in accordance with the agreement of the local government. In terms of local conditions, the local government converts the operating method autonomously.

Table 4-5 | Operating Method for the Integrated Sewerage Facility Recommended by the Ministry of Environment

Type	Characteristics
Outsourcing	Reduced economic burden on local government if a private enterprise invests in the facility in advance by contracting out all or part of the right to operate/manage
Public corporation	Established through a joint investment by local government Possible to pursue management efficiency and public interest, but position changes for civil servants are unavoidable and it is difficult to achieve the goal if there is a shortage of economic resources
Intersourcing	Public institution and a private enterprise co-found an SPC (Special Purpose Company) to operate and manage the sewerage facilities

The status of the integrated management of the sewerage facilities, at the upper region of a dam, is as follows: 153.43 million won in operating expense (117.2 million won from public funds and 362.3 million won from the local government) has gone into this project, which completed the new installation and improvement of 434 sewerage facilities - 55 sewerages, 397 small sewage treatment facilities, maintenance of sewerage pipes reaching 1,754km in total, and the installation of drainage facilities for 68,837 households. The KEC (Korea Environment Corporation) manages facilities on consignment through agreements with 28 local governments, and 15 of them contract out to KEC en bloc, including the unit treatment facilities. But it is planned that the integrated management centre would be under direct operation by KEC, and the unit treatment facilities, on KEC's responsibility, would be operated through the third outsourcing method in the future. As this project was carried out, the distribution rate of sewerage in rural area of the upper region of dam was increased from 27% to 71%, and the water quality at tributary and brook appeared to be improved by around 66% in water quality measurement for 75 facilities in the vicinity. The Ministry of Environment plans to carry out the project titled "Integrated Management for Operating Sewerage Facility" targeting all the sewage treatment facilities of the entire country, based on the success of "Pilot Project of Integrated Management for the Sewerage Facility of the upper region of dam (2012-2013)".

Chapter 5

Application of Small-scale Water Supply and Sewerage Systems to Developing Countries

Application of Small-scale Water Supply and Sewerage Systems to Developing Countries

Drinking water and health hygiene are directly connected to people's lives. It is a basic human right that community residents be supplied with safe drinking water and are thus protected from water-borne diseases and given comfort and a healthy environment. Nevertheless, it has been reported that about 780 million people in the world (mainly in the least-developed and developing countries) are not supplied with safe drinking water, and that about 2.5 billion people in the world suffer from a lack of basic public sanitation (Unicef, 2012). Capitals or large cities have about 80% coverage in water supply and sewer services, but rural areas have very low coverage, with water supply coverage of 29% and sewer coverage of 49%. In particular, the rural areas in the least-developed or developing countries have a far more severe shortage of drinking water supply and public sanitation. Those areas do not have sufficient water infrastructure, and require small scale water and sewer systems, which have relatively low operating cost and easy maintenance, rather than large-scale systems that absolutely require financial and technical expertise. As a recent case, in Jeffisi, a town in Ghana (Africa), the Korea Environmental & Industry Technology Institute (KEITI) under the Ministry of Environment (MOE) and a private company in Korea have jointly installed small-scale water and sewer systems with a capacity of 100 tons per day in order to supply safe drinking water for the 4,000 residents. For rural areas where sources of water pollution are scattered in diverse locations, middle- and large-sized wastewater treatment systems, which require the installation of lengthy sewer pipes, are not appropriate due to the local topology. Instead, it is more desirable to select economical, reasonable, and small-sized on-site treatment systems that treat waste water at the source, and are easy to maintain.

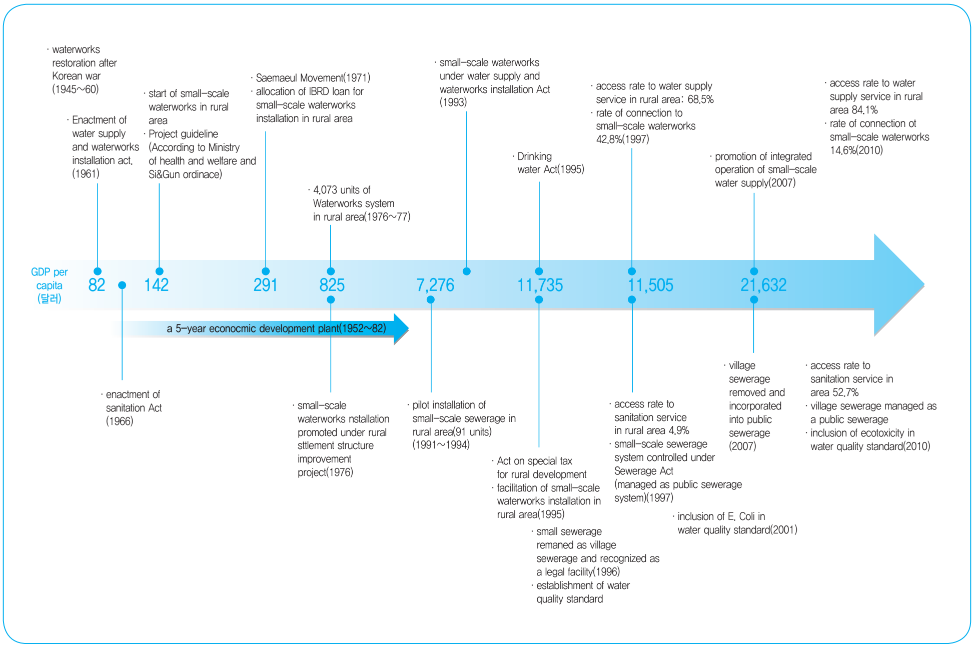
Based on Korea's experience of rural development through its 1970 Saemaeul Movement (a community project to supply safe water and improve the environment in rural areas in which small sized waterworks and sewerage systems were introduced and operated, contributing to an improvement in the living environment of the areas), we suggest how to effectively install and operate small-sized waterworks and sewerage systems in developing countries.

1. Phased Development through Government Support

In general, waterworks and sewerage infrastructures are mainly provided to cities, and rural areas with relatively low population density have insufficient infrastructure. This leads to an increasingly wide gap between cities and rural areas in waterworks and sewerage coverage. Improving the coverage of small-scale waterworks facilities and their effective operation requires the government's active will, cooperation and budget support.

In Korea, as seen in [Figure 5-1], the government had started the installation of village waterworks systems in 1967 as a part of its local community development policy, and then, with the 5-Year Economic Development Plan and the Samaeul Movement providing momentum, promoted waterworks projects in rural areas in earnest. In the early 1970s in Korea, when its GDP was less than 2 million dollars, the government had selected priority areas for waterworks installation, including those vulnerable to the spread of water-borne diseases and those in which water pollution prevention projects were urgent or potentially effective in disease prevention. The beneficiary residents actively participated in facility construction and operation, with no wage. As a result of the 5-Year Economic Development Plan and the Saemaeul Movement, the improved standards of living in both rural and urban areas and an increase in water contaminant discharge from the increased use of agricultural chemicals and fertilizers had led to poor water quality. For this reason, in 1995 the government established a Special Tax for Rural Development and pushed ahead with the construction of village sewer systems in rural areas. In 2007, when the GDP per capita of Korea exceeded 20,000 dollars, the government began to introduce the integrated operation of village waterworks systems and village sewerages to improve their operation efficiency. In 2010, ecotoxicity criteria was incorporated in the water quality standards for sewage processed water. In this way, facility operation management, water quality standards, and water treatment technology have been developed through phased application in line with economic development, industrialization, and public awareness.

Figure 5-1 | Phased Development of Waterworks and Sewerage in Rural Areas in Korea



2. Appropriate Technology and Active Community Engagement

For developing countries, which are relatively low in terms of their economic level and environmental awareness, it is very important to introduce appropriate technologies that do not require a large amount of capital and are very simple to apply. In particular, small-sized waterworks and sewerage facilities are remotely located in villages, and thus are difficult to manage. Accordingly, such facilities require systems that are optimized for local circumstances, a manual for systematic operation management, and the active engagement and awareness of the residents who are the main agents of facility operation and management.

2.1. Small-sized Waterworks

There are three main considerations for the efficient installation and operation of small sized waterworks: type of water source, water treatment facility and operation, and water quality control.

2.1.1. Selection and Installation of Water Source

Water sources for village waterworks and small-sized water supply facilities include underground water and valley water. For underground water, most wells have a low depth in the range of 30-50m and are in fact surface water, not bedrock water. As such, increased development activities, the use of agricultural chemicals, or the generation of livestock wastewater in the area will degrade the water quality of the water source. Such water sources also have another problem, in that they are easily depleted by even a short spell of drought. When valley, spring or stream water is used as a water source, the lack of means to protect the water source is very likely to lead to a build-up of water pollutants, including sand, animal excrement, and plants at the bottom of water tanks, resulting in the pollution of source water.

Therefore, if underground water is used as a water source, it is necessary to take actions to prevent pollution caused by the spread of point and non-point pollution sources, and then install disinfectant auto-feeders. If sufficient underground water is not available in the area, it is necessary to install some facilities to extract as much underground water as possible and purify the extracted water through filtration systems. As an underground resource, underground water is absolutely affected by topology, geology, and weather, and the recharge budget cannot be artificially controlled because recharged underground water contains dissolved minerals from distribution lithofacies. For these reasons, underground water tube wells require simple equipment to make underground water drinkable and to prevent pollution.

Valley water as a water source is exposed to the outside and can potentially be polluted by animal excrement with pathogenic microoganisms and protozoa that can cause water-borne infections such as typhoid fever and dysentery. This requires that special attention be paid to water source management. Therefore, valley water has to be checked through water quality analysis by qualified technicians to determine whether it is suitable for water supply. A water supply source should be selected that cannot be accessed by humans or animals. To limit access, fences and warning posts should be installed around the boundary of the water source. In addition, water tanks should be equipped with disinfectant auto-feeders, which should be thoroughly maintained to protect against freezing and bursting in winter. Also, the tank should maintain a constant concentration of disinfectant through the use of solid chlorine, under thorough management.

2.1.2. Water Treatment System Selection and Water Quality Control Based on Local Characteristics

As village waterworks or small-sized water supply facilities are usually located in remote areas or coastal and island areas, social overhead capital facilities including civil and electrical facilities are prerequisite, taking account of the volume, weight, and required power of the facilities. Because of the limited size of the site and other difficulties, treatment facilities need compact and highly efficient unit process equipment. Difficulty in securing finance for operating and maintenance costs and professional manpower also highlights the need for processes that are low in maintenance costs and easy in operation and management. In addition, the choice of treatment processes should be based on the water source. If the raw water is surface water, filtration is necessary to remove turbidity and microorganisms. If the raw water is underground water, the main targets of removal are pathogenic microorganisms and nitrate nitrogens. Therefore, in order to secure safe water quality and promote convenient operation for the village waterworks of the area, it is more economical and effective to select the proper treatment system according to the characteristics of the raw water used in the area.

Most small-sized waterworks supply water that has simply been disinfected without any special purification system, or raw water as it is. Chlorine disinfection is carried out empirically and intermittently by non-professional managers using solid chlorine. This leads to a failure to maintain an adequate level of residual chlorine. Chlorine disinfection also causes complaints due to the smell of disinfectants. Therefore, in order to remove fecal pollution sources and maintain a residual chlorine level that meets the criteria, it is necessary to consider using an automatic disinfection facility, select a suitable disinfection method for the local characteristics, for example, chlorine, ozone, or UV disinfection, and carry out regular examinations of water quality.

2.1.3. Operation and Management of Small-sized Waterworks

Most village waterworks and small-sized water supply facilities are operated by non-professionals or the representative of the village or area, and this can result in improper maintenance. Measures to solve this problem include: 1) construction of operation and management systems, 2) provision of professional training to village representatives, and 3) entrustment to a specialized private agency. If entrustment is used, tube well or disinfectant auto-feeder management works should be entrusted to the company that installed the equipment.

In Korea, for the purpose of improving the poor management of village waterworks facilities due to insufficient manpower and a lack of expertise by local managers (that is, village foreman), each local government is required, under Articles 47 and 55 of the Water

Supply and Waterworks Installation Act (hereafter referred to as “the ACT”), to establish and implement its own ordinance on the operation and management of village waterworks and small-sized water supply facilities so as to operate and manage the facilities in a sanitary and effective way. For example, the Incheon Village Waterworks and Small Sized Water Supply Facilities Operation and Management Ordinance prescribes that the manager of the village waterworks is the Mayor of Incheon and the manager of small sized water supply facilities is the representative of the user representatives’ council of the area; that is, the council composed of residents who use the village waterworks. Under the Ordinance, the manager is responsible for the entirety of the operation and management works of the village waterworks, including facility operation, maintenance, and disinfection. Under Article 25 of the Water Source Management Rules and Article 4 of the Drinking Water Quality and Examination Rules, raw and processed waters are required to be analyzed for water quality, and the results must be retained for 5 years for raw water, and 3 years for processed water. When the water quality of a village waterworks facility is determined to be inadequate, the facility must repeat the examination for the item that failed to meet the criteria. If it is determined inadequate in the repeated examination, the facility must take corrective actions immediately. Training on facility operations and management must be provided by the Mayor at least once each year to the representative of the village waterworks facility council. For entrusted management, Article 22 of the Act requires that the entirety or part of village waterworks maintenance, operation and management works may be delegated or entrusted by the Mayor to the representative of the user representative council or any competent private agency.

2.2. Small-sized Sewerage System

Considerations for the effective installation and operation of small-sized sewerage facilities can be largely divided into geographical and economic conditions; location of treatment facility; planning zone and sewage quantity; and selection of treatment methods.

2.2.1. Geographical and Economic Conditions

Villages in rural areas have houses that are relatively sparsely arranged compared to those in an urban area. To derive plans for sewage treatment that are economical and feasible, it is important to select treatment zones that fit the geography of the area. For piplelines, treatment facilities, and processed water drainage ways, it is most economical to install them in a gravitational way. However, the most feasible type of installation for the geographic conditions should be selected. For example, pipelines can be installed for pumping flow if gravity flow is not practical. Also, pipe burial routes should avoid heavy duty roads but select agricultural roads or intra-village roads. The location of a treatment facility should be selected after taking account of the village living zone in order to facilitate the cooperation and engagement of community residents.

2.2.2. Facility Planning and Siting for Small Sized Sewage Treatment

When planning a small sized sewage treatment facility, the sewage generation should be based on the estimated sewage quantity 5 to 10 years in the future, taking into account the expected population growth. Contamination loads should be estimated from the measured water quality of inlet sewage and effluent. Unlike large-sized public sewage treatment facilities in large cities, small-scale facilities in rural areas are mostly installed on a village basis or within the boundaries of a residential district. Therefore, the facilities should be planned so as not to cause odors and not to become visually unpleasant. In addition, the installation of small-scale sewage treatment facilities should be:

– Above the surface of sewage pipeline extensions and influent pipelines

– In a location with no risk of flooding during floods

– In a location with no ground subsidence and with suitable geology for facility load

– In a location where infrastructure, including electricity and waterworks, can be easily secured

– In a location with enough space to install facilities

– In a location where discharge of processed water is possible and easy

2.2.3. Selection of Appropriate Aewage Treatment Methods

In Korea, the small-scale sewage treatment methods initially applied were selected with an inadequate review of regional sewage generation, and so have many operational problems. Furthermore, they required complicated operation techniques and showed a decline in operation efficiency when run for a long period of time. Village sewage treatment facilities, and particularly those in rural areas, are absolutely short of the technical manpower for maintaining the facilities and have difficulty in financing maintenance costs. Such facilities need treatment technologies that are easy to maintain without expertise and low in terms of maintenance costs. Also, optimum technologies should be selected such that post-treatment effluent can be recycled for use as agricultural water or instream flow, and that they can be adjusted to meet future water quality standards that will likely become stricter.

Selected sewage treatment methods should be those that are the most economical and efficient in terms of construction cost, ability to meet effluent quality standards, and ease of maintenance. Care should be taken to collect the opinions of sewerage experts on the problems of sewerage management, including operation and maintenance difficulties, clogging of soil pores, etc. (Ministry for Food, Agriculture, Forestry, and Fisheries and Ministry of Environment, 2007). <Table 5-1> summarizes the criteria for selecting optimum treatment methods for small scale public sewage treatment facilities.

Table 5-1 | Selection Criteria for Sewage Treatment Methods

Criteria	Description
Results of pre survey	- To select methods based on the analysis of influent quality and the results of field survey
Reliability of treatment performance	- method with high efficiency in terms of simultaneous removal of organics, nitrogen and phosphorus - method capable of reliable adjustment to water quality variation (that is, increase in seasonal and yearly contamination) - method capable of reliable operational adjustment to influent of low concentration and low flow - method appropriate for future influent of high concentration in the event of modifying into separate sewer systems or reconstructing
Ease of operation management	- method stably adjustable to changes in external impact factors such as water quantity, quality and temperature, and that provides easy operational adjustment - method that allows simple operation management and easy maintenance - method that allows easy automation
Workability	- method whose structure is simple to construct and is unlikely to generate problems in construction - method that allows easy extension
Economy	- method with superior economy in terms of both initial investment cost and maintenance cost - method with inexpensive construction cost - method with low maintenance cost - method with less sludge generation
Proven methods	- reliable method that has been applied and verified many times - method with accumulated operating skill - method that is normally installed and operated - method whose technology has been proven by, for example, designation as a new technology under relevant laws.
Technology transfer and technical self-sufficiency	- method that allows technology transfer and technical self sufficiency - method that allows technical support in the event of problems in sewage treatment facilities

Source: Ministry of Environment (2007b)

Also, it is important that the characteristics of the selected optimum treatment method be considered in the placement of structures, and that facility design, plantation, and environmental arrangement be harmonious with the environment of the rural area. Prevention of cold weather damage in cold climate areas, and underground placement of facilities to ensure harmony with the surrounding scenery also deserve consideration.

An additional environmentally friendly and economical option is to make use of the features of rural areas, that is, natural purification by agricultural lands, streams, water channels, and soils. In agricultural lands, for example, nitrogen removal can be achieved through denitrification as the vegetation principle of rice. Fallow paddies and vacant lands can also be used for additional removal of nitrogen and organic matters by cultivating water hyacinths or other aquatic plants that are very effective in the intake and decomposition of nutrient salts.

2.2.4. Unification of Responsible Departments and Follow-up Management

In Korea, the separation of duties among government departments in early days led to a lack of consistency in facility installation and poor facility checkup and maintenance. In each responsible government department, the criteria for evaluating the achievement of project goals has been focused on securing treatment facilities through project cost support for local governments, and has neglected follow-up management. Consequently, their function to check and manage in-service facilities by evaluating the level of goal achievement of the facilities is currently poorly performed.

Other problems in village sewage treatment facility operation management include: poor maintenance due to a shortage of manpower and frequent changes in responsible personnel and their lack of expertise; and imperfection in the relevant laws with regard to the maintenance and conservation of facility performance when compared to municipal sewage treatment plants, which are subject to technology diagnosis by a specialized agency every 5 years.

To solve these problems, it is necessary to unify the responsible government departments, continue to provide responsible officials with specialized education, and encourage the active cooperation and engagement of community residents. Possible options include the entrusting of work to competent specialized private agencies depending on local economic conditions, and the introduction of unmanned automated operation or a remote controlled system that, compared to manual control, has the advantages of, for example, reducing operating costs, increasing accuracy and efficiency, and ensuring reliable operation. When village sewerage facilities, most of which are under unmanned operation at present, are integrated with automatic control via an intelligent system or with internet-based remote monitoring and control programs, facility efficiency or maintenance will be considerably improved (An Choonghee et. al, 2011). <Table 5-2> shows the criteria for introducing unmanned automated systems to small-scale sewage treatment facilities.

Table 5-2 | Criteria for Introducing Unmanned Automated System to Small Scale Sewage Treatment Facilities

Category	Site criteria
Spacial	– Topographically isolated area in which in-person inspection is difficult – Area with low risk of flooding that has a mild climate and is relatively safe from climate fluctuations – Area in which facilities are dotted throughout the jurisdiction region so that management in person at the proper cycle is difficult – Area around which there is a large-sized treatment facility that can act as an integrated control center
Technical	– Area in which intercepting sewers are relatively well maintained so that change in influent quality is not large. – Area in which change in village population is not large, and thus change in influent flow is not large. – Area that has a facility suitable for applying automated systems (for example, membrane separation, SBR, and the like)

Source: Ministry of Environment (2009)

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APPENDIX: Small-scale Water Supply and Sewerage Treatment Technology

1. Small-scale Water Supply Treatment Technology

1) Disinfection

Disinfection systems can be divided into automatic disinfectant feeding systems and non-powered disinfectant feeding systems, according to whether or not a power supply is used. Most of the current disinfectant feeding systems are automatic and are equipped with a sensor to ensure the correct input of disinfectant and a measured value and status data transfer system, and some are equipped with a solar battery as an auxiliary power source.

For a hand-operated disinfectant feeding system, solid chlorine, i.e., bleaching powder, may be used in an amount of either 5g or 20g, and available chlorine is approx. 70%. After checking the capacity of the water tank and the quantity of water used, chlorine should be put into the tank. Manual input methods include a method of directly putting solid chlorine into the water tank and a method of hanging the solid disinfectant wrapped with a net or in an empty container in the water.

An automatic chlorine feeding system automatically puts 5g or 20g of solid chlorine into the water tank at specified intervals. As this method is now strongly recommended by the government, it is thus expected to be installed in most small-scale water supply systems from now on.

This automatic chlorine feeding system is convenient to use, because the method of operation is set up, it feeds the chlorine automatically. The operating instructions should be thoroughly read, and a copy of the instructions attached to the feeding system so that they can be constantly referred to. A typical automatic feeding system is shown below:

Figure A-1 | Automatic Chlorine Disinfection System

A chlorinated disinfection system can react with the chlorine that is used as a disinfectant and produce trihalomethane (THM), which is a carcinogenic substance, and cause an unpleasant smell from remaining chlorine. That is why ozone or UV disinfection is now being used as an alternative.

UV and ozone disinfection systems produce neither trihalomethane nor an unpleasant smell, and there is no residual effect of chlorine disinfection. In addition, UV disinfection is easy to install and maintain, though the UV ramp needs to be replaced periodically. The initial investment required for ozone disinfection is higher than for chlorine disinfection, and the system is somewhat unstable. Therefore, in consideration of the regional characteristics such as the status of the area to be supplied and consumer requirements, it is necessary to organize and run an integrated disinfection facility to supply safe water.

Table A-1 | Comparative Chart of the Characteristics of Different Disinfection Systems

Division	Chlorine disinfection		UV disinfection	Ozone disinfection
	Hypochlorite solution	Solid chlorine		
Scale of treatment facility	Large, Medium	Small	Small, Medium	Large, Medium
Reliability of the system	Good	Good	Good	Good
Operation control method	Injection rate	Difficulty	Main water from lamp	Input power
Configuration of the system	Fairly Simple	Simple	Simple	Complicated
Dangerous chemical transport	High	Mid	Unnecessary	Unnecessary
Safety management in site	Significant	Mid	Low	Mid
Disinfection performance	Good	Good	Good	Good
Suppressing virus activity	Poor	Poor	Yes	Good
Toxicity to fish	Yes	Yes	No	Negligible
Harmful by-products	Yes	Yes	No	Negligible
Residual disinfection effect	Yes	Yes	No	No
Necessary contact time	Long	Long	Short	Mid
Ammonia reaction	Yes	Yes	No	No (in neutral pH)
Color removal effect	Poor	Poor	No	Yes
pH dependance	Yes	Yes	No	No (in neutral pH)
Corrosiveness	Yes	Yes	No	Strong

Reference: A report evaluating the current disinfection technologies (Japan Sewerage Corporation, 1997.7)

2) Filtration Technology

Filtration is the most widely used treatment process in small-scale water supply facilities, and is a physical method that removes suspended solids such as sand, gravel, activated carbon, germanium, etc. according to the pore size of the filter medium. This process can be combined with a chemical process through which suspended solids of a size smaller than that of the pores are coagulated by the input of chemicals and thus expand their size, so that the physical removal process can be promoted.

When the filtration process is applied to the village drinking water system, if high-turbidity muddy water flows into the system during rain, treatment efficiency could rapidly decrease. In the worse case scenario, filtering sand could be swept away. Thus, in consideration of those matters, a proper filtration system should be installed, operated and managed. <Table A-2> is a comparative chart of filtration processes.

Table A-2 | Types of Filtration Treatment and their Characteristics

Filtration method	Merits	Demerits	Notes
Slow sand filtration	Low price Easy to run Possible to remove more than 99% of Giardia Cyst No additional processes	Impossible to apply to high turbidity Eliminating surface impurities Large site required (1-4 L/min/m^2)	This consists of a fine sand layer of about 1m, a gravel layer of about 30cm and a lower part ejector. Top-down treatment system
Diatomite filtration	Easy to run Effective for removing spore, algae and asbestos Low initial investment Useful in case of emergency or seasonal overload	Appropriate for a low number of microorganisms and low-turbidity (10NTU). Coagulant addition and filtering are required. Constant thickness of diatomite needs to be maintained	Laminating or coating diatomite on the surface of filter cartridge or porous support material. Min. quantity of diatomite used for support material is about 1kg/m^2. Appropriate thickness of a diatomite layer to effectively remove Giardia Cyst is about 3-5mm. Periodic filter backwashes about every 1-4 days are required.
Direct filtration	90-99% of virus removal Possible to remove 99.99% of Giardia	For high efficiency elimination, coagulating process is essential. Appropriate for areas where there are no seasonal changes in flow rate.	This is very similar to the typical filtration method, but precipitation process is omitted. Required concentration of general coagulant is 1-30ppm.

Filtration method	Merits	Demerits	Notes
Package filtration	Small system Economical Easy to run Automatic operation is possible	In the event of a high-turbidity overload or when the quality of original water is variable, careful operation is required.	Systematization of all the processes including chemical input, coagulation, precipitation and filtration. It is critical to correct chemical input according to changes in the quality of source water
Membrane filtration	Small system Easy to automatically run Suitable for small water treatment facilities Excellent in removing microorganisms, organic matter and floating matter that affects taste, chromaticity and smell.	Suitable pre-treatment required. Treatment efficiency decreases as a result of membrane fouling. Periodic washing and chemical cleaning are required.	Removal of impurities through the use of semipermeable cellulose acetate (CA) membrane, polyamide (PA) membrane, polysulfonate membrane, etc.
Cartridge filtration	Easy to run, maintain and manage Small system	Appropriate for low-turbidity water Periodic replacement of cartridge filter is required. Difficulty in automation. High maintenance costs	Installing ceramic or polypropylene filter on the pressure vessel. Applying disinfectant to the surface of filter to prevent proliferation of microorganisms.

3) Nitrate Removal Technology

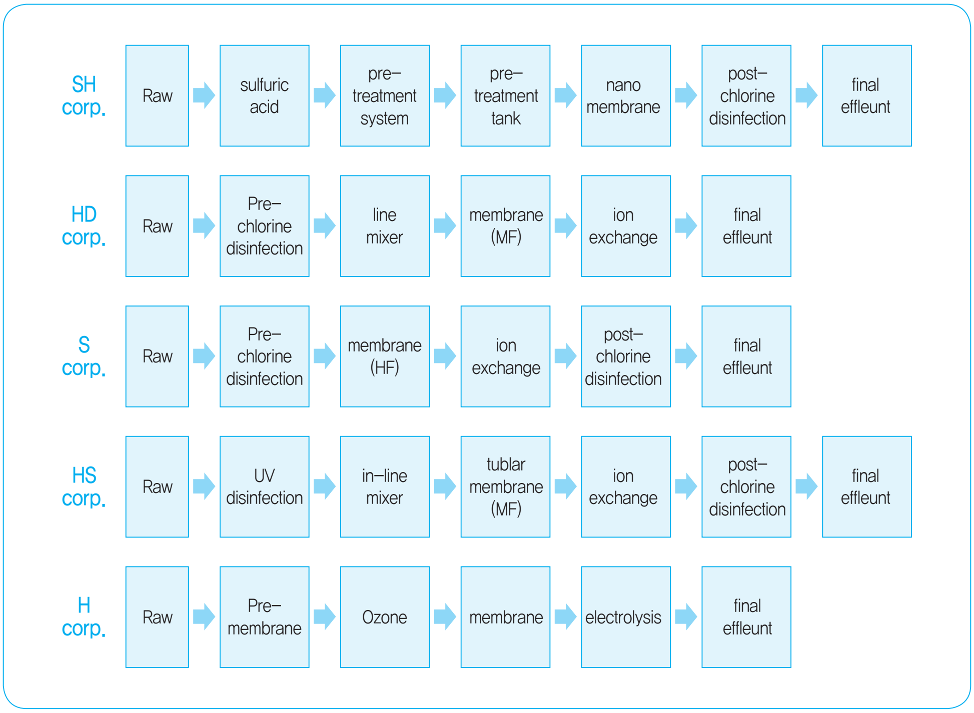
The ion exchange resin method is widely applied to remove nitrate nitrogen, and in this process, resins in the form of particles are used. This method is a process of exchanging chlorine ion attached on anion resin for nitrate nitrogen ion. However, since underground water generally contains bivalent sulfate ions, which are more easily adsorbed onto resin than univalent nitrogen ions, the treatment efficiency of nitrate nitrogen ions could decrease, and thus periodic replacement of the resin is needed.

Reverse osmosis is a method used to separate nitrate nitrogen ions by making underground water pass through a membrane with high pressure. This method is not ion selective, and thus even harmless ions could be eliminated, and a fouling phenomenon caused by pollutants could occur. As such, this causes a decrease in treatment efficiency. In addition, since high water pressure is needed for periodic washing and transmission of water, relatively high energy is consumed and a skilled operation specialist is required.

The electrodialysis method, which uses an ion exchange membrane that selectively passes cation or anion, makes cations pass through an anion exchange membrane and anions pass through a cation exchange membrane using DC voltage. In contrast to reverse osmosis, whose driving force is pressure, this method is run by electric power. Chemicals are not used, and thus an environment-friendly process through which ionic substances are eliminated and recycled such as in the ion exchange resin method is unnecessary. However, the frequent treatment of electrolytes requires an enormous amount of power consumption caused by a high electric resistance of ion exchange membrane. As such, maintenance is not an easy task. In the electrolytic method, nitrate nitrogen is electrolyzed electrochemically using an insoluble electrode or a carbon steel electrode. Since the electrolytic process does not need chemicals, this is an environmentally friendly process. However, its operating conditions are not simple and this method is not appropriate for an area with large environmental and seasonal changes.

Currently, considering the merits and demerits of those processes, an all-in-one integrated process is actively being developed and applied, which is to treat chromaticity and turbidity through a separating membrane, coliform bacteria by chlorine, UV and ozone, and nitrate nitrogen by ion exchange resin, electrolysis bath and nano membrane.

Figure A-2 | An all-in-one Treatment Process for Village Drinking Water System (Korea Environment Corporation, 2005)



Reference: Korea Environment Corporation (2005)

2. Small-scale Sewerage Treatment Technology

1) Activated Sludge Process

The activated sludge process is a biological method of treating sewage by combining organisms in sewage and aerobes. Aerobes proliferate by aeration and this metabolism leads to the decomposition of sewage. These proliferated aerobes would be separated in floc form by the solid-liquid separation at a settlement tank, then partially sent back or treated as disposal. There are some considerations when applying the activated sludge process: I) more than 1 aeration tank is required in case of emergency such as maintenance, II) oxygen should be supplied effectively for the smooth growth of aerobes which decompose and digest sewage in the aeration tank, III) operation of settlement tank with returning and disposal of sludge should be effective to improve the treatment efficiency of sewage.

2) SBR (Sequencing Batch Reactor)

SBR, with the development of automatic operation technology, has been developed to operate relatively easily at small sewage treatment facilities. SBR is generally known to have transformed within the activated sludge process spatial concept into temporal concept. It is a method of treating sewage in which all incoming sewage, aeration, stationary, settlement and discharge processes occur continuously in one reactor. SBR is widely applied to small sewage treatment facilities because it has the following advantages:

- It is resistant to load variation and/or shocking load because the process of incoming sewage itself functions as an equalization basin.
- All the processes progress at one reactor, so the required site area can be reduced.
- Generally, there is no need to return sedimentation and/or sludge.
- Sedimentation efficiency is good due to the control over the growth of filamentous by proper change of incoming sewage process.
- Automatic operation makes it easy to operate the facility, and offers flexibility according to the properties of incoming sewage.

3) Extended Aeration

Extended aeration is a method that simultaneously elevates the concentration of sludge in the secondary aeration tank and extends its residence time. As the residence time in the aeration tank becomes longer, the aeration time is also extended so that sludge can stay in the aeration tank from the log-growth phase to endogenous respiration. This leads to sludge autooxidation, which reduces the sludge generation amount at the final settlement tank. However, when the sludge reaches the autooxidation stage, its sedimentation and activity tend to be lower, and nitrification of sludge makes pH levels drop.

4) Oxidation Ditch Method

The oxidation ditch method is operated with a relatively low load of organisms so that it affects the treated water quality little, even when there are some changes to incoming sewage amount, water quality variation and water temperature drop. Nitrogen removal by denitrification can be up to 70% through intermittent aeration operation. However, it requires a wide site area, since the residence time should be long and the depth of water should be shallow.

5) Rotating Biological Contactor

Rotating biological contactor is a method to treat sewage by using a rotating contactor in water. When the contactor comes out of the water to the air, microorganisms attached to the contactor decompose and remove the contaminant after contact with the air. This can increase the BOD of the treated water quality due to the nitrification, but its sedimentation is satisfactory at the final settlement tank because there is no sludge bulking, which can occur in the Activated sludge process.

6) Contact Oxidation Method

The contact oxidation method is a sewage treatment method that uses bio-film that is formed and attached to the surface of a carrier deposited in the reactor. The oxygen required for the oxidation of organisms is supplied by aeration equipment of the reactor. One characteristic of this method is that many more organisms can be grown and maintained in a reactor without returning sludge than in the Activated sludge process, resulting in high treatment efficiency of incoming contaminant loading. Design factor and facility components can be divided into various methods according to the reactor type and the properties of carrier, but the criterion of space loading for organisms is generally 0.3kg/m^3/d.

7) Trickling Filter Process

Trickling filter process is a sewage treatment method that causes organisms in sewage to be oxidized by bio-film, which is formed and attached by watering the incoming sewage to a filter bed of the reactor. Trickling loading, one of the design factors, varies according to the BOD of the incoming sewage, but its load factor is approximately 25-15m^3/m^2/d when the BOD is 100-200mg/L. Meanwhile, crushed stone, which has a wide and rough surface, and plastics are used in filter media comprising the filter bed.

8) Contact Oxidation System Topsoil

Contact oxidation system topsoil is a sewage treatment method used in combination with the existing contact oxidation method that takes advantage of the unique purifying effects of soil microbes. Aerobes in the aeration tank eliminate organisms in sewage, and ∮100-200mm of crushed stone, which is the contact filter media, is used as filler to prevent the loss of aerobes. This increases the decomposition by soil microbes through contact between sewage surface and soil with a 20-30cm layer of poromeric special soil covered on top, which is suitable for inhabitation of soil microbes. Organisms in sewage are eliminated by the aerobes attached at the filter media in a contact aeration tank and the soil microbes cultured in topsoil, and there is an additional advantage, such as a deodorizing effect. In addition, the treated water quality is great regardless of the location and/or the scale of treatment, and thus the treated sewage water can be reused as agricultural water or for toilets. During repair check, however, topsoil needs to be removed, while selection of topsoil must be done carefully and special attention is required to maintenance using perennial lawn. Also, since there are no limitations on range of areas and treatment capacity and the quality of the treating water is superior, treating water can be recycled in agricultural or toilet usage.

9) Capillary Permeation Trench Method

The capillary permeation trench method is a sewage treatment method that allows sewage from the primary septic tank to pass through a facility called a trench structure, and takes advantage of the activities of aerobes-anaerobes. This trench has multiple layers with different porosities, and is installed under a 1m depth of soil where the soil microbes live. This soil trench makes the sewage sink to the soil evenly, so that the sewage can be permeated and absorbed into soil. Afterwards, it moves as unsaturated flow through capillary siphonage. Incoming sewage is treated by microbes living in soil with the actions of moisture capacity, permeability and water permeability. It requires attention when there are a large amount of organisms or suspended solids in the sewage, as they may cause blocking.

This method involves less energy and/or operating costs. However, there are some problems with this method; 1) it requires a relatively wide site to install the soil trench for complete treatment, 2) many facilities undergo a decline in treatment efficiency and mismanagement due to its difficult installation. Unlike other methods, it requires extreme caution as it is a method installed under the ground that is difficult to operate, but most are not installed properly. It is rarely used these days due to the blocking of soil pores.

<Table A-3> below compares the operation, maintenance and treatment efficiency of major methods applied to small sewage treatment facilities.

Table A-3 | Comparison of Methods Applied to Small Sewage Treatment Facilities

Classification	Activated sludge process	Extended aeration	Contact oxidation method	Trickling filter process	SBR
Handling capacity with regard to load variation	weak	excellent	excellent	excellent	weak
Treatment efficiency and stability of water quality	water quality can be degraded due to sludge bulking in settlement tank	water quality can be degraded due to sludge bulking in settlement tank	good	good	good
Ease of operation	normal	requires technical expertise	easy to operate but requires a long time to recover if there is elimination of bio-film	requires operation experience	requires technical expertise to operate automati-cally
Convenience of facility maintenance	normal	normal	normal	difficult	easy
Economic evaluation and facility expense according to facility scale	favorable for large facilities	widely applied to small facilities but requires a wide site area and construction expense	economical for medium-scale facilities or smaller	aeration tank required with higher capacity than contact oxidation	relatively high facility expense but low operation and maintenance expense

Comparing the methods applied to the small sewage treatment facility, the average incoming flow rate is 46-104.8 m^3/d and the average facility capacity is 51.5-130.3 m^3/d. It was also reported that the average operating expense is from 1,190,000 to 3,604,000 won and the average target population is from 122 to 450.

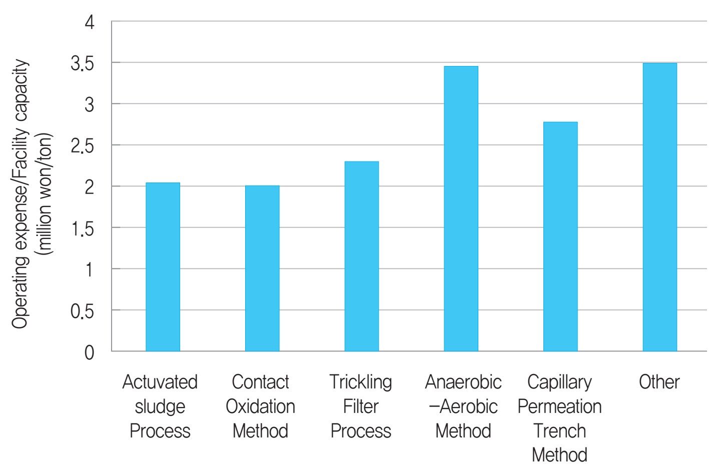
Table A-4 | Facility Resources by Method

Classification		Activated sludge process	Contact oxidation method	Trickling filter process	Soil trench process	Anaerobic-Aerobic process (SBR)	Others
Flow rate (m³/d)	Range	15-467	8-310	42-50	20-120	20-160	30-95
	Average	104.8	105.3	46.0	51.1	60.5	61.2
Facility capacity (m³/d)	Range	50-500	50-500	50-53	50-165	50-200	56-170
	Average	121.3	130.3	51.5	60.9	74.5	102.7
Operating expense (1 million won)	Range	40-529	45-671	113-125	63-343	70-512	200-448
	Average	254.0	268.0	119.0	171.9	259.9	360.4
Target population (persons)	Range	60-1700	54-2644	78-166	60-362	45-486	175-1110
	Average	429	450	122	199	231	441

Source: Lim Bong-soo, Lee Chang-gyun (2011)

[Figure A-3] shows the operating expense by facility capacity. It shows that the operating expense when the anaerobic-aerobic method is used tends to be higher than other treatment methods, at approximately 3.5 million won per ton.

Figure A-3 | Operating Expense to a Facility Capacity by Treatment Method



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