December 2021

Ensuring Clean Water for All: Implementing a Tele Monitoring System to Better Manage Water Quality in the Republic of Korea(2007–2021)

KDI SCHOOL
KDI School of Public Policy and Management

PROJECT DATA

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Region East Asia	**Sector** Environment
Implementation Years 2007 to 2021	**Implementing Agencies** Ministry of Environment, Korea Environment Corporation
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Development Challenge Clean Water	**Delivery Challenges** Human Resources and Organizational Capacity, Lack of Regulation and Legislation, Economic Costs

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Executive Summary

In 1991, a toxic substance called phenol was discharged from an electronics factory into the Republic of Korea's Nakdong River, poisoning the local tap water supply. That incident—and other similar catastrophes—forced the government to improve the management of hazardous materials being treated and discharged into Korea's waterways.

Throughout the 1990s and early 2000s, the Ministry of Environment made incremental progress in improving water management by tightening regulations on wastewater discharged into rivers. In 2007, however, the ministry decided a new approach was necessary to reduce the risk of pollution incidents occurring.

That year, the government launched a Water Quality Tele Monitoring System, requiring facilities that discharged wastewater to install devices that measured pollutant levels automatically and transmitted those measurements in real time to a control center operated by the Korea Environment Corporation, an organization affiliated with the Ministry of Environment.

To operationalize the new system, the government had to overcome capacity, coordination, and economic challenges. Free technical support

This case study was prepared by Jeeyoung Kim based on desk research and fieldwork carried out in 2021. The case study was supported by the Korea Development Institute School of Public Policy and Management, and is aligned with the case study program of the Global Delivery Initiative. Many people assisted in the preparation of this case study; the author would like to thank in particular the stakeholders interviewed during fieldwork, who generously shared their time and insights about the program.

and government subsidies drove high levels of compliance from companies that discharged wastewater—even from small businesses that faced relatively high compliance costs. The new approach—which was implemented iteratively over more than a decade—helped improve water quality across Korea. The average concentration of most major pollutants declined as the Tele Monitoring System expanded nationwide.

Introduction

"There's a weird smell in the tap water," complained residents of Daegu City, the Republic of Korea, on March 17, 1991. Staff at the city's water purification plant were inundated with calls from residents complaining of the water's smell and experiencing symptoms such as vomiting, diarrhea, and stomach pain.[1] The culprit was found to be phenol—a toxic substance that had leaked from a nearby electronics factory and flowed into the Nakdong River. Located in Southeast Korea, the Nakdong was a major source of drinking water for about 10 million people, including the residents of Daegu. The incident raised concerns about wastewater discharged during industrial processes. Individual factories or public wastewater facilities collected and treated industrial wastewater, but the phenol leak in the Nakdong River made clear that the system needed urgent improvement.

Though only 35% of Korea's population had access to tap water in 1971, investment in water infrastructure saw millions more Korean's gain access to water in the 1970s, 1980s, and 1990s.[2] As water supply increased, however, water pollution emerged as a major problem, mostly due to industrial developments and urbanization. Areas where pollutants were concentrated, such as industrial complexes, were of particular concern to the Korean government.

Efforts to improve the management of industrial wastewater began in earnest in 1971, when the government introduced a permit system for wastewater discharging facilities and expanded the application of effluent limits for wastewater discharged. The system was strengthened over time. To control the concentration of water pollutants from industrial wastewater, the central government set permissible emission levels on 22 substances in 1981. The Water Quality Conservation Act was enacted in 1991 to prevent harm to citizens' health and environmental hazards due to water pollution and to appropriately manage and conserve public waters.[3] Policy measures and interventions for industrial wastewater management prescribed in the Water Quality Conservation Act[4] were as follows:

- Prior installation permits and declarations of emission facilities as the basic policy instrument for industrial wastewater management
- Guidance and inspection by governments to verify legal requirements
- Permissible emission levels for water pollutants
- An emission charge as a kind of economic control measure
- The installation and operation of public wastewater treatment facilities

In the wake of another tap water incident in Dalseong, Gyeongsangbuk-do Province on January 4, 1994, the prime minister, Hoi-chang Lee, announced a new plan to improve water quality in the Nakdong River and other major waterways in Korea. The Ministry of Environment began the installation of an automatic water quality measurement network in four major rivers to quickly respond to water pollution accidents by continuously monitoring the water quality of major water sources and areas vulnerable to pollution accidents in 1995. In 1997, the government set permissible emission levels for nitrogen and phosphorus and applied emission levels to the whole nation in 2003. Companies had to remove water pollutants at wastewater discharge facilities, dispose of pollutants properly, and discharge wastewater at or below the levels set out in the Water Environment Conservation Act.

In the late 1990s and early 2000s, Water Quality Tele Monitoring Systems (TMS), which could measure pollutants in discharged wastewater in real-time and track water quality electronically, emerged as a promising tool for managing industrial wastewater. "The basic principle of TMS is to check whether the substances

1) The JoongAng , March 13, 2021
2) Ministry of Environment (2019). 99% of Koreans had access to tap water by 2019.
3) www.law.go.kr
4) The name of the act was amended in 2007 to The Act on the Conservation of Water Quality and Aquatic Ecosystem, and amended again in 2018, to The Water Environment Conservation Act.

monitored[5] are properly processed [before being discharged]", said Dae-ho Han, a senior researcher at the Korea Environment Institute, "If the items are properly processed, it can be seen that hazardous substances are well managed. It is a real-time monitoring tool that checks whether the operation is working well." In 2004, a company named Guemho Express won a prize from the Minister of Environment for a water quality TMS.[6] The success of tele monitoring systems—such as the one run by Guemho Express—led to the government looking at how TMS could be implemented broadly. Manual inspections and tests were costly and time consuming, and the number of locations to check only increased over time. From 2004 to 2006, the number of workplaces in Korea discharging wastewater increased from 39,012 to 45,163.[7]

On January 25, 2006, ministers of relevant ministries and professionals from the private sector met to discuss water regulations and to develop a method of calculating the emission charges envisioned in the Water Environment Conservation Act. The ministers attending decided to establish a water quality tele monitoring system that could measure the pollution levels in discharged wastewater. The purpose of installing and operating TMS was:[8]

i. To prevent water pollution accidents with real-time management and inspection of the quality of discharged water at public wastewater treatment facilities, public sewage treatment facilities, and wastewater discharge plants
ii. To induce process improvement by analyzing and managing the water quality status by itself
iii. To advance water quality management by calculating rational and objective effluent discharges and by grasping the level of discharged pollution accurately and to utilize basic data for improvement of water environment policy

Sung-shin Jang, the division manager of Wastewater Quality TMS Management Division at the Korea Environment Corporation[9] said, "The real-time Water Quality Tele Monitoring System was introduced to enhance the efficiency of process operation by the workplace itself by calculating a rational effluent charge and providing a real-time measurement value for the quality of water discharging to the river."[10]

Delivery Challenges

Human Resources and Organizational Capacity

For the TMS to work, the staff operating the system and the public officials inspecting wastewater facilities had to understand the technology and have the skills to work with it. At the time, however, local governments and private sector companies did not have sufficient capacity. Local governments had difficulty inspecting wastewater discharge facilities since the system was new and staff lacked technical background and knowledge. Operational problems in industrial workplaces were common. According to Sung-shin Jang, "While operating TMS, workplaces experienced the issue of whether the measured values of water quality TMS were reliable." Workplaces first had to boost capacity in order to resolve such technical issues and operational problems.

Lack of Regulation and Legislation

At the time, existing laws and tools available to the Ministry of Environment meant it had limited ability to expand the use of TMS beyond where it was already being used voluntarily. Telemonitoring systems were an extra cost for businesses, and any mandate would require a new law. Before implementing TMS nationwide, the ministry had to revise the Act on the Conservation of Water Quality and Aquatic Ecosystem and set standards to maintain the reliability and accuracy of the results recorded by the measuring instruments.

Economic costs

Installing and operating TMS was a major expense, especially for small and medium-sized companies that could not afford to buy the devices used to monitor water quality. Each TMS was comprised of five main devices (see Figure 1) that together cost about 200 million Korean

5) Examples of monitoring substances measured included Chemical Oxygen Demand (COD (mg/L)), Total Nitrogen (TN (mg/L)), Total Phosphorus (TP (mg/L)), Suspended Solid (SS (mg/L)), and PH.
6) Yonhap news, 2004.3.22 "Guemho Express, water award"
7) Ministry of Environment (2020), "2020 generation and treatment of industrial wastewater"
8) Ministry of Environment, Korea Environment Corporation (2019), pp.3
9) The Korea Environment Corporation (known as K-eco) is an organization affiliated with the Ministry of Environment.
10) Author interviewed with Sung-shin Jang on April 22, 2021

won (about US$170,000). In addition, businesses also had to pay ongoing operational costs.

Figure 1 Targeting Facilities and Monitoring Items[11)]

Tracing the Implementation Process

Preparing for the new system

The Ministry of Environment made its initial management plan for a water quality Tele Monitoring System in October 2004. In order to improve the emission charge system, the ministry also prepared a method for calculating effluent charges based on automatic measurement data of water quality TMS by calculating the pollution level and discharge of wastewater and imposing an effluent charge. The following year, the Ministry of Environment announced that it planned to equip water quality TMS step by step and held public meetings to explain the plan and collect opinions from stakeholders. Around the same time, the Korea Environment Corporation conducted extensive research on control systems for water pollutants.

Early in 2006, the Ministry of Environment got to work on the legal changes necessary to put its plan into action. In April, the ministry revised the Act on the Conservation of Water Quality and Aquatic Ecosystem to create a legal basis for installing measuring devices. Over a period of two years, the ministry spent 12 billion Korean won (about US $10 million at the time) to set up the wastewater TMS control center, a nationwide monitoring center, at the Korea Environment Corporation.

Launching the new system

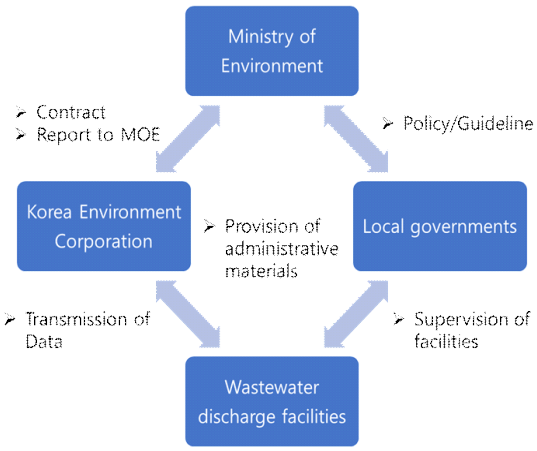
In January, 2007, the construction of the water quality TMS control center at the Korea Environment Corporation was completed. The Ministry of Environment contracted Korea Environment Corporation to operate the control center.

The ministry planned to expand the number of facilities using TMS over the course of three years, beginning in 2007. In May, through a change to the Act on the Conservation of Water Quality and Aquatic Ecosystem, the ministry mandated that public sewage and public wastewater treatment facilities install measuring devices for water quality TMS. The Act was amended to expand the mandate to private businesses, beginning with those that discharged the most wastewater. Businesses discharging more than 2,000 tons of wastewater per day had to install devices by September 2007, businesses discharging more than 700 tons per day had to comply by September 2008, and businesses discharging more than 200 tons per day had to comply by September 2009. Beginning in early 2008, the Ministry of Environment and Korea Environment Corporation operated a central situation room which could respond to any difficulties that companies faced in using the new system. “Korea Environment Corporation actively responded to any complaints [or other issues raised] by persons in charge of their workplace,” said Sung-shin Jang.

The ministry provided wastewater management guidelines to local governments and distributed a manual for how to administer permits. Local governments supervised facilities. According to the Water Environment Conservation Act, class I wastewater treatment facilities (facilities that discharged more than 2,000 ㎥ of wastewater per day) to class III (facilities that discharged between 200 ㎥ and 700 ㎥ of wastewater per day) had to notify Korea Environment Corporation of their installation of TMS and transmit relevant data to it. The water quality TMS control center of Korea Environment Corporation monitored data, provided technical support to facilities and administrative materials to local governments, and reported outcomes to the Ministry of Environment every year (see Figure 2) (SOOSIRO).

11) Wastewater Telemonitoring System (Soosiro) 2021, Korea Environment Corporation (keco.or.kr)
The name of Wastewater Telemonitoring System website is SOOSIRO.

Figure 2 Implementation system of TMS



Improving capacity

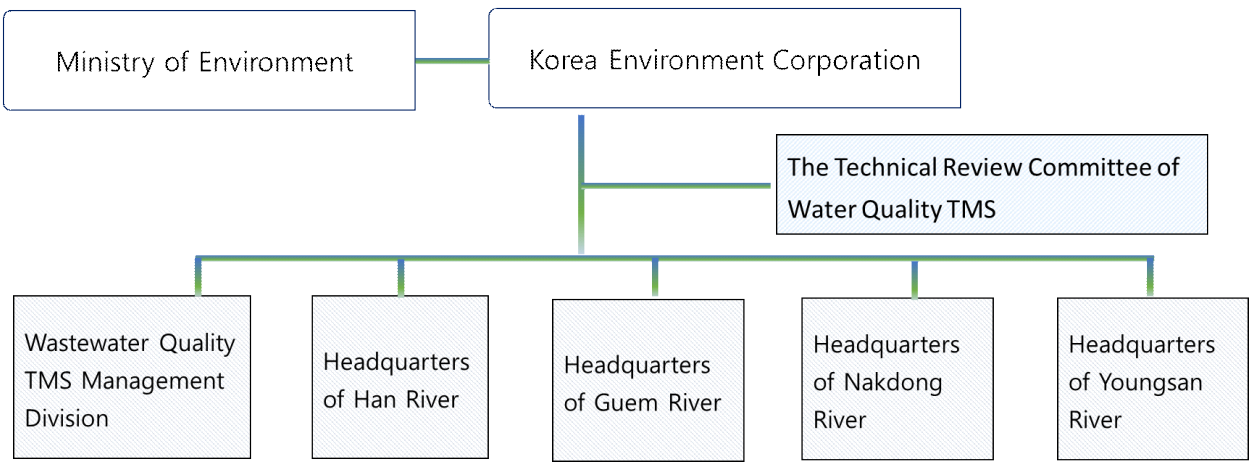
In mid-2007, Korea Environment Corporation created a water quality TMS website and launched a technical support team to diagnose operational problems in workplaces and devise solutions for those problems. "We improved the system by revising related regulations and implementing various preemptive technical support to minimize confusion at businesses," said Sung-shin Jang. Korea Environment Corporation organized the technical support area into five teams: one in Incheon Metropolitan city and four others for specific rivers (see Figure 3). The technical support teams had a shared goal: that companies and facilities could install, operate, and manage the measuring equipment and transmission equipment in accordance with the water pollution test standards.

The technical support procedure had four steps (see Figure 4). After a business submitted an application for technical support, local governments made candidates lists, and then the Ministry of Environment confirmed who would be supported considering the demand of local governments. Then, Korea Environment Corporation provided technical support and reported the results to the ministry.

The technical support included review of regulations and methods of installation, operation of devices and maintenance, and guidance for administrative matters. Different support was provided for each "business stage", or each step in the process of implementing TMS (see Table 1). When a company applied for technical support, the control center team visited that company to provide free consultation services. "The technical support is for business consulting and manufacturer consulting," said Sung-shin Jang. "For business consulting, we have consulting for newly built facilities which need to be equipped with devices, technical consulting for facilities with insufficient operation, technical support for operation inspection of measuring equipment, and customized process diagnosis. For manufacturers, we provide preliminary technical support for performance testing of measurement device and pre-integrated tests for data collection."

In March 2008, Korea Environment Corporation published its water quality TMS installation and operation manual, which included related laws, procedures, and test methods. The corporation distributed about 3,000 copies of the manuals to local governments and companies.

Figure 3 The Organization Chart of Technical Support[12)]



12) Ministry of Environment, Korea Environment Corporation (2009), pp.3

Figure 4 Technical Support Application Process

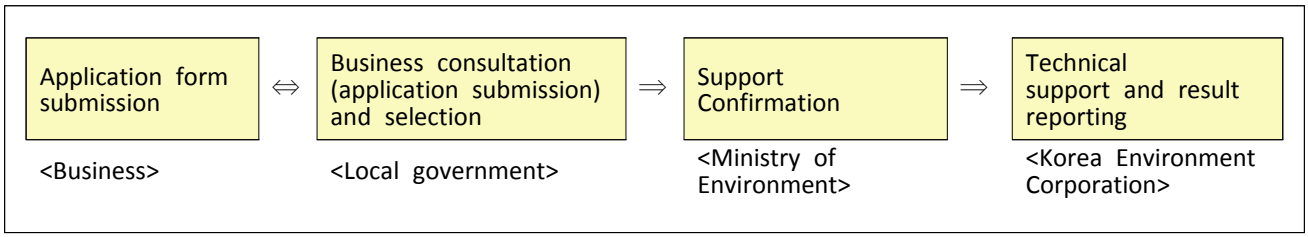


Table 1 Support by Business Stage[13)]

Stage	Support
Basic Plan	Guide of regulations Support for tours to excellent facilities and consulting for equipment manufacturers
Installation of measuring devices	Location for measuring station Review of regulations regarding measurement items Methods of installation according to condition
Test drive	Operation of devices and maintenance How to take actions in case of nonconformity of integration and quality verification test
Operation of TMS	Measures to secure consumables, reagents, etc. Administrative matters necessary for operation

Reforming and improving the system

Ensuring the data collected by the TMS was accurate and reliable was an ongoing challenge that required strong oversight. "Unlike wet analysis[14)] which is analyzed by humans, TMS is a mechanical analysis that may malfunction due to the limitations of the device," said Dae-ho Han. "Thus, differences in accuracy may occur." In order to analyze data that appeared inaccurate or abnormal, Korea Environment Corporation organized a technical review committee. The committee consisted of 10 members, with representatives from universities, research institutions, local governments, the association for measuring devices, and industrial companies. The committee's first meeting took place on February 19, 2009. In June 2009, the Ministry of Environment and Korea Environment Corporation published a technical support case book for water quality TMS installation and operation.

Boosting transparency

To increase the transparency of the TMS system and the operations of facilities that discharged wastewater, the Ministry of Environment wanted to disclose readings from the TMS system to the public in real time.
The ministry and the Korea Environment Corporation held a public meeting to collect opinions on whether data should be released, and what would be the best method for doing so. The two organizations decided to publicly release TMS data on the TMS website, and following a trial period in December 2020, the public could freely access pollutant discharge levels of facilities online.

Improving policy implementation: Collaborative Governance

To discuss how to solve operational problems, the Ministry of Environment organized SOOSIRO support group on March 25, 2019. SOOSIRO means often or anytime in Korean. The ministry operated SOOSIRO

13) Ministry of Environment, Korea Environment Corporation (2009), pp.4
14) Wet analysis refers to chemistry performed on samples in the liquid phase.(https://www.labtesting.com/services/materials-testing/chemical-analysis/wet-chemistry/)

support group in two ways. First, to reform water quality TMS and improve the system, SOOSIRO support group had about 30 persons from the Ministry of Environment, regional agencies, the Korea Environment Corporation, the National Institute of Environment Research, and the Korea Testing Laboratory. The group met three times in 2020 to discuss operational problems and make suggestions for improvement.

Second, to support companies, SOOSIRO support group operated education and training programs for workers of companies. SOOSIRO support group provided technical support and consulting to them. The on-site support had status diagnoses for measuring equipment and management plans for worksites lacking in operation and management.

In addition, to support local governments, the support group held joint inspections with experts. "The water quality TMS system is a government-led business, and it is necessary to collect opinions between various stakeholders in order to promote measures to improve water quality TMS operation and management systematically, "said Sung-shin Jang. "SOOSIRO support team was made up to make decisions on TMS-related issues effectively and quickly, and to apply them in the field."

Economic support to companies

The government targeted more companies to incorporate into the TMS system through amendments to the Water Environment Conservation Act, and in November 2019, small and medium-sized businesses were mandated to install TMS by 2021.

To gauge the costs involved, in 2020 the ministry surveyed the demand for TMS installation and researched the costs of TMS installation and operation. To reduce the economic burden on small and medium companies, the Ministry of Environment budgeted 2.6 billion Korean won (approximately US$2.2 million) in the 2021 budget year, and requested the additional budget from the Ministry of Strategy and Finance. With that support, the Ministry of Environment could subsidize 40% of the cost of TMS. Local governments contributed a further 20% of total costs in 2021, bringing the total subsidy available to 60% of the actual cost. Given that the standard total cost is approximately 250 million Korean won (about US$210,100) comprising installation costs of 200 million Korean won and operating costs of 50 million Korean won, the subsidy covers installation costs of up to 120 million Korean won (about US$100,800) and operating costs of up to 30 million Korean won (about US$25,210). "We expect that the burden on small to medium-sized enterprises is reduced by supporting the installation and operation of automatic water quality measuring devices this year," said Jae-hyun Park, Director General of the Water Environment Policy Bureau of the Ministry of Environment, in a public release from the ministry (MOE, 2021).

Another monitoring system for wastewater treatment

While the TMS managed wastewater discharge, an additional system was necessary to monitor the transport and treatment of wastewater. At the time, the monitoring system for water treatment was entirely paper-based, with wastewater discharge facilities entering into contracts with wastewater treatment companies and submitting paperwork on those transactions to local government. The system was burdensome for both companies and government officials, offered weak oversight compared to a more robust electronic system, and was potentially vulnerable to malfeasance (for example, weak oversight made it easier to dump wastewater illegally).

In October 2019, the Ministry of Environment revised the Water Environment Conservation Act to introduce online monitoring of transportation between companies. After a six-month trial period, class 4 and 5 companies were required to register for the online system by April 2020. This replaced paper submissions to local government with an online registration system to monitor facilities of class 4 and 5[15] which form a large majority of wastewater facilities. All consignment transactions between the wastewater consignment facility and the wastewater treatment company were managed in real time through the electronic takeover management system, called MULBARO. In order to monitor the status of wastewater in real time on all wastewater transport vehicles nationwide, in 2020 the government supported the total cost of installing the necessary verification equipment, which was 700 million Korean won (about US$ 621,000) in the 2020 budget, and 2.8 million Korean

15) A class 4 facility discharges between 50 and 200m^3 of wastewater per day, class 5 is a facility that is not class 1 to 4.

won (about US$ 2,480) per vehicle. "With the operation of the MULBARO system, wastewater consignment transactions are made transparent," said Mi-ja Park, Director General of the Water Environment Policy Bureau of the Ministry of Environment in a public statement. "The process of discharging, transporting, and treating wastewater can be tracked in real time, preventing illegal activities such as dumping of wastewater." (MOE, 2020)

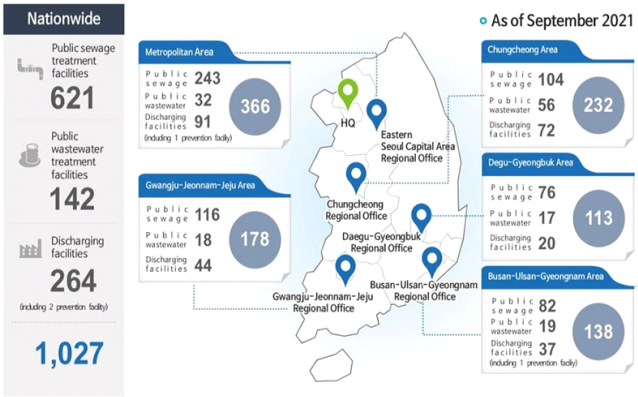
Expanding oversight of micropollutants

Water quality TMS was a key instrument to manage wastewater treatment, however, it could only monitor five substances (see Figure 1). The system was unable to measure micropollutants, the pollutants that have a toxic effect at very small concentrations, for example, perfluorinated compounds (PFCs)[16]. In 2018, NGOs and citizens requested government reform to better manage PFCs. To meet these needs and to measure and monitor micropollutants and unknown materials, the Ministry of Environment established a monitoring center for micropollutants in Nakdong River in 2019, which was the first research center dedicated solely to micropollutant monitoring. In addition, the ministry revised the Water Environment Conservation Act to set standards for PFCs in drinking water.

Outcomes

As of 2021, facilities obliged to install TMS included public sewage treatment facilities discharging over 700 ㎥ per day, public wastewater treatment facilities discharging over 700 ㎥ per day, and wastewater discharging facilities discharging over 200 ㎥ per day. As of September 2021, 1,027 water quality TMSs were installed across the nation, including 621 at public sewage facilities, 142 at public wastewater facilities, and 264 at private businesses (see Figure 5).

Figure 5 Water TMS Installation Status[17]



In 2008, Samsung Electronics Co., Ltd shared its experiences in operating water quality TMS for three months in three wastewater facilities. According to the company, TMS reduced its costs by more than 90 million Korea won (about US $77,000) per year. The TMS allowed the company to better manage its effluent, and with better management the company was able to improve processes and cut unnecessary costs. For example, following the installation of TMS, the firm decided to extend the replacement cycle of activated carbon used in its filtration facilities from 6 months to 12 months, generating cost savings.[18]

In 2012, the Ministry of Environment announced that wastewater decreased 33% (56,000 tons per year) from 2008 to 2011, and credited water quality TMS for the reduction. The amount of effluent from sewage and wastewater facilities was 219,000 tons per year in 2008 and it was 163,000 tons per year in 2011. In Korea, more than 95% of wastewater was monitored by installing 653 water quality TMS in 2011.[19]

Water quality TMS enhanced the management of each facility by ensuring wastewater discharge was monitored 24 hours a day. "It has the effect of making the workplace manage itself," said Won-sik Lee, director of the water pollution control division of the department of water environment management of the Korea Environment Corporation. "It is possible to determine pollution

16) Perfluorinated compounds (PFCs) are a group of chemicals containing fluorine. These chemicals have been used since the 50s in a large number of household products, for instance in Teflon and stain resistant products. (https://ec.europa.eu/health/scientific_committees/opinions_layman/en/phthalates-school-supplies/glossary/pqrs/perfluorinated-compound.htm)

17) Wastewater Telemonitoring System (Soosiro) 2021, Korea Environment Corporation (keco.or.kr)

18) Ministry of Environment, 2008.12, "The process improvement and economic effect of Water quality TMS"

19) Ministry of Environment, 2012.6.28, "33% decrease of water pollutants by Water quality TMS"

information quickly and accurately through water quality TMS, [and detect] if wastewater is discharged into rivers illegally. In terms of preventing water pollution accidents, water quality TMS can be effective by monitoring the pollution load."[20]

Lessons Learned

Working collaboratively with the private sector helped with policy development and implementation

Although water quality TMS was government-led, the government worked together with businesses to make the system work. The decision to introduce water quality TMS was made in The Regulatory Reform Ministers' Meeting composed of ministers and professionals from the private sector. In December 2007, the Ministry of Environment held a meeting with about 100 manufacturers, 150 water quality TMS officials from local governments, and 250 workers from public and private wastewater facilities. Attendees shared information about water quality TMS and best practices. The ministry also surveyed attendees to gauge the opinions of all stakeholders about the water quality TMS policy, which contributed to the ministry making appropriate decisions on issues while installing and operating TMS. In the implementation of water quality TMS, SOOSIRO support group organized in 2019 also collaborated closely with businesses, local governments, and research institutions.

Continuous reform of new institution could develop wastewater management

After a preparation period of 3-4 years, during which the government researched and planned how to introduce a real-time monitoring system, the Ministry of Environment and Korea Environment Corporation continued with a slow and iterative approach. After the introduction of TMS, the government gradually improved the system by revising laws and regulations and enacting standards for the installation of measuring devices, calculation of excess emissions, and communication. The government also gradually expanded the number of facilities that had to comply with the policy over time, beginning with those that discharged the most wastewater. The MULBARO system to reform the monitoring system for industrial wastewater treatment, and the new research center for monitoring micropollutants in Nakdong River, are two further examples of how the ministry strengthened wastewater monitoring over time. In this way, the government reformed the wastewater monitoring system by responding to new challenges and policy conditions.

Subsidies and technical support drove compliance

The Ministry of Environment and the Korea Environment Corporation published a water quality TMS manual to smooth implementation of the new system and created a situation room to help companies to respond to difficulties. The TMS Control Center, run by the Korea Environment Corporation, provided further support by visiting companies armed with consultants and various preemptive technical support measures to minimize difficulties in implementing the system. According to a satisfaction survey of about 200 facilities in 2015, 99% were satisfied with the technical support.[21] As the number of targeted facilities expanded, the government provided subsidies for small and medium-sized companies as an incentive to encourage the installation of measuring devices.

Transparency fostered mutual trust between governments, businesses, and the public

Anyone could access the COD, T-P, T-N, and SS information of a facility on the SOOSIRO website, which was an easy system to use. Transparent access to information also contributed to building public confidence in the government's water quality policy. "In other countries, various remote monitoring services have been introduced, but there is no case in which administrative data is applied nationwide like Korea," said Sung-shin Jang. "In addition, the TMS control system operated by Korea Environment Corporation provides the same information to the facilities and the administrative agency. Thus, we can ensure transparency in data processing and form a sense of mutual trust."

20) Author interviewed with Won-sik Lee on April 23, 2021

21) Korea Environment Corporation (2016), p 15

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