Water Management in Korea:
Experiences and Achievements

August 2017

Ministry of Environment
Water Management in Korea:
Experiences and Achievements

August 2017
Executive Summary

Korea, which was one of the poorest nations in the world up until the 1960s, has become a leading exporter, now ranking 6th in the world. However the rapid economic growth had serious impacts on water management. In the 1990s, a series of major water pollution incidents occurred and they exacerbated drinking water safety concerns. It was not just a series of tragic affairs but an opportunity to strengthen water quality management system and develop relevant technology. It stimulated the investment in the waterworks and sewerage infrastructure by central and local government.

Expansion of water and sewage infrastructure and reinforced environmental regulation significantly improved the national water quality. It also greatly contributed to the improvement of public health including reduction of water-borne diseases. It would be worthwhile, especially for the developing countries, to explore the water-related challenges that Korea faced with during economic growth. Korea’s experiences such as international aid in water sector and the development & deployment of fundamental water/ wastewater treatment processes can provide important implications for other countries that are suffering from similar issues. The state of the art trend such as converging ICT with water technology and creating added value from sewage treatment plants can give valuable insights in the 'future' water and cities.
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Chapter 1.
Introduction
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Introduction

Korea was one of the poorest nations in the world up until the 1960s, but just half a century later, the "miracle of the Han River" has been achieved. Korea has become a leading exporter, now ranking 6th in the world. This pace of growth was possible because of development policies, macroeconomic stabilization, and investment in public infrastructure and human capital. It was based on the expansion of export-driven economy. Korea’s national income, which was barely $45 when it gained its independence in 1945, is currently $20,000.

![Figure 1-1](image-url) GDP trend per capita in Korea compared to the OECD average.

Rapid economic growth, population growth, urbanization, and improved living standards have had a significant effect on water management. Demand for water has increased considerably due to population growth and industrial development. Higher domestic and industrial pollutant discharge had resulted in significant water quality deterioration.
Waterborne diseases such as cholera occurred frequently in the 1960s due to the lack of water and sanitation infrastructure. A series of major water pollution incidents occurred in the 1990s, which exacerbated issues associated with drinking water safety. This served to raise awareness of the water quality protection and the drinking water safety.

These crises pertaining to water availability, sanitation, and pollution did not deter Korea’s economic and social development. Instead, Korea converted them into an opportunity to improve its water management policies and technologies.

Multi-purpose dams were built since the 1960s. This allowed the country to secure its water resources and meet the rising water demand during the industrialization period. Korea had rapidly modified its urban sewage management system and expanded the capacity of domestic sewage treatment plants (STPs) and industrial wastewater treatment plants (WWTPs). The water quality of rivers and lakes was significantly improved by the expansion of sewage infrastructure and the reinforced environmental regulation. The improved water quality resulted in higher water-related recreational activities and healthier aquatic ecosystem.

Currently advanced and innovative technologies such as membrane separation process and information and communication technology (ICT) are actively applied to water management sector. For instances, STPs is not regarded just as the facilities treating ‘dirty water’. Rather they are regarded as the facilities recovering the valuable resources from the wastewater and creating added value such as renewable energy, drought-proof water resource, community parks and sports complexes etc.
It would be worthwhile, especially for the developing countries, to explore the water-related challenges that Korea faced with during economic growth. Korea’s achievement and limitation on various water issues can provide important implications for other countries that are suffering from similar issues.

The purpose of this report is to share the Korea’s policies, technology, and industrial developments in water management and to contribute the policy development and implementation in the global community. This report is organized as follows. Chapter 2 will explore the water management problems in Korea over time, to provide historical context to the Korea’s water management framework and issues. Chapter 3 will examine the policy efforts to expand the water and sanitation service after the Korean Water. Chapter 4 will review the policy measures to deal with the severe water quality contamination incidents during the industrialization and urbanization period. Chapter 5 will introduce the ongoing policy activities on research and business development (R&BD) in water management to meet current and future needs. Lastly, Chapter 6 will summarize the features of Korea’s water management policy and draw its implications to global community and individual countries.
Chapter 2.  Korea’s Main Water Management Issues

Section 1: Rapid Population Growth and Lack of Water & Sanitation Infrastructure


The population in Korea increased at an alarming rate after the Korean War. In the 1960s, the population growth rate was barely 3% per annum. However, the “baby boom” phenomenon, where the birth rate increases exponentially, lasted for 20 years from 1955 to the mid-1980s. The Korean population, which was at 25.01 million in 1960, grew by 50% and reached 37.41 million people in 1980.

(Figure 2-1) Population Growth of Korea

Starting from the 1950s, after the Korean War, urbanization has proceeded very rapidly, especially in Seoul. The population residing in urban areas according to administrative district increased from 24.5% in 1955 to 28.0% in 1960 as more people moved from rural areas to cities. In 1960s, industrialization and urbanization
advanced at an even greater speed as several industrial complex zones were established according to central government’s ‘Five-Year Economic Development Plan’. 30 years later, the population residing in urban areas increased to 75% by 1990.

While it took 150 to 200 years for other developed countries to reach an urbanization rate of 75%, it took just 30 years in Korea. Rapid population concentration at urban areas inevitably led to many social and environmental problems. From 1960s to the 1980s, the environmental infrastructures were far insufficient to properly treat the increased wastewater discharge from domestic and industrial sectors. At that time the domestic sewage from cities was discharged to streams without treatment or just after minimum primary treatment and it threatened the drinking water safety.

1.2. Poor Sanitation Condition in Urban Areas.

The first modern drinking water treatment plant (DWTP) was built by Korean Water Works Co. at Ttukseom, Seoul in 1908. Until the early 1960s, merely 17.1% of population was connected to public water supply and remaining more than 70% of population depended on groundwater well or other unsafe water sources.

Although majority of people depended on drinking water from stream without proper treatment, neither expansion nor maintenance of sewage infrastructures was carried out properly up to 1970s. Government could not accurately estimate the number of people connected to STPs.

(Figure 2-2) Change in Urbanization Rate.

(Figure 2-3) A crowd of citizens waiting for public water supply

(Figure 2-4) Laundry at Cheonggyecheon (stream) in the 1930s.
1.3. Waterborne Infectious Diseases

Lack of safe drinking water supply and proper sewage treatment in urban areas provoked the occurrence of waterborne infectious diseases. According to “Chosun Waterworks”, published in 1912, only 1.091 of the 9,241 groundwater wells in Seoul (12%) were adequate for drinking. This figure shows how serious the drinking water safety issue was at that time.

The issue had been addressed even in the 1960s. According to the National Groundwater Well Survey, which was conducted by the Ministry of Health and Society in 1969, 64% of groundwater wells across the nation did not meet the drinking water quality standards. The groundwater well which exceeded drinking water quality standards was prohibited for drinking water. And water quality conservation measures were taken to improve groundwater quality for drinking.

Waterborne infectious diseases were common in the 1800s and 1900s due to the poor water and sanitation conditions and they were a serious social issue. In 1821-1822, cholera occurred firstly throughout the country and the mortality by cholera was greater than 80-90%. Waterborne infectious diseases occurred nearly every year up until 1891. While the total population was about 8 million in 1895, 300,000 people died of cholera in the same year. Frequent recurrence of waterborne infectious diseases lasted until the 1960s.

Section 2: Intensified Deterioration of Water Quality

2.1. Pollution of Urban Streams

As the central government prepared the “5 Year Economic Development Plan” in 1962 and actively promoted industrialization, mass population moved from rural areas to Seoul, Busan, Daegu, and other large cities seeking jobs. The strikingly rapid urbanization produced many unauthorized shantytowns at city outskirts. Most of houses in shantytowns were not connected to proper water and sanitation services. Because there were no individual toilets in these towns, residents used community latrines and the collected feces and urine were directly discharged to nearby urban streams or ponds. During the monsoon season, heavy rains caused an overflow of the collected excreta. Untreated industrial wastewater and sewage overflow caused sever pollution of urban streams. Large-scale fish kill incidents occurred at urban streams and water pollution became a big social issue.
After the 1970s, many urban streams were covered with pavement and used for traffic roads and parking lots. Many natural streams were converted to straightened streams during urban redevelopment project in order to drainage the flood flow rapidly and to provide land for urban housing. It resulted in dried-up of stream flow and deterioration of stream ecology.

2.2. Large-scale Industrial Pollution Accidents

The 1990s was a very important time in the history of water management in Korea. During this period several water pollution accidents occurred consecutively, driving strong policy measures to be implemented. Until the 1970’s the government had placed all its focus on industrialization. Throughout the 1980s Korea hosted several international events including the "1986 Asian Games" and the "1988 Seoul Olympics". In the preparation of such international events, the government recognized importance of water environment. Environment Agency was established in 1980 and expanded the sewage management policy including constructing STPs in major cities. However, after 1991, a series of major water pollution accidents occurred and hit the front page of newspapers. The most remarkable accident was the Nakdong River phenol pollution accident, which occurred on March 16, 1991. The Daegu Metropolitan City received a huge number of civil complaints about the odor from tap water. The investigation found that phenol solutions were leaking from storage tanks at the Doosan Electronic factory in Gumi City. The leaked phenol solution was discharged directly into the Okgyecheon Stream, a tributary of the Nakdong River. The chemical was flowing into the water-intake point located 70 km downstream. The phenol in the intake water reacted with the disinfectant, chlorine, during water treatment process and caused intense foul odor in the produced tap water.
In the wake of the 1991 incident, water pollution accidents continued to occur throughout the 1990s. For example: in January 1994 foul odor came from tap water from the Nakdong River, a large scale fish kill in the Imjin River in August 1994, discharge of untreated sewage from Daejeon STP in April 1995, and an oil tank spill accident at the Chuncheonho (lake) in March 1999.

In 1989 and 1990, daily newspapers frequently reported that microorganisms, heavy metals and disinfection by-products were being detected in tap water. After 1991, the press reported lots of news on illegal discharge of industrial wastewater and the insufficiency of sewage management technologies.

As water pollution accidents became a national issue, the government and the general public became more aware of the importance of water-source protection and drinking water safety. The string of water pollution accidents contributed to improve the government’s response capacity to water pollution accidents and led to policy measures to prevent similar accidents from occurring in the future.

Section 3: Climate Change and Aging Infrastructure

3.1. Increased Drought and Flood Risks

In the past 100 years (1912 - 2008), the annual mean temperature of Korea’s six major cities increased by 1.7℃, which is higher than the world average temperature increase (0.74℃). The temporal and spatial variability of precipitation in Korea has been gradually increasing since the 1970s.
The changes in rainfall pattern are expected to become more severe by climate change. Between 2061 and 2090, the annual mean temperature is expected to increase by 3.6°C and the annual precipitation will rise by 168mm (14%) compared to the past 30 years (1971 - 2000).

(Table 2-1) Changes in annual mean temperature and precipitation

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<tr>
<td>Annual Mean temperature</td>
<td>12.5°C</td>
<td>12.88°C</td>
<td>+0.38°C</td>
<td>14.53°C</td>
</tr>
<tr>
<td>Annual Mean precipitation</td>
<td>1,230mm</td>
<td>1,341mm</td>
<td>+9.0%</td>
<td>1,299mm</td>
</tr>
</tbody>
</table>


Changes in rainfall patterns will affect the frequency and magnitude of droughts and floods, and may heighten the risk of meteorological disasters. Korea has experienced severe droughts every five to ten years since the 1900s. Since 1990, droughts occurred every two to three years and severe droughts occurred every seven years depending on the region. In the future (2061 - 2090), the drought occurrence interval is expected to increase by three to four times compared to 1977 - 2006. In 2015, Korea experienced the third lowest precipitation since 1973 and a severe drought in Northwestern Chungnam Province.

The number of days with heavy rainfall, exceeding 80mm per day, also increased to more than double that of the 1970s and it has exacerbated the difficulty of water management. The inundation at Gwanghwamun in Seoul in 2010 and Seocho-gu region in 2011 clearly demonstrate the insufficiency of urban drainage capacity.
3.2. Changes in Water Quality and Aquatic Ecosystems

Climate change may affect water quality and aquatic ecosystems including higher non-biodegradable organic compounds, algal abnormal proliferation, and aquatic habitation changes in the habitation of aquatic organisms.

Increase in rainfall intensity can cause more soil erosion and result in higher non-biodegradable organic compounds in water-intake sources. Those compounds can induce the formation of disinfection by-products, such as trihalomethane (THM), in water treatment processes, which generate taste and odor problem in tap water.

Algal growth depends on temperature, intensity of light, and nutrients such as nitrogen (N) and phosphorus (P). Hence increased sunlight and water temperatures and excessive nutrient inflow can intensify summer algal bloom. It can cause eutrophication in lakes, water treatment process failures, and fish resources reduction.

From 1989 to 2008, stream water temperature statistically significantly increased at 14 out of 97 watersheds. Lake water temperature also increased statistically significantly in 12 out of 49 lakes. Increased water temperatures in streams and lakes can lead to the proliferation of warm-temperate species.

3.3. The Deterioration of the Waterworks and Sewerage Infrastructure

Korea has paid little attention on the asset management of existing waterworks and sewerage infrastructure because its primary focus in water policy was the expansion of them. Regional water supply system, which serves more than two cities and provinces, has 4,957 km of pipelines. 10% of them are 16-20 years old and 19% of pipelines are over 21 years old.
Chapter 2. Korea’s Main Water Management Issues

Since the sewerage system was constructed after the waterworks, its overall deterioration is less critical than waterworks. However, large STPs whose capacity accounts for significant proportion were constructed several decades ago. STPs which are over 20 year old make up 57% of the total treatment capacity. It implies that large-scale investment will be required for the old STPs for rehabilitation or reconstruction in the near future.

![Diagram (Figure 2-15)](image)

(Figure 2-15) Composition ratio of deterioration according to the number and the capacity of sewage treatment facilities


Aging waterworks and sewerage systems has already generated damages. Since water supply pipelines were built from the 1960s, interruptions of water supply occur at the old water supply system. Recently, sinkholes on street which is produced by the breakdown of old sewage pipelines and sinkhole-damages are a significant issue for the city infrastructure managers.

![Diagram (Figure 2-16)](image)

(Figure 2-16) Composition ratio of deterioration according to the number and the capacity of sewage treatment facilities

Chapter 3. Water and Sanitation Improvement
Chapter 3.
Water and Sanitation Improvement

Section 1: Water & Sanitation Improvement in Urban Areas

1.1. Reconstruction after the Korean War

The most of waterworks facilities that were built during the period of Japanese occupation were destroyed during the Korean War of 1950. Therefore, the interruption of public water supply was inevitable even in metropolitan cities. The construction of waterworks infrastructure built before 1960 had been funded by international aids and municipal bonds. Those international aids were granted from the Foreign Operation Administration (FOA), International Cooperation Administration (ICA), and the Agency for International Development/Development Grant (AID/DG) etc.

The equipment for waterworks construction was supplied from those international aids and it was used in 67 cities whose public water supply systems had been severely destroyed during the Korean War. By the end of 1955, the public water supply systems could be recovered to their condition before the War. The total capacity of public water supply system at the time was approximately 900,000 m³/day. Several drinking water safety control measures in public water supply system were also established in major cities such as Seoul, Daegu, Incheon, and Busan. According to the measures, Duryu DWTP in Daegu, Gimpo water-intake reservoir and Guui DWTP in Seoul were constructed in 1959.
1.2. The period of the "5 Year Economic Development Plan"

In 1962, the "5 Year Economic Development Plan" was established in order to build a basis for a self-supporting economy. During the 5-year economic development plan, investments in waterworks and sewerage infrastructures were led by the national government, and funded through international loans. During this period, not only USA but also Japan, Germany and others supported the construction of waterworks and sewerage infrastructures.

From 1962 to 1981, the construction of public water supply system was carried out in 11 major cities including Seoul and Incheon. After that, from 1982 to 1986, the construction was carried out at small to medium local cities whose water demand was rapidly increasing. During those period, Korea received various kinds of support such as free technical cooperation or international cooperation loans from the International Bank for Reconstruction and Development (IBRD), International Development Association (IDA), and the Asian Development Bank (ADB).

In June 1976, Chongyecheon STP with 150,000 m³/day, the first STP in Korea, was constructed in Seoul. By 1980, several STPs were constructed in major cities including Joongrang STP in Seoul, Yongho STP in Busan, Gyeongju STP in Geongsang Province. Construction of STPs and sewage pipelines were funded from various sources including the Asian Development Bank (ADB), the International Bank for Reconstruction and Development (IBRD), KfW Bankengruppe (KFW), and the Overseas Economic Cooperation Fund (OECF).

Not just remaining as a passive recipient of international aids, Korea utilized the loan business as an opportunity for Korean companies to benefit from technology transfers from foreign engineering firms. In 1965, HDR, Inc. from the United States and Mirim Technology Group from Korea (later merged with Korea Engineering Consultants Corporation) jointly conducted a feasibility study on the water supply system in Incheon and Daegu. The joint works between the donor countries’ companies and Korean companies were instrumental in improving the technical capacity of Korean engineers. The Gwangam and Sanyu DWTPs in Seoul were constructed in 1976 and 1978, respectively. Their construction was funded from a loan from France. The loan required the condition of concluding a contract for the concept design, treatment processes, and supply of foreign materials from Degremont, a French water treatment company. In the process, Korean companies were able to acquire the sedimentation design technique that had been laid out and supervised by Degremont. In the 1982 waterworks expansion project in Daegu, Gwangju, and Masan, the waterworks facilities were jointly designed by Stanley Associates Engineering of Canada and a Korean engineering companies. Through the cooperative work, the Korean engineering companies could learn the advanced waterworks design skills.

While, the water resource development was carried out by Korea Water Resources Development Corporation, a government-owned public corporation established in 1967 according to the "5 Year Economic Development Plan", neither a governmental...
organization nor a public corporation was established for taking charge of managing the waterworks and sewerage infrastructures. Compared with the management of water resources infrastructures such as dams, the existing waterworks and sewerage infrastructures could not be systematically managed at that time.

K-water

K-water is a public corporation that was established in 1967 as a specialized water resource development agency under the Comprehensive Land Development Plan. As national industrial complexes became fully established and both domestic and industrial water demand rapidly increased, the name changed to “Korea Water Resources Corporation” in 1988 and it became dedicated to the projects related to water resources. K-water laid the foundation for long-term water resource development projects by conducting surveys on the Han River watershed with international institutions. K-water currently carries out many projects including the investigation of the 4 major river watersheds, management of multi-purpose dams, regional water supply, concessional operation of local governments’ waterworks.

Lack of a Government Organization for Waterworks and Sewerage Management

In 1980, the Environment Agency was established as a central administrative organization, but there was still no local environmental office that was dedicated to the management of waterworks and sewerage infrastructures. Although the Environmental Monitoring & Management Office was established to monitor environmental quality and to control the industrial point sources, its main focus was to measure the environmental pollution level due to the limited manpower. The adequate management of waterworks and sewerage infrastructures were beyond its capability.

1.3. After the 1988 Seoul Olympics (1988 – Present)

During the preparation of 1988 Seoul Olympics, Korean government constructed many waterworks and sewerage infrastructures. The national government’s proactive water policies following the consecutive water pollution accidents of the 1990s also greatly contributed to the expansion of those infrastructures. Such proactive water policies include the "Comprehensive Clean Water Supply Measure", the "Water Quality Improvement Measures", and the “Comprehensive Measures for Water Quality Management in the 4 Major Rivers”. Moreover, in order to successfully implement water quality control measures, Korea reorganized the administrative organizations which were related to water quality management. Korea also established 'Korea Environment Management Corporation’ to support the expansion and management of waterworks and sewerage infrastructures.

Water-related Administrative Organizations in Korea

Water management in Korea is divided into five departments in the central government. The most important administrative organizations are the Ministry of Environment (ME) and the Ministry of Land, Infrastructure and Transport (MoLIT). ME and MoLIT take charge of water quality and water quantity policy, respectively. ME is responsible for water quality and aquatic ecosystem management, industrial wastewater regulations, and the management of local waterworks and sewerage. MoLIT takes charge of droughts and floods control, river maintenance, operation of dams and weir, and metropolitan waterworks. In addition, The Ministry of Agriculture, Food and Rural Affairs is in charge of irrigation water, the Ministry of the Interior and Safety is responsible for maintenance of small-/medium-sized stream and disaster management, and the Ministry of Trade, Industry and Energy is in charge of the operation and management of hydroelectric dams.

Due to serious water pollution accidents in the past, the government’s water management organizations have undergone substantial modification and the environmental authority has been empowered more power and larger domain. The organization and authority of ME’s water management has been evolved as follows.
Chapter 3. Water and Sanitation Improvement

○ Period of the “Environmental Pollution Prevention Act” (1960–1979)
- In the early days of urbanization and industrialization, the “Environmental Pollution Prevention Act” was enacted in 1963 to protect people’s health from pollution. Policies were established to protect human health from industrial wastewater. The Pollution Control Office was established in 1967 in the Environment & Sanitation Division of the Ministry of Health and Social Affairs. The functions and staffs of Pollution Control Office were gradually expanded and National Institute of Environmental Research was established in 1978.

○ Period of the “Environmental Protection Law” (1980–1989)
- The “Environmental Protection Law” was enacted in 1978 to shift the environmental policy from passive response on health and hygiene issues to proactive pollution prevention and environmental conservation. In January 1980, the Environment Agency with 13 divisions under 7 bureaus was established by the Ministry of Health and Social Affairs. Important environmental policies were established at the time, such as environmental quality standards and monitoring, industrial discharge permit, environmental impact assessments, and the dispute settlement system on environmental pollution damages. At that time, the Ministry of Construction was responsible for waterworks and sewerage management and the Environment Agency was mainly responsible for the regulation of industrial wastewater. In December 1989, the status of Environment Agency was raised to Environmental Administration in order to strengthen its authority and functions.

- In order to manage the complex environmental problems more effectively, the “Environmental Protection Law” was divided to six individual laws including “Water Quality Conservation Act”, the “Clean Air Conservation Act” etc. In March 1991 and January 1994, serious water pollution accidents occurred at the Nakdong River. In May 1994, the status of Environmental Administration was raised to the Ministry of Environment. The Departments of Waterworks and Severage under the Ministry of Construction and the Department of Drinking Water under the Ministry of Health and Social Affairs were transferred to ME. The regional offices of ME were reorganized into 4 River Watershed Environmental Offices (Han River, Nakdong River, Geum River, Yeongsan River) and 3 Regional Environmental Offices (Wonju, Daegu, Jeonju). Because ME could control not only regulations but also the construction and management of water and wastewater infrastructures, ME was able to develop and implement more integrated water quality management policies such as “Comprehensive Water Management Measures” and the “Nakdong River Water Quality Improvement Measures” in 1996.

○ Period of Watershed Management (1999–Present)
- In 1998, the water quality of the Paldang Lake, which was the water-intake for the Seoul metropolitan area, deteriorated significantly due to the de-regulation policies. Various policy measures could not improve the water quality of the 4 major rivers. The government held a total of 420 stakeholder meetings and public hearings from 1998 to 2002 and established the “Comprehensive Water Management Measures for the 4 Major Rivers”. It included the control of total maximum daily loads, designation of riparian zone and riparian land purchase system, adoption of water user charge for the down streams and support for the residents at upper streams etc. The “Law Regarding Han River Water Quality Improvement and Citizen Support” was enacted in 1999 in an effort to legally support those policy measures. In 2002, special laws were enacted for the remaining three rivers.

The new government launched in 2003 set up a “Sustainable Water Management System” as one of their top 100 national projects. Water Policy Research Team composed of 18 experts and civic group members was established in 2004. The Team developed discussions on the re-organization of national water management system with relevant government’s departments (6 times), stakeholder groups (4 times), Government Innovation Committee and Presidential Office (3 times). Then, the Team published the “Sustainable Water Management Policy” report. In October 2005, the “National Water Management Committee” was established and it announced a plan to enact the “Basic Law on Water Management” and to transfer the authority of water quantity management from the Ministry of Construction to ME. Legislative notice was made in 2006, but the reform failed due to a disagreement between ME, Ministry of Construction, and the National Assembly.

The newly launched government in May 2017 announced to integrate the administrative organization on water quality, quantity, and water-related disaster prevention. The authority of water quantity management will be transferred from MoLIT to ME, and ME will take charge in both water quantity and quality. In July 2017, the revision to the "National Government Organization Act", which empowers ME with water quality and quantity management, was not approved by the National Assembly due to a difference in opinions between parties. Unlike 2006, both ME and MoLIT are currently making efforts to pass the revision again. They holds consecutive meetings with academia, business and civic groups to draw the consensus on the vision and roadmap for the integrated water management. If the National Assembly approves the revision to “National Government Organization Act”, Watershed Management Committee will be established in 2019, and the current centralized water management system will be converted to de-centralized, watershed-based and participatory governance.
Korea Environment Management Corporation

The Korea Environment Management Corporation (KECO) was established in 1987 for the professional operation and management of the environmental facilities. It has contributed greatly to the development of the waterworks and sewerage systems. The KECO has been in charge of the contract management of industrial WWTPs owned by the national and local governments. It has implemented construction agency projects such as the expansion of WWTPs and the installation of advanced wastewater treatment processes. Nowadays, KECO expands its business range to include the operation of nation-wide automatic water quality monitoring network, construction and support of public STPs, water quality improvement projects at water-intake areas etc.

As a result of these efforts, the population connected to public water supply, which was below 20% in the 1950s, rapidly increased to 97% by 2015. The total capacity of DWTPs also increased by more than 100 times, from 240,000 m³/day in 1950 to 26,824,000 m³/day in 2015.

Percentage of population connected to STPs, which was at a mere 8% in 1981, also rose to 92.9% by 2015. During this period, sewerage infrastructures were not only expanded but regulations regarding the STP effluent guidelines were strengthened. In order to comply to the strengthened regulations, existing STPs adopted tertiary wastewater treatment process to remove nitrogen (N) and phosphorus (P) from their effluents.
Section 2: Water & Sanitation Improvement in Rural Areas

2.1. The Village-scale Water Supply Project

In the early 1960s, waterworks and sewerage facilities were not properly established in the highlands, relocated resident settlements, and city outskirts. As a result, water and sanitation issues in these areas became even more severe. Although the public water supply systems were constructed at that time, they could not meet the rapid increasing water demand. In the summer, when water shortages increased, water wagons were deployed in areas where the public water supply systems were insufficient.
In order to improve the living condition and water & sanitation status in rural areas, the Korean government promoted the "Village-scale Water Supply Project". In 1967, the Ministry of Health and Social Affairs introduced the "Village-scale Water Supply Project" for seven villages as a part of community development policy. The residents were highly satisfied with the village-scale water supply systems because they were convenient and easy to maintain. Since then, the Village-scale Water Supply Project has been expanded, and by 1970, the project had been set up in 418 villages. When the Saemaeul Movement gained momentum after 1970, the establishment of Village-scale Water Supply Project in rural areas was further promoted.

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<td>Name</td>
<td>Simple Water Supply Facilities</td>
<td>Easy Waterworks</td>
<td>Village Waterworks</td>
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<td>Relevant Provisions</td>
<td>- Administrative Guidelines (1967–1086)</td>
<td>- Waterworks Law</td>
<td>(Same)</td>
</tr>
<tr>
<td>Installation Target</td>
<td>- Village with at least 20 houses</td>
<td>- Water supply population between 100 and 2,500</td>
<td>(Same)</td>
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In order to encourage the installation of the village-scale water supply system the government subsidized the construction costs using loans and the budgets of local government. The residents burdened 1/3 of the budget to set up the construction plan and launch the full-scale project. The remainder was subsidized with the budgets of central and local government each providing 1/3 of the total costs. Central government used funds from ADD and IBRD loans to support this initiative.

Upon allocating the project expenses, the highest priority was given to villages that had (1) outbreaks or risk of waterborne infectious diseases, (2) outstanding town of Saemaeul Movement (3) isolated islands, and (4) villages with the ability to pay for at least 1/3 of the construction costs. As a result, 6,520 of village-scale water supply system and 10,120 small-scale water supply facilities were established by 2015. This has contributed to improvements in the living condition and water & sanitation status in rural areas.
2.2. Rural Area Living Environment Improvement Project

In the early 1970s after the Korean War, a series of projects related to the water resource development were executed including small stream maintenance, groundwater well maintenance, community groundwater well development etc. From 1970 to 1980, the Saemaeul Movement was in full force, and the scope of the project extended to the improvement of the rural area living environment. This included: the water supply project, sewerage improvement, river closures, the construction of irrigation facilities etc.


Section 3: Drinking Water Safety Management

3.1. Strengthening the Drinking Water Safety Regulations

In the early 1990s, a series of water pollution accidents increased the public’s distrust of tap water. The government strengthened the water quality regulation of the drinking water. In the 2000s, the government made efforts to supply safe drinking water such as establishing the "Comprehensive Measures to Improve Water Quality Management (2001)" and "Comprehensive Measures to Improve Tap Water Quality (2005)."

Water quality standards for drinking water in Korea were first established in 1963 when tap water quality standards were created through a decree from the Ministry of Health and Social Affairs: the "Water Quality Standards, Water Quality Inspection Methods, Health Diagnosis, and Hygiene Standards through the Waterworks Law". In 1984, the "Rules Related to Drinking Water Quality" were enacted in order to manage the quality of all types of drinking water, such as water supply facilities, mineral springs in rural areas, and tap water. After the 1990s, tap water quality standards were strengthened to the level of World Health Organization (WHO) guidelines.

The Ministry of the Environment invested a total of 19.6 trillion KRW (1 KRW ≈ $1131 USD) between 2001 and 2005 to implement tap water quality improvement projects. The purpose of the “Comprehensive Measures to Improve Tap Water Quality Management” (2001) was to identify the causes of viruses in water-intake sources and to strengthen safety regulation regarding the overall tap water production and supply system. It included short-term measures for urgently resolving matters such as the expansion of drinking water quality standards, the improvement of deteriorating waterworks facilities, strengthening operational management, and improving the aged systems. The "Comprehensive Measures for Improving Tap Water Quality" that was established in 2005 included the preparation of safe water-intake sources, the construction of DWTPs and the management of water supply pipelines in order to deliver safe and clean tap water to the public. More detailed projects...
included the management of indoor water supply pipelines, the improvement of old water pipelines, the posting of the tap water manager’s real name, and the public notice of the violation of drinking water quality standards.

### 3.2. Expansion of Advanced Water Treatment Process

In order to clear the anxiety and distrust surrounding drinking water safety, an advanced water treatment process was introduced to water purification plants. This consisted of membrane filtration and an advanced oxidation process. It removed taste and odor inducing substances, trace organic substances, ammonia-nitrogen, and chlorine-resistant pathogenic microorganisms.

The advanced water treatment process was first introduced at 3 DWTPs in the Han River watershed, 15 DWTPs in the Nakdong River watershed, and 2 DWTPs in the Geum River watershed. All of those sites had suffered from deteriorated water quality of water-intake sources due to domestic or industrial wastewater. The government subsidized the construction cost of advanced water treatment process using Watershed Management Fund, which was made of the charges levied on the downstream water users. The adoption of advanced water treatment process in DWTPs increased by about three times by 2015, compared to 2000 when the advanced treatment process was first introduced.

In the future, the government plans to expand the advanced water treatment processes to deal with the challenges of tap water quality posed by the deteriorated water-intake quality and aging water supply facilities. It is expected that the capacity of the advanced water treatment process will account for 70% (19,071,000 m³/day) of the total DTWPs’ capacity by the year 2025.

### Section 4: Outcome by Water & Sanitation Improvement

#### 4.1. The Improvement of Drinking Water Quality

There were many violations of water quality standards at village waterworks facilities until the 1990s, but this number has been steadily decreasing since the 2000s. As a result of introducing the advanced water treatment process, there were fewer complaints about the taste and smell of tap water. Strengthened management across the entire tap water production process led to a drastic decrease in violations of drinking water quality standards at DWTPs, and village waterworks facilities.
Eight DWTPs located downstream of the Nakdong River introduced ozone oxidation and activated carbon adsorption process. Such advanced processes resulted in additional removal efficiency of total organic carbon (TOC), KMnO4 consumption, and UV254.

(Table 3–5) Additional removal rate at 8 water purification plants downstream of the Nakdong River after implementing the advanced water treatment process.

<table>
<thead>
<tr>
<th>Category</th>
<th>TOC</th>
<th>KMnO4 Consumption</th>
<th>UV254</th>
</tr>
</thead>
<tbody>
<tr>
<td>O3</td>
<td>7 (±3.3)</td>
<td>19 (±9.7)</td>
<td>34 (±18.8)</td>
</tr>
</tbody>
</table>

4.2. Decrease of Waterborne Diseases

Waterborne diseases, in particular Category I lethal communicable diseases such as cholera and typhoid fever, occurred on a large scale in the 1960s. Occurrences of these diseases sharply decreased as the safe water supply system was expanded to rural areas through the Saemaeul Movement.

As waterworks facilities were installed in rural areas, the proportion of parasite-positive youths drastically decreased from 71.3% in 1971 to 0.6% in 1991.

(Figure 3–11) Occurrence of waterborne infectious diseases (cholera, typhoid fever) (1954–2015)

Chapter 4. Water Technology & Industry Development
Chapter 4.
Water Technology & Industry Development

Section 1: R&D and Its Application

1.1. Waterworks and Sewerage R&D Project

Although the first STP in Korea, Cheonggyecheon STP, was constructed in 1976, prior to the 1988 Seoul Olympics the waterworks and sewerage technology was on a low level. Most of the STPs established in cities were equipped with biological wastewater treatment process, but there were also many plants equipped with merely primary treatment process.

(Table 4-1) Status of public sewage treatment plants in operation during the 1988 Seoul Olympics.

<table>
<thead>
<tr>
<th>Location</th>
<th>Year of Operation</th>
<th>Facility Capacity (1,000/day)</th>
<th>Sewerage Pipeline Method</th>
<th>Sewerage Treatment Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheonggyecheon, Seoul</td>
<td>1976</td>
<td>150</td>
<td>Activated Sludge</td>
<td></td>
</tr>
<tr>
<td>Gyeongju</td>
<td>1978</td>
<td>25</td>
<td>Separated System</td>
<td>Anaerobic Lagoon</td>
</tr>
<tr>
<td>Jungang 1</td>
<td>1979</td>
<td>210</td>
<td>Combined</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Jungang 2</td>
<td>1987</td>
<td>700</td>
<td>Combined</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Dalseo, Daegu</td>
<td>1986</td>
<td>250</td>
<td>Combined</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Daejeon</td>
<td>1986</td>
<td>150</td>
<td>Combined</td>
<td>Primary Treatment</td>
</tr>
<tr>
<td>Jeonju</td>
<td>1986</td>
<td>100</td>
<td>Combined</td>
<td>Primary Treatment</td>
</tr>
<tr>
<td>Gumi</td>
<td>1986</td>
<td>124</td>
<td>Combined</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Ansan</td>
<td>1986</td>
<td>121</td>
<td>Separated System</td>
<td>Primary Treatment</td>
</tr>
<tr>
<td>Gwacheon</td>
<td>1986</td>
<td>30</td>
<td>Separated System</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Munui</td>
<td>1986</td>
<td>0.5</td>
<td>Combined</td>
<td>Long-term aeration activated sludge</td>
</tr>
<tr>
<td>Tancheon, Seoul</td>
<td>1987</td>
<td>500</td>
<td>Combined</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Anyangcheon, Seoul</td>
<td>1987</td>
<td>1,000</td>
<td>Combined</td>
<td>Primary Treatment</td>
</tr>
<tr>
<td>Nanji, Seoul</td>
<td>1987</td>
<td>500</td>
<td>Combined</td>
<td>Primary Treatment</td>
</tr>
<tr>
<td>Uijeongbu</td>
<td>1987</td>
<td>60</td>
<td>Combined</td>
<td>Activated Sludge</td>
</tr>
</tbody>
</table>
The development of sewage and wastewater treatment technologies in Korea began in full force in the late 1980s. After the 1988 Seoul Olympics, foreign loans were appropriated for building STPs with the secondary treatment process. The "Advanced Technology Development Project (G7 Project)" has been in progress since 1991, in an effort to improve science and technology to the level of the 7 most advanced countries (G7). This contributed greatly to the development of waterworks and sewerage technology. During the "G7 Environmental Technology Development Project" (1992-2001), 357.3 billion KRW were invested over the course of 10 years and 331 technologies were developed. In the First, fundamental and core technologies were developed, and then the practical feasibility was investigated for selected core technologies in a viewpoint of commercialization. Such R&D strategy induced vibrant R&D activities on water technology with a focus on pilot test and field research.

After the G7 project, the "Next Generation Core Environmental Technology Development Project" was implemented from 2001 to 2010 in order to strengthen the competitiveness of the environmental industry. The "Next Generation Core Environmental Technology Development Project" was executed by the specialized R&D planning organization, the Korea Environmental Industry Technology Institute (KEITI). To this end, the "Water Treatment Advancement Project Group" was formed, whose research area included the optimal management of water pipeline network, the development of membrane materials for water treatment, and the development of highly efficient and ultra-concentrated STPs. This all contributed to the development of waterworks and sewerage technology.

### Table 4-2 Technical developments related to waterworks and sewerage from the Next Generation Core Environmental Technology Development Project.

<table>
<thead>
<tr>
<th>Field</th>
<th>Detailed Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Projects</td>
<td>- Eco-friendly effluent treatment and management technology</td>
</tr>
<tr>
<td></td>
<td>- Advanced sewage and wastewater treatment and core element technology</td>
</tr>
<tr>
<td>Eco-Star Group Project</td>
<td>- Highly efficient and concentrated treatment technology for highly concentrated wastewater from food industry.</td>
</tr>
<tr>
<td></td>
<td>- Optimized water pipeline network design and water quality management</td>
</tr>
<tr>
<td></td>
<td>- Treatment process of highly toxic electronic industrial wastewater</td>
</tr>
<tr>
<td></td>
<td>- Membrane materials for water treatment</td>
</tr>
<tr>
<td></td>
<td>- Commercialization of a mid-to-large advanced membrane separation system.</td>
</tr>
<tr>
<td></td>
<td>- Highly efficient and dense STP technology</td>
</tr>
<tr>
<td>Aquatic Ecosystem Restoration Project Group</td>
<td>- Riparian ecology field.</td>
</tr>
<tr>
<td></td>
<td>- Ecological integrity field.</td>
</tr>
<tr>
<td></td>
<td>- Aquatic ecosystem in rivers and lakes.</td>
</tr>
</tbody>
</table>
1.2. Demonstration of Technology and Field Application

In the late 1990s and the early 2000s, a variety of new waterworks and sewerage technologies were developed through R&D projects. However, their field applicability had yet to be verified. In 2000, the Korea Environment Management Corporation (KEMC, the predecessor of present KECO) established the "Wastewater Treatment Model Facility Complex", a sort of test-bed, at the Guri STP in Gyeonggi Province in order to assess the performance of the developed technologies. 27 companies applied their own treatment technology at the model facility in Guri STP, and performance evaluations were conducted for 6 months or more including the winter season. Tested treatment technologies included the SBR(sequencing batch reactor) process for small STPs, BNR(biological nutrient removal) process for medium and large STPs, and the MLE(modified Ludzck-Ettinger) process for sewage with a high nitrogen concentration.

The "Wastewater Treatment Model Facility Complex" served as a test-bed to verify the uncertainties regarding the field applicability and performance of newly developed technologies. The performance assessment results were used as important supporting data when the government established the policy on expanding the advanced treatment process in existing STPs.

The "Water Treatment Advancement Project Group" has developed PVDF membrane and module, which are now ranked fourth in the world following the likes of the United States, Japan, and Germany. Pressurized and immersed membrane separation systems were also developed for application in DWTPs. These treatment processes meet the WHO drinking water quality guidelines for pathogenic protozoa, while taking up less land space and exhibiting higher energy efficiency. This membrane separation process was applied to the Yeongdeungpo DWTP in Seoul in 2011 and has been used to produce high quality tap water.

Section 2: Expansion of Water & Wastewater Infrastructures

2.1. Sewerage Expansion

Many discussions have been held regarding the expansion of public sewerage system. There are two main approaches by which the sewerage infrastructure can be rolled out. The "pipeline-precedence" approach constructs sewer pipelines first in a planned sewerage area, then STPs are later constructed. Alternatively, the "simultaneous construction" approach constructs both sewer pipelines and STPs simultaneously. United States and Europe expanded their sewerage by pipeline-precedence way, while Japan constructed both pipelines and STPs simultaneously. Unless the sewer pipelines are maintained properly, the rainwater or groundwater can intrude the sewer lines. Such intrusion in sewer pipeline network dilutes the influent sewer concentration at STPs and hinders the efficient operation of STPs. Conversely, if the sewer pipeline is installed before STPs, then sewage from the city will be captured and transported by sewer lines. Because STP is not built yet, the sewer outfall will discharge untreated domestic sewers directly into streams. It can
cause rapid deterioration of the steam’s water quality. Although the construction of STP is planned in advance, the deterioration of stream water quality during the sewer pipeline maintenance project could lead to public distrust for government’s water policy. Therefore, the government decided to build the STPs prior to sewer pipelines, but accelerate sewer pipeline maintenance projects as soon as the planned STPs were constructed.

In the 1990s, the government carried out a major STPs construction projects and about 110 STPs were built nationwide between 1991 and 1999. After the completion of the STP construction project, the government declared 2002 as the “Year of Sewer Pipeline Maintenance” and conducted a major sewer pipeline maintenance project. Due to the limited government budget, private fund has been invested in sewer pipeline maintenance project through BTL (Build-Transfer-Lease) method since 2005. The concessionaire (private company) makes an investment to build (B) sewer pipelines. After the completion of construction project, the ownership of the sewer pipelines is transferred (T) to the governments. But the concessionaire still has the right to lease (L) the sewer pipelines to the government. Private company can recover the investment through lease fee paid by government.

Today, large-scale STPs (a.k.a. Water Reclamation Centers) with a treatment capacity that exceeds 1 million m³/day are established in four places in Jungang, Tancheon, Nanji, and Seonam in Seoul. These STPs were equipped with advanced treatment facilities in 2013 – 2014. Advanced treatment process will be installed by the end of 2018 in order to comply with the strengthened STP effluent guidelines for total phosphorus (T-P). The Jungrang STP plans to improve the existing activated sludge process in line with the strengthened effluent guidelines. It intends to pack the treatment processes compactly and to house the packed processes underground.

The Nanji STP plans to reduce the odor generated at treatment processes and to construct culture/sports facilities by 2019. Like Jungrang, in the long run, Nanji STP also plans to house its digestion processes underground and to create parts aboveground for community residents.

The Tancheon STP has been operating a sludge drying facility since 2011. It saves its energy cost by recycling the final residue of dried sludge in the thermoelectric power plant, and replacing LNG (liquified natural gas) with the digester gas. Currently about 28% of Tancheon STP’s area is used for sports complex, outdoor performance stage and parking lots. By 2013 the Seonam STP had also completed the implementation of advanced treatment process and a step-by-step project to modernize the facility is underway.

2.2. Advance Sewage Treatment Process Penetration

In 1996, total nitrogen (T-N) and total phosphorus (T-P) were added to the STP effluent guideline and biological nitrogen and phosphorus treatment techniques began to be applied. New regulation on T-N and T-P simulated the development and application of advanced wastewater treatment processes in STP. In order to find
the optimal advanced treatment method, a "Pilot Project for Advanced Sewerage Facilities" was conducted in 14 regions including Gyeongan STP in the Gyeonggi Province.

To deal with the algal bloom in major rivers, the government further strengthened the T-P guidelines in 2012. The stricter regulation of T-P resulted in the introduction of chemical precipitation process in many STPs. ME and KECO conducted a pilot project on chemical precipitation at 4 different STPs (Yangpyeong, 2nd Hwado, Boeun, and Yeongdong). The tests were carried out for 6 months to identify the optimal coagulant dose and operation conditions. The pilot study results were disseminated to other STPs.

The proportion of the capacity of advanced treatment process to the whole STP’s capacity was initially quite low, at 14.5% in 2000 and 28.0% in 2005. However, in 2015, after the revision of T-P effluent guideline, the capacity of advanced treatment process accounted for 94.6% of the whole STP’s capacity.

2.3. The Improvement of Aging Waterworks Infrastructure

Since waterworks infrastructures were constructed before sewerage in Korea, rusting and damage in old water supply pipelines occurs. Sometimes it causes the interruption of water supply service. In accordance with the 'Comprehensive Measures to Improve Tap Water Quality Management', from 2001 to 2005, the government carried out a series of projects including the maintenance of the indoor water supply pipelines, rehabilitation of old pipelines etc. As a result, 23,839 km of old water pipelines were replaced by the year 2007.

Since 2017, the government has been promoting the ‘Local Waterworks Modernization Project’ and the ‘Aging Local Waterworks Improvement Project’. The purpose of those projects is to minimized the leak from the old water pipelines and to secure the safety of the supplied water. A total of 3 trillion KRW over the course of 12 years starting from 2017 will be invested to the vulnerable local governments. The project will include the investigation and maintenance of aging pipelines, building the block water distribution systems, and the upgrade of old DWTPs.

(Figure 4–4) Deteriorated Water Supply Pipeline Underground and the Comparison of Old Pipelines with the Rehabilitated One

Source: http://www.waterjournal.co.kr/news/articleView.html?idxno=30927

(Figure 4–3) The capacity of Advanced Wastewater Treatment Process and total STPs
2.4. Scientific Water Quality and Pollutant Monitoring

Today in Korea, Tele-Monitoring System (TMS), a remote water quality monitoring system, has been established. Automatic sensors were placed at the outfall of major industrial wastewater dischargers, WWTPs and STPs. The measured data by the sensors are transmitted in real time to the KECO’s “Water Quality TMS Control Center”. The collected data is utilized for the TMDL regulation, the calculation of wastewater effluent charges, and other water quality management policies. TMS is considered as an example of a major step forward in water regulation, which combines Korea’s outstanding IT infrastructure and sensor technologies. TMS was installed at major point sources nationwide from 2008. It began full force operations in 2009 and a total of 917 water quality control centers were in operation as of 2015. KECO makes efforts to upgrade the TMS control centers and to improve the reliability of the measured data.

Section 3: Outcome by Infrastructure Improvement

3.1. High Quality Tap Water Production and Leakage Reductions

The nationwide waterworks leakage rate decreased from 13.6% in 2003 to 10.9% in 2015. The decrease in leakage rate results from the waterworks infrastructure improvement projects such as water supply pipeline maintenance. As shown in Chapter 3, the proportion of capacity of advanced water treatment process exceeded 35% of the total DTWP’s capacity by 2015. The government plans to increase the ratio to 70% by 2025.

Despite the government’s efforts, the public waterworks has still not regained the public’s trust on tap water safety. According to a survey conducted in 2012, the level of satisfaction toward tap water is only 61.5%, and the proportion of people who drink tap water directly is extremely low, 5.4% in 2013. Based on the survey, citizens are reluctant to drink tap water directly due to concerns about the pollution of water-intake sources, distrust of water storage tanks and pipelines, and the presence of fine debris or odor of tap water.

(Figure 4-5) Block Diagram of Remote Water Quality Monitoring Systems.

(Figure 4-6) Ratio of revenue water and water leakage
3.2. Water Quality Improvement in Rivers and Lakes

The water quality of rivers and lakes, which had been severely polluted during the industrialization era, has gradually improved. It resulted from the strengthening of environmental regulations in the late 1990s, the constructions of STPs, and the expansion of advanced treatment process. Biochemical oxygen demand (BOD), an indicator for the biodegradable organic matter, had exceeded 100 mg/L at certain urban streams in the 1980s. But in 2000s, BOD concentration had significantly improved.

3.3. Stream Ecology/Landscape Improvement

People pay more attention in water quality and aquatic ecology of water policy. For example, since 1987, ME has carried out the Ecological River Restoration Projects. It improves the water quality of contaminated streams and restores damaged biological habitats. The project generated vivid success stories where the steam recovers its ecological integrity and raises social & economical values. The Yangjaecheon Ecological River Restoration Project, which was executed between 1995 and 2000, and the Cheonggyecheon Ecological River Restoration Project, which was carried out between July 2003 and September 2005, are regarded as successful models for the urban stream environment.

The restoration project resulted in overall improvement of water quality such as BOD, chemical oxygen demand (COD), T-N, and T-P. As the habitat environment and biological habitats were improved, the number of plant (herbaceous), benthic, and insect species were significantly increased after the restoration projects.

In addition, the majority of streams in the nation are now achieving ‘Good Water’ status with respect to the BOD concentration. As of 2015, 95 of the 114 watersheds satisfied "Good Water".
Real estate price near Cheonggyecheon rose after the restoration project. In January 2002, before the project commenced the price of a 3.3m² apartment located more than 1 km away from Cheonggyecheon was higher than that of apartments within 1 km of the stream. However, once the Cheonggyecheon Restoration Project was introduced, the price per 3.3m² of apartments less than 1km from the stream rose from a mere 5.99 million KRW to 9.88 million KRW after March 2006. This exceeded the price of apartments that were more than 1 km away from Cheonggyecheon. During the same period, the price per 3.3m² of apartments that were even closer to the stream, within 700m, rose to 10.39 million KRW. The higher price increase at the apartment closer to the Cheonggyecheon supports the impact of the Cheonggyecheon restoration on the real-estate value of buildings.

(Table 4-5) Water quality and ecosystem change by Ecological River Restoration Projects.

<table>
<thead>
<tr>
<th>Category</th>
<th>BOD</th>
<th>COD</th>
<th>T-N</th>
<th>T-P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before project</td>
<td>7.8 mg/L</td>
<td>9.1 mg/L</td>
<td>8.5 mg/L</td>
<td>0.5 mg/L</td>
</tr>
<tr>
<td>After project</td>
<td>2.6 mg/L</td>
<td>5.2 mg/L</td>
<td>2.7 mg/L</td>
<td>0.1 mg/L</td>
</tr>
<tr>
<td>Project Achievements</td>
<td>66.5% reduction</td>
<td>43.4% reduction</td>
<td>67.6% reduction</td>
<td>71.8% reduction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Plant (herbaceous)</th>
<th>Periphytic algae (species diversity)</th>
<th>Benthic organisms</th>
<th>Insects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before project</td>
<td>78 types</td>
<td>1.94 types</td>
<td>28 types</td>
<td>47 types</td>
</tr>
<tr>
<td>After project</td>
<td>92 types</td>
<td>2.09 types</td>
<td>33 types</td>
<td>71 types</td>
</tr>
<tr>
<td>Project Achievements</td>
<td>17.9% increase</td>
<td>7.7% increase</td>
<td>17.9% increase</td>
<td>51.1% increase</td>
</tr>
</tbody>
</table>

(Figure 4-9) Before and after the restoration of the Yangjaecheon and Cheonggyecheon streams.

Chapter 5.
The Future of Water Management
Chapter 5.  The Future of Water Management

Section 1: Non-traditional Water Resources

1.1. Water Reuse

Korea is currently investing about 1.4 trillion KRW in order to develop non-traditional water resources, and is promoting private investments in water reuse. The target investment areas include: 19 regions with industrial complexes and manufacturing areas within 5 km of STPs, regions where a water shortage is expected, and regions with high water prices.

Among these, the Pohang water reuse facility completed in July 2014 was the first of its kind to be established in Korea. Private-Public Partnership was applied in this project through a BTO (Build-Transfer-Operate) system. The total cost of the project was 125.8 billion KRW (consisting of: 68 billion KRW of national government’s grant, 7.5 billion KRW of local government’s budget, and 50.3 billion KRW of private capital). The facility uses the membrane filtration (MF) and reverse osmosis (RO) separation techniques. It supplies 100,000㎥/day of treated industrial wastewater to nearby companies, through an 11.81 km pipelines, and at a low price. It contributes to mitigate the water demand in POSCO National Industrial Complex and to improve the industries’ productivity.
Korea is expanding the reuse of the treated STP’s effluent to mitigate droughts. The Boryung STP is also an interesting water reuse project. The water reuse system is being built at the STP to replace 10,000 m³/day of industrial water demand with the treated effluent. Currently, the industries located at western Chungcheong province depend on their industrial water from Boryung Dam. But recent severe drought threatened the water safety of domestic as well as industrial water use. Water reuse in industries can contribute to secure the domestic water demand which mainly depends on the Boryung Dam. When construction is completed in the latter half of 2019, annually 3.65 million m³ of raw water from the Boryeong Dam can be used for domestic water reserves. The STP’s effluent will be treated by RO membrane and supplied to the Boryeong thermal power plant (5,000 m³/day) and the Shinboryong thermal power plant (5,000 m³/day). A total of 12.9 billion KRW will be invested in this project.

1.2. Seawater Desalination

The Korean government is expanding the scale of its seawater desalination R&D in order to develop core technology to solve the water shortage issues posed by climate change. MoLIT has established a team dedicated to seawater desalination at the specialized R&D planning agency, Korea Agency for Infrastructure Technology Advancement. It has increased R&D budget for seawater desalination technology from 4.6 billion KRW in 2013 to 16 billion KRW in 2016. The budget will be increased to 30 billion KRW by 2020.

RO-based desalination technology was developed by the government-funded R&D project, and allowed the country to take part in the overseas desalination market. In October 2013, Korean desalination company received 130 million USD worth of orders for 220,000 m³/day seawater desalination plant in Antofagasta in Chile. It is the largest RO desalination plant in Latin America, which can serve 550,000 people per day. In November 2014, a RO desalination plant was built in the Gijang district of Busan, Korea.

In the future, the Korean government plans to establish a master plan for the implementation of seawater desalination in coastal industrial complexes nationwide to secure the industrial water supply under the higher possibility of abnormal droughts. The government also plans to expand Korea’s participation in the seawater desalination business with the Middle East and North African countries.
Section 2: Convergence of ICT and Water Technology

2.1. The Advanced Intelligent Water Distribution System

Korea has built an integrated water management system using ICT technology. It can minimize rusting in old water supply pipelines and prevent the water supply interruptions. These innovations are the result of the "Advanced Intelligent Water Distribution System (GBEST)" project that was initiated by ME and KEITI in 2011.

The integrated water distribution consists of real-time supervisory control systems: integrated Database (DB) and Geographic Information System (GIS) based platforms, and top applications.

The real-time supervisory control systems for water distribution networks consists of several elements: a survey, design, simulation, information management, optimal operation, monitoring, and facility management. The distribution networks are managed through a standardized and integrated DB and GIS based platform. The top applications can be used for optimal distribution network design, optimal distribution system operation, trouble response, maintenances etc. The integrated water distribution system is expected to be commercialized and widely applied in water businesses.

The integrated water distribution management system has secured a proven track record by building domestic and international test-bed for technical system verifications, reference condition set-up, and business impact analyses. In Korea, the Seongnam pilot plant, Yeongweol test-bed with 1,000 households, and Paju test-bed with 10,000 households were built. The test-bed was also established in the Hanoi region of Vietnam. Testing water pipeline monitoring, water leak detection, and leak management was carried out at the Vietnamese test-bed.

2.2. Smart Water Grid (SWG)

The Smart Water Grid (SWG) combines ICT technology with water management technology. SMG technology has been developed for the integrated management of various water resources with respect to distribution, management, and transport in the ICT-based platform.

<table>
<thead>
<tr>
<th>Category</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring the entire water system and implementing the SWG</td>
<td>- Water supply and demand assessment program.</td>
</tr>
<tr>
<td></td>
<td>- SWG integrated database.</td>
</tr>
<tr>
<td></td>
<td>- SWG integrated operational support program.</td>
</tr>
<tr>
<td></td>
<td>- Prediction of spatial distribution of precipitation by climate change.</td>
</tr>
<tr>
<td></td>
<td>- Long and short-term water shortage scenarios with multiple water sources.</td>
</tr>
<tr>
<td></td>
<td>- Real-time assessment methods for multiple water sources, etc.</td>
</tr>
</tbody>
</table>

(Figure 5-4) Block diagram of the GBEST Top water distribution integration management system.
Section 3: Discovery of New Water & Wastewater Services

Because of urban growth, it is often the case that a sewage treatment plant that was originally located far away from the old city center will find itself situated in the middle of residential and commercial areas. To address this situation, Korea is transforming the STPs into resident-friendly facilities such as parks or sports complexes. This is achieved by integrating and densely packing the sewage treatment process and putting the packed process underground. In order to resolve complaints about the odor from STPs, the process modernization is accompanied. Putting the STPs underground is significant in that it will turn the sites which were previously perceived as being unpleasant or repelling into an attractive space. This will enhance the economic and cultural value of the areas around a STPs.

The Jungrang and Seonam STPs in Seoul and the Hanam Basic Environment Facility (Hanam Union Park/Tower) are examples of how environmental complexes can be established, by setting some of the facilities underground. The Bakdal STP in Anyang was recently put completely underground so that all of the space on the surface could be utilized. The modernization of existing treatment plants is a very difficult project, since it is necessary to maintain a continuous and adequate
treatment of sewage during the construction work. It frequently involves large-scale excavation, compacting the treatment processes, and the combined installation of drying, digesting, and power generation facilities.

(Figure 5-6) Examples of Partially (left, Suyeong STP in Busan) or Fully Underground STPs (right, Bakdal STP in Anyang).


(Table 5-3) Examples of STPs built Partially or Fully Underground.

<table>
<thead>
<tr>
<th>Region</th>
<th>Facility name</th>
<th>Underground Facility Capacity (m³/day)</th>
<th>Underground Level</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seoul</td>
<td>Jungang Water Reclamation Center</td>
<td>250,000</td>
<td>Partially underground</td>
<td>The existing facility was put underground</td>
</tr>
<tr>
<td>Seoul</td>
<td>Seonam Water Reclamation Center</td>
<td>360,000</td>
<td>Partially underground</td>
<td>The existing facility was put underground</td>
</tr>
<tr>
<td>Seongnam</td>
<td>Pangyo</td>
<td>47,000</td>
<td>Completely underground</td>
<td>New installation</td>
</tr>
<tr>
<td>Hanam</td>
<td>Hanam</td>
<td>32,000</td>
<td>Completely underground</td>
<td>New installation</td>
</tr>
<tr>
<td>Incheon</td>
<td>Hakik</td>
<td>125,000</td>
<td>Completely underground</td>
<td>New installation</td>
</tr>
</tbody>
</table>

Source: KECO, Aug. 17, 2012, Press release

Section 4: Expanded Role of Private Sector

During the industrialization era, Korea promoted economic development policies led by the central government. This meant that private sectors were highly dependent on the government. The basic water-related industry was also under the jurisdiction of public corporations or organizations such as the Water Resources Development Corporation (currently K-water) and the Korea Environment Management Corporation (currently KECO). Those institutions played an important role in supporting and implementing the government’s water policies.

Opening the waterworks and sewerage business to the private sector was discussed in the 2000s to enhance the competitiveness of domestic water industry and to improve the quality of water service. However, opening of the waterworks business to the private sector did not proceed at the time, due to publics’ huge...
concerns and oppositions against the “privatization of water”. In case of sewerage sector, private sector began participating in the contracting business of operation and maintenance (O&M) of STPs throughout the country, starting with the Gwangju STP in 1998. Since the 2000s, global water companies such as Veolia and Suez have entered the O&M business of public STPs in Korea, and are now in competition with domestic water companies. Korean government has been trying to expand the private sector’s participation in the sewerage market. Recently, the government revised the relevant law to give the contracting companies more authority and autonomy in the O&M business of public STPs. Although the proportion of private consignments for the O&M business of public STPs has increased in recent years, private companies generally only carry out consignment projects at small STPs. Public corporations, managed by central and local governments are still primarily responsible for the O&M of large-scale STPs.

At present, Korea’s water market amounts to about 17 billion USD (based on public institution orders), which makes it the eighth largest in the world. The Korean water market has grown by about 5% over the last 10 years and is known to have strengths in the facilities and construction field.

Therefore, the Korean government is implementing policies to support the water industry as it finds new growth engines in the water sector, and to enhance the creativity and innovation of the private sector. The government recently established the “National Smart Water Industry Fostering Strategy” that will support the private sector’s development and commercialization of original technologies related to water. A major private enterprise support system in the water industry is the “National Water Industry Cluster”, which is currently being developed in the Daegu National Industrial Complex. This is scheduled to be completed in December 2018, and is being built through an investment of 233.5 billion KRW on a 649,000 m² site. It is intended to support the entire life cycle of companies from technology development to demonstration and commercialization.

![Market size of Global Water Industries](image)

Section 5: Contribution to International Community

Korea is the first former aid recipient to join the Development Assistance Committee (DAC) in the Organisation for Economic Co-operation and Development (OECD). Korea now contributes to resolving global water issues through Official Development Assistance (ODA). As of 2013, Korea offered the fourth largest ODA support in the water supply and sanitation sector, following Japan, Germany and the United States.

![Graph showing ODA expenditure in the water supply and sanitation sector by countries (as of 2013). Source: OECD-DAC, 2013.]

![Graph showing KOICA’s support in the water sector. Source: KOICA, 2011. A study on the aid strategy in water sector and the corporation model.]

Such support is mainly provided through the Korea International Cooperation Agency (KOICA). In the water sector, in terms of expenditure, KOICA provided the most ODA support to Sri Lanka, Cambodia, and Ecuador in 2012. On a cumulative basis from 2006 to 2012, KOICA’s support for the top five countries, including Sri Lanka, Cambodia, Nepal, Laos, and Vietnam, amounted to 24.1 billion USD (48.7% of total water ODA).

<table>
<thead>
<tr>
<th>Table 5-4</th>
<th>Korea’s ODA support trend in the water resource sector (2006-2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>2006</td>
</tr>
<tr>
<td>Water resource policy and administrative management</td>
<td>0.5</td>
</tr>
<tr>
<td>Water resource protection</td>
<td>0.0</td>
</tr>
<tr>
<td>Large scale drinking water supply and sanitation</td>
<td>14.7</td>
</tr>
<tr>
<td>Large scale drinking water supply</td>
<td>0.0</td>
</tr>
<tr>
<td>Large scale sanitation</td>
<td>0.0</td>
</tr>
<tr>
<td>Basic drinking water supply and sanitation</td>
<td>2.0</td>
</tr>
<tr>
<td>Basic drinking water supply</td>
<td>0.0</td>
</tr>
<tr>
<td>Basic sanitation</td>
<td>0.0</td>
</tr>
<tr>
<td>Stream maintenance</td>
<td>1.2</td>
</tr>
<tr>
<td>Waste management and disposal</td>
<td>0.3</td>
</tr>
<tr>
<td>Training and education (Drinking water supply and sanitation)</td>
<td>0.0</td>
</tr>
<tr>
<td>Hydraulic power generation</td>
<td>0.2</td>
</tr>
<tr>
<td>Agricultural water resource</td>
<td>1.7</td>
</tr>
<tr>
<td>Agricultural water resource (Water resource field (total))</td>
<td>20.4</td>
</tr>
</tbody>
</table>

By sector, Korea contributed 65.4 million USD to the large-scale drinking water and sanitation sectors, which accounts for 44.8% of the total budget in water sector. The basic drinking water supply and sanitation, hydroelectric power generation, and water policy and management sectors also occupy a large proportion of the total investment.
Chapter 6.
Korea’s Experience and its Implications

This report explored Korea’s water management issues from the past to the present and reviewed the experiences and achievements of Korea’s water management sector. Several notable lessons can be drawn from Korea’s experience as follows:

First, Korea experienced serious water pollution problems during industrialization and urbanization. A series of severe water pollution accidents in 1990s were a huge milestone in environmental policy, especially in water quality management. Those accidents were not just a series of tragic affairs but an opportunity to strengthen water quality management system and develop relevant technology.

Second, in the post-war reconstruction period of the 1960s, Korea received support through international aid in the form of funds and technical assistance. Korea did not remain as a passive beneficiary country, but instead used its joint works with foreign and domestic engineering companies as a classroom to improve the technical power of domestic water industry.

Third, the central government strategically led the investment in the waterworks and sewerage infrastructure. The percentage of population connected to public water supply and STPs dramatically increased to the level of developed countries. The supply of safe drinking water to the public and the adequate management of domestic and industrial wastewater greatly contributed to the improvement of public health including reduction of youth parasitic infections and extension of healthy life expectancy.

Fourth, the decisive R&D investment by the government and industry generated tangible water solutions such as membrane separation technology and ultra-compact STPs design & construction. The strategic R&D between universities, government-funded research institutes, and private companies played an important role and Korea strived to apply the developed technology to fields such as DWTPs and STPs. In recent
years, innovative technologies have been developed for managing tap water quality in real time using ICT. The underground STPs where the treatment processes were densely packed and placed underground are producing added values for the residents.

Fifth, private water companies in Korea are securing a competitive edge in the engineering and construction field, and are trying to develop original technology and to build their experience in operation and management. Global water companies such as Veolia and Suez have entered the Korean STPs-operation business. Public corporation and private companies are now participating in consignment management of STPs. Korean conglomerates who have a global presence in the field of desalination are seeking to enter global markets through strategic mergers and acquisitions with international water companies.

Sixth, although Korea still has unsolved or potential water issues including urban drainage, drought, algal bloom, ecological deterioration, climate change adaptation etc., Korea is laying a foundation for systematic responses in the future.

References


