Operation & Management: Developing New Water Supply-related Technologies

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Introduction

Leading the advancement of water supply technologies through research and development

With the aim of producing world-class, healthy, and clean-tasting city water ("Arisu"), Seoul's Waterworks Research Institute strives to develop innovative new technologies for delivery of clean tap water from purification centers to homes through a safe supply and distribution system.

The Institute focuses on developing sustainable technologies that will help it prepare for the changing domestic and international environment including climate change and water scarcity and create new value and opportunities. Its commitment has enabled the Institute to acquire 2 international and 11 domestic patents, making it a leading organization in the development of Korea's water supply-related technology. With approximately 40 distinguished researchers with MAs or PhDs and 678 state-of-the-art analysis devices, the Institute examines Seoul's raw and purified water as well as that of other municipalities, serving as an internationally-accredited examination body under the Korea Laboratory Accreditation Scheme (KOLAS).

Overview of the Policy

Introducing major new technologies researched and developed by the Seoul Waterworks Research Institute

<< Development of new water supply network analysis and simulation technology

<< Study of measures to reduce corrosion of water distribution and supply pipes and improve tap water quality

<< Research and development of an integrated telemetry system

<< Development of a new method to examine membrane module damage that can be used in a variety of fields

Background

Our ultimate goal is to ensure rigorous quality management at all stages, from raw source to every household faucet, and realize a stable water supply that meets the demands of Seoul residents for clean water.

Many domestic and global changes -- political, social, and economic -- surrounding water supply have suggested the importance of developing key technologies to achieve such goals. Thus, the Seoul Metropolitan Government is making aggressive efforts to develop such supply system technologies that can lead the future, covering the source of water all the way through delivery of clean tap water to household faucets.

The most critical technologies for building consumer confidence in tap water and providing high-quality service to residents include: a membrane filtering system to completely remove particles generated from diverse industrial developments; optimal management of water pipes; quality management of the supply system; prevention of pipe corrosion to block any and all potential complaints about "rusty" water; and an integrated remote metering system, which is an ideal IT conversion for the improvement of metering efficiency.

Process of Policy Implementation

- 1980~1990s: With establishment of the Institute in 1989, efforts to lay the foundation for water quality management and technological development began in earnest. Stable management of water quality and supply were the highest priorities, leading to the hiring of the necessary personnel and initiation of research.
- 2000~ : Water quality management was the primary focus until 2000. As a result, our analysis technique and capability grew to be the best in Korea. We were able to bring in state-of-the-art analysis equipment thanks to aggressive investment and focus on technological development to further improve the quality of Arisu.
- 2007~ : Our analysis techniques have advanced significantly, and have been recognized as world-class by a variety of analysis institutions in advanced countries. We began to see some results from joint technological developments, and development efforts were extended to the sewage system as the need for R&D in the area increased.
- 2012~ : The need to develop leading technologies was highlighted to ensure continued growth of the Institute and to secure a growth engine for the future. To that end, we created an exclusive body for future strategies in charge of early collection of information on global technological trends and suggesting future directions.
- 2014~ : We set an ambitious goal of becoming a world-class comprehensive water study center with new transformation initiatives. Various meaningful changes are underway such as

attracting new researchers and organizational restructuring towards more effective technological development.

※ Waterworks Research Institute Achievements

Nov. 1989 Appointed as a potable water quality examination body

Apr. 2003 Appointed as the national institution for virus examination

Sept. 2004 Accredited as the national institution for protozoa examination

Jan. 2005 Appointed as the internationally-accredited examination body under KOLAS

May 2006 Appointed as an agent for inspection of environmental monitoring device accuracy

Jun. 2009 Appointed as the national institution for norovirus examination

Appointed as the national certification testing institution for membrane module capability

Introduction of Studies on Major New Technologies

1. Water Supply Network Analysis & Water Quality Simulation

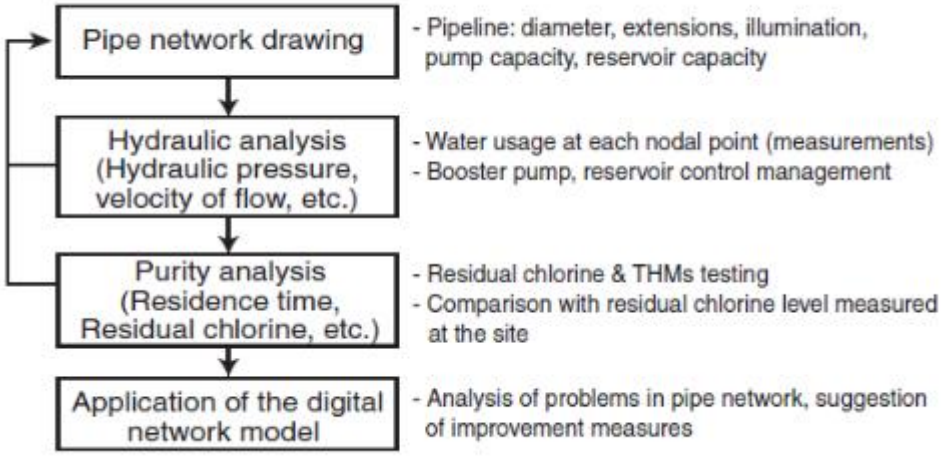
| Background |

Growing need for…

- Better maintenance and management of water distribution and supply system
- Enhanced crisis response ability in accordance with changes in the city environment
- Application of computer technology to water distribution and supply network management
- Water quality management technology to meet public demand

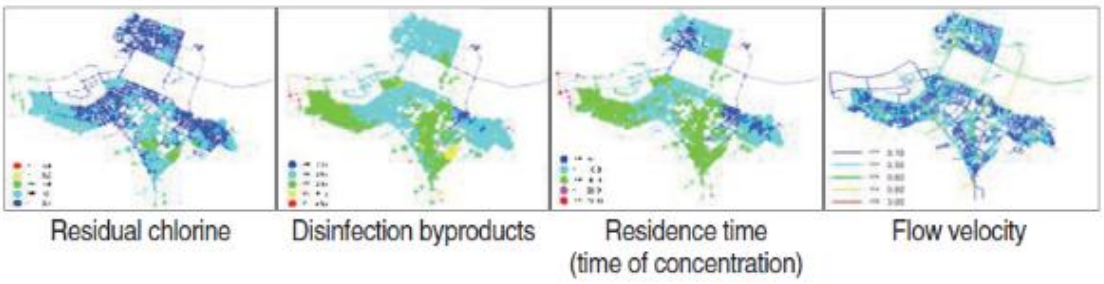
| Research Overview |

- Distribution and supply network model created



• Purity fluctuation modeling

Computer simulation and analysis of residual chlorine, disinfection byproducts, residence time, and flow velocity



I Applied Technologies & Their Impact I

• Set the seasonal standard residual chlorine level at each purification plant.

The standard residual chlorine level in transmitted water can be set in a systematic manner using the pipe network model. This method can help lower the chlorine level at purification plants, thereby getting rid of unpleasant taste or odor in the water supply as well as reducing costs related to chlorine purchases.

• Conduct hydraulic analysis, water purity assessment, and evaluation by small block.

There are two examination criteria: safety in terms of water purity and stability in terms of hydraulic pressure. The evaluated items under water purity include residual chlorine and THMs, which are disinfection byproducts. Items under hydraulic pressure include minimum hydrodynamic pressure, average pressure by block, and pressure fluctuations. Such items help us identify and resolve problems in each category.

• Prepare contingency plans.

Towards application to disaster or accident response plans, pipe network analysis can be used to forecast the impact of damage to transmission pipelines and power interruption at

pressurizing stations, expected recovery time, and impact of contaminant inflow.

• Enhance pipe network maintenance and management capabilities.

The digital pipe network model can be used for hydraulic pressure and residual chlorine management and to contribute to the improvement of overall water supply management capability.

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2. Measures to Reduce Pipe Corrosion & Improve Tap Water Purity

| Background |

• To curb the corrosion of water pipes, the United States and European countries have water purity specialists manage the pH level at purification centers or use corrosion inhibitors. In particular, the US has been using phosphate-based corrosion inhibitors at purification plants since the 1930s; with enactment of the Lead and Copper Rules in 1991, the number of purification facilities using corrosion inhibitors increased significantly.

• Korea does not yet have anti-corrosion measures in place at the purification center level to prevent “rusty” water. For more effective prevention, Korea should also require that water suppliers implement anti-corrosion measures, as is done in the US, Europe, and Japan. Korea also needs to develop new technologies for monitoring and reducing tap water pipe corrosion at purification plants.

| Research Overview |

• Langelier Saturation Index (LSI) assessment of the Han River system

The US and Germany maintain their LSI level at 0, whereas Japan keeps it at −1.0 to 0. The Korean government monitors LSI but is still studying what its ideal range should be. Purified water has greater potential to cause corrosion due to the chlorine and coagulants injected during the purification process, which cause the pH level to drop. If an alkaline chemical is added to neutralize the water toward the end of the purification process, the corrosivity drops.

• Suggestion of LSI monitoring

We suggested that the Ministry of Environment include tap water LSI in the list of water quality assessment categories to better manage ductile cast iron pipes with cement linings, prevent old water pipes at homes from causing rusty water, and reinforce the safety of corrosion inhibitors currently managed in small units such as apartment complexes.

• Development of corrosivity index and corrosion prevention technology

To prepare for the introduction of LSI management standards, Seoul installed the first ever

pilot plant for corrosivity management in 2007. It also obtained three new patents for a Method of Corrosion Inhibition in Water Pipes (18 January 2008), a Method for Corrosion Prevention in Water Distribution Systems by Lime Slurry (14 November 2008), and a Method for Supplying Water with Controlled Corrosive Characteristics (25 August 2010). These techniques are the first in the world to use carbon dioxide to completely dissolve limewater in tap water, and differ from the techniques used in the US or Japan since they use hydrated lime powder for simple application by workers at plants; they can also turn 99.9% of hydrated lime into calcium.

Anti-corrosion process	(CO2+hydrated lime)	(CO2+ hydrated lime+ phosphate)	(Phosphate)
Iron (mg/L)	0.13	0.07	0.59
Reduction of rusty water (%)	97.6	98.7	89.1

| Implementation Experience & Know-how |

• At the initial stage of the project, no limewater dissolved when theoretically 0.13% was supposed to. Nonetheless, innovative technological development led to the increase of Ca solubility to 40ppm.

• We suggested that the Ministry of Environment add new LSI monitoring categories (1 September 2005), which laid the foundation for potential corrosivity management in the future, since it led to enactment of a relevant act on 22 December 2011 and its enforcement on 1 July 2012.

| Research Outcomes |

• After assessing the LSI of all pipes in the Han River system, we asked the Ministry of Environment to add LSI to its purity assessment criteria to extend water pipe lifespan and

prevent the delivery of rusty water to faucets at home. Consequently, LSI was added to the Ministry's monitoring list on 1 July 2012. The Ministry and the Institute are working on a joint research project to develop a new index for managing corrosivity that suits the Korean water conditions better.

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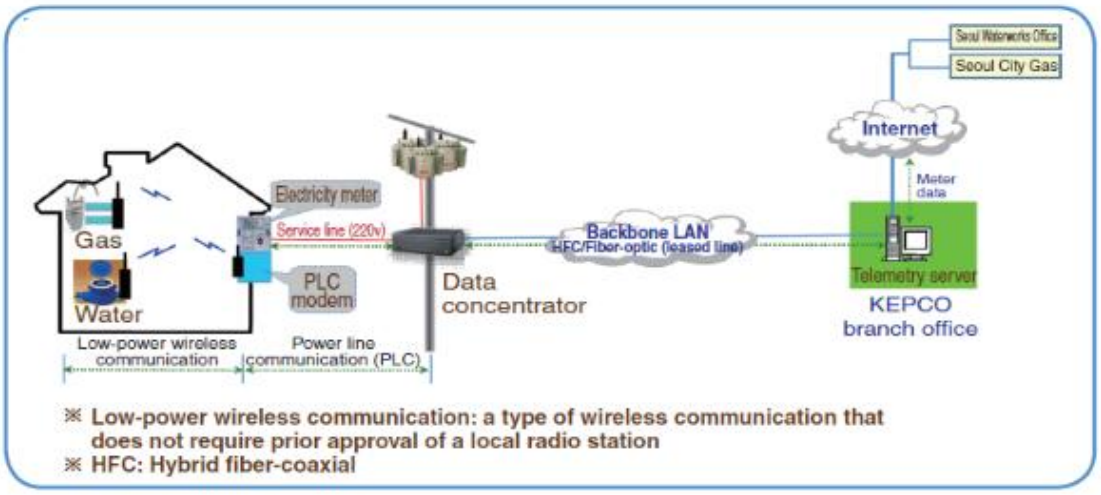
3. Integrated Telemetry System

| Research Overview |

• Integrated telemetry is the process of sending and receiving usage data for water, electricity, gas, and other utilities altogether at remote points. This project has used power line communication to combine telemetry systems for water, electricity, and gas at the lowest cost. Using power lines to communicate requires that data be sent from water meters to digital electricity meters. Thus, the data was sent through low-power wireless communication. The integrated telemetry system structure is illustrated below.



At least 100 houses in Mok-dong, Yangcheon-gu had new meters installed. The new system was connected to eighty-six 15mm faucets and sixteen 20mm faucets. We monitored the measurements from each faucet, identified the reasons for any abnormalities through on-site surveys, provided solutions to the problems, and analyzed the outcome of pilot operations. To guarantee compatibility of the integrated telemetry system, we teamed up with the Korea Electric Power Research Institute (KEPRI) to study, design and develop the digital water meter and wireless communication protocols. These protocols were then applied to the

integrated telemetry simulator for 43 days to check whether data moved from digital water meter to the main server without issue.

| Research Outcomes |

• During the pilot period, the monthly average success rate of communication varied between 85.4% and 95.9%, with an average success rate of 91.9%. Between January and June 2009, the average success rate of participating companies was between 86.3% and 99.3%. The rate of successful connection in water supply telemetry rose to a reliable level thanks to the development of a new device technology.

• After the pilot operation, we found that the greatest challenge was ensuring the interoperability of digital water meters, mobile metering devices, and digital electricity meters. Thus, together with KEPRI, we designed a protocol for digital water meters and one for wireless communication. We then tested the feasibility of the protocols by applying them to the water telemetry simulator in our lab. After 43 days of pilot operation, we confirmed that the initial registration data was being sent from metering devices to the server without problems. We also found no issues with data linkage between the two protocols as well as in the measured data and connectivity.

• An integrated telemetry system using power line communication is unprecedented. This project confirms that the integrated metering system has technical strength over the independent water supply metering system. Certain sections of the network use cable communication since the underground water meters do not provide a favorable environment for wireless communication. This reduces the range of wireless communication and renders repeaters for improving wireless connectivity unnecessary; hence fewer installations and lower maintenance.

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4. Membrane Module Damage Assessment Technology for Broad Application

| Background |

In current water treatment centers, raw water passes through a flocculation tank and a sedimentation basin. Sand filters are commonly used to remove contaminant particles in the water during the process. Note, however, that sand filters cannot remove organic particles, viruses, protozoan cysts, or other particles smaller than 1μm since such filters are designed to remove those at least 10μm. For such reasons, integrity tests are conducted to check if

the membrane can remove pathogenic microorganisms or whether it suffers any damage. A damaged membrane adversely affects the purity of water as it cannot remove particles effectively. Therefore, damage should be detected at the early stages for repair or replacement. Note, however, that as such damage is invisible to the naked eye, it is extremely difficult to detect early.

To resolve this, we have developed a new integrity testing method of reducing the surface tension of a liquid solution, which allows more accurate testing at lower pressure.

Citric acid for cleaning the membranes is used to adjust surface tension. This increases resolution of the direct integrity test and enables low-pressure detection of small ruptures or damage. Pressure-drop testing is a convenient method that can be applied easily to actual purification plants.

| Research Outcomes |

• In a direct integrity test to verify that a membrane module is highly effective at removing contaminants, a method using a reduced liquid surface tension can be applied in the following steps:

- Create a solution of water and a chemical that reduces the surface tension of water.
- Inject the solution into the filtration membrane module.
- Close the raw water and filtered water supply valves of the membrane module while keeping the air pressure supply and discharge valves open.
- Close the air pressure supply valve: Measure changes in air pressure after a certain duration of time.
- Compare the measured air pressure with a preset standard value to detect possible damage to the membrane. The pressure-drop method enhances the resolution of the membrane integrity test.

| Application & Impact |

This method can be applied to integrity tests in any field utilizing a membrane module. It allows direct integrity testing of the membrane filter during chemical cleaning or the maintenance cleaning process, making it adaptable to any site that uses membrane filters.

| Impact of the Applied Technology |

Pressure-drop testing is a practical method that gives enhanced resolution, enabling direct integrity testing and chemical cleaning of membrane filters at the same time. Damage on the membrane surface can easily be identified and fixed during the chemical cleaning process so that the damage does not lead to degradation of water purity.

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Policy Outcomes & Evaluation

- Patents: 16 (13 obtained, 3 in progress)

No.	Division	Type	Certification No.	Registration Date	Owner-ship	Title of the Invention	Remarks
1	Water Treatment	Patent	10- 0720140	2007.05.14	Joint	Operation Selection Device using the Water Code of Membrane Filtration Device and Method Thereof	
2	Water Treatment	Patent	10- 0720139	2007.05.14	Joint	Operation Control System using the Water Analysis of Membrane Filtration Device and Method Thereof	
3	Water Treatment	Patent	10- 0791896	2007.12.28	Joint	Membrane Filtering Water Treatment Apparatus Having Pretreatment Selectively Controlled by the Quality of Raw Water and Method Using the Same	
4	Water Distribution & Supply	Patent	10- 0797847	2008.01.18	Seoul	Method of Corrosion Inhibition of Water Pipe	
5	Water Treatment	Patent	10- 0843656	2008.06.27	Joint	Advanced Water Treatment Equipment using Two-layer SMF	
6	Water Distribution & Supply	Patent	10- 0853382	2008.08.18	Joint	Method for the Corrosion Prevention of Water Distribution Systems by Lime Slurry	Not trans-ferred
7	Advanced Water Treatment	Patent	10- 0890246	2009.03.17	Seoul	Upflow Ozone Contractor for Suppressing Residual Ozone	
8	Water Distribution & Supply	Patent	10- 0979250	2010.08.25	Seoul	Method for Supplying Water with Controlled Corrosive Characteristics	
9	Water Treatment	Patent	10- 1164600	2012.07.04	Seoul	Membrane Integrity Test through the Lowering of Surface Tension	
10	Water Treatment	Patent	10- 1179008	2012.08.27	Seoul	Baffle for Preventing the Congestion of Water at Purification Plants or Reservoirs	
11	Water Distribution & Supply	Patent	10- 1309980	2013.09.11	Joint	Post-welding Treatments to improve the corrosion resistance level of Duplex Stainless Steel for Water Supply Facilities	
12	Advanced Water Treatment	Chinese Patent	ZL200980122 574.3	2013.09.11	Seoul	Upflow Ozone Contractor for Suppressing Residual Ozone	
13	Advanced Water Treatment	Japanese Patent	Patent No. 5356512	2013.09.06	Seoul	Upflow Ozone Contractor for Suppressing Residual Ozone	
14	Advanced Water Treatment	US patent	Application submitted (US)	2009.05.28	Seoul	Upflow Ozone Contractor for Suppressing Residual Ozone	Application submitted
15	Wastewater Treatment	Patent	Application submitted	2013.10.22. (10-2013-0125686)	Seoul	Reject Water Recovery and Total Phosphorous Control Device	Application submitted
16	Wastewater Planning	Patent	Application submitted	2013.10.17 (10-2013-0124104)	Seoul	Water discharge delaying device	Application submitted

- New Excellent Technology (NET) certification: 3 certificates (completed)

No.	Division	Type	Certification No.	Registration Date	Ownership	Name of the Technology
1	Water Treatment	NET	NET certification NO.198	2007. 03.19	Seoul Metropolitan Government, Daewoo E&C	Pressurized MF with Auto-controlled Pretreatment and Purification Technique using SMF for the Recovery of Discharge Water
2	Water Treatment	NET	NET certification NO. 235	2007. 11.23	Seoul Metropolitan Government, Taeyoung Corp., Greenex, Korea Institute of Civil Engineering and Building Technology (KICT)	Membrane Separation-Type Advanced Water Treatment System using Auto-coagulant Control and Selection of Pretreatment by Code of Raw Water Quality
3	Water Treatment	NET	NET certification NO. 270	2008. 12.24	Seoul Metropolitan Government, Hanwha E&C, Taeyoung E&C, KICT	Advanced Drinking Water Treatment Technology using the Korean Submerged MF with an Intermittent Air Scouring Filtration System

Q&A

How has the Waterworks Research Institute supported other local water supply quality examinations?

• The Waterworks Research Institute has shared water quality analysis methods with local water suppliers, which include methods related to membrane module testing, protozoan, advanced water treatment, sample analysis, potable water quality standards, virus (purified water) and water treatment solution testing, etc.

• In 2013, 117 organizations, including the city of Wonju, Gangwon-do, received support from the Institute, generating KRW 79.414 million in profit. As of June 2014, 68 organizations including Hanam City and Gyeonggi Province had received the Institute's support, with KRW 43.495 million worth of profit generated.