

Multiple-Check System for Inspection of Tap Water Quality

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Overview

- ① Management of water supply quality at source ⇒ Securing safety of raw source water (Intensified management during vulnerable periods like water shortages)
- ② Management of purified water quality ⇒ Maintenance of optimal quality of purified water (Annual average turbidity of 0.06 NTU or less)
- ③ Management of water quality during water distribution and supply ⇒ Establishment of outreach administrative services (Arisu quality confirmation system, etc.)
- ④ Inspection of water quality at faucet and during supply ⇒ Improvement of water quality for citizens (Inspection of faucets at 450 locations, etc.)
- ⑤ Reduction of residual chlorine at faucet ⇒ Supply of pure-tasting, odorless tap water (Residual chlorine maintained at 0.1~0.3mg/L)

Background

Since the Ttukdo Arisu Purification Center, the first modern water purification plant in Korea, began to generate tap water in September 1908, water quality inspections included 14 items such as turbidity, pH, hardness, and residue on evaporation until the time Korea was liberated from Japanese colonial rule in 1945. When the “Regulations on Medical Examinations and Sanitation” were enacted on March 11, 1963, standards for water quality and selection of water quality inspection items were determined, with the number of legally-required inspection items increasing to 29 and including ammonia nitrogen, etc.

In August 1989, it was reported in the press that the tap water was contaminated with microorganisms and heavy metal. Disinfection by-products such as trihalomethane were detected in 1990. The Nakdong River, one tap water source, was polluted by the illegal disposal of phenol by Doosan Corporation in Gumi in 1991. Strong odors originating from the river were reported in 1992. As these incidents continued to occur over the years, tap water quality emerged as a major social issue. These consecutive incidents of contamination inevitably resulted in a general distrust of tap water, and it was accordingly seen as polluted and unsuitable for drinking.

In order to break through this distrust, the Seoul Metropolitan Government (SMG) prepared to counteract contamination and established a better water quality inspection system by expanding the number of inspection items and strengthening the inspections themselves. In July 1997, the SMG then designated 2 more items to be included in water quality monitoring in addition to the established legally-required items.

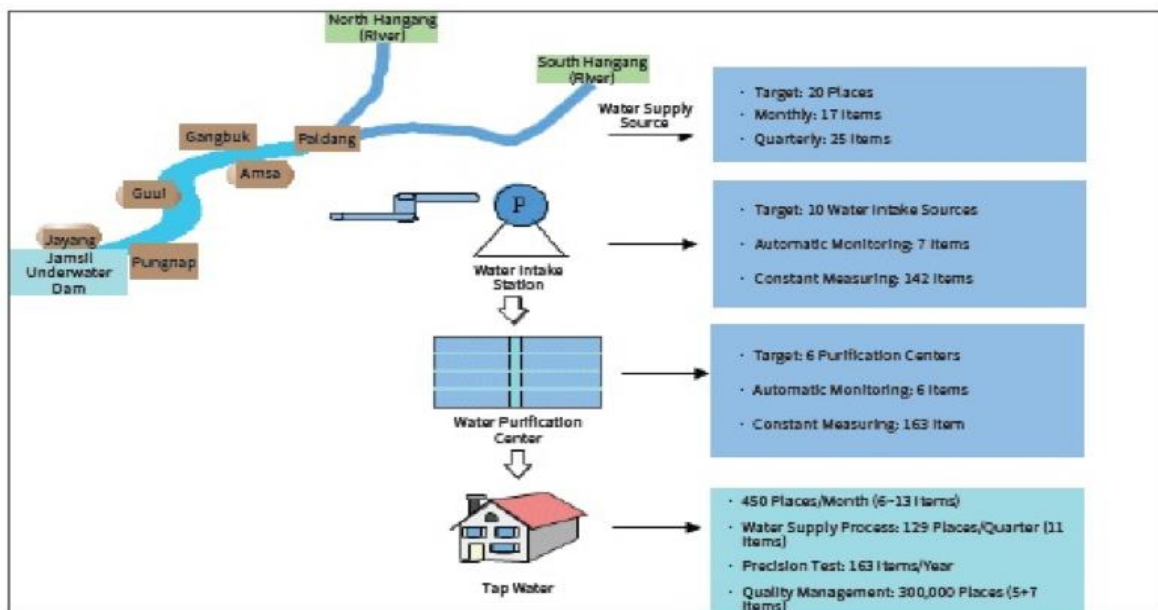
Since then, the items have constantly expanded and monitoring includes 104 items, while water quality inspections include 59 legally-required items. In 2014, trace amounts of toxic substances such as disinfection by-products were added. Finally, all items designated by the WHO (World Health Organization) were included in water quality inspections, with inspection findings announced to the public, proving Seoul's tap water, "Arisu," was safe.

To effectively cope with the odors generated largely due to algae growth around the catchment areas, Seoul has run an algae warning system since 2000. However, tap water odors occurred at times even when algae warnings were not issued. The first odor warning system in Korea was begun for geosmin and 2-MIB in 2012 in addition to the algae warning system to respond to and treat odorous substances preemptively and efficiently to supply clean-tasting tap water without the smell.

As of 2014, water quality inspection was done on 59 legal items in Seoul.

Management of Tap Water Quality

<Figure 1> Water Quality Inspection System for Raw Source Water, Purified Water & the Water Supply System



Water Quality Management System Using Multiple Test Methods: Management of Quality of Raw Source Water, Purified Water & the Water Supply System

Water Quality Management of Water Supply Sources & Raw Intake Water

Of the 6 water purification plants in Seoul, Gwangam Purification Center obtains its raw water from the Paldang Water Source Protection Area (157.3 km²) while the other 5 plants, including Gangbuk Purification

Center, obtain their raw water from the Jamsil Water Source Protection Area (6.45 km²). The SMG endeavors to ensure the safety of raw water by forecasting water quality and dealing with sources of pollution through inspections of the main flow of the Hangang and its tributaries, which impact the city's water supply sources.

The main inspections of water supply sources and raw intake water are conducted by the Water Supply Institute and the purification centers. The water is inspected for 7 items, including phenol and ammonia nitrogen, using an automatic water quality measuring system in real time. Biological warning systems are in place in the Gangbuk, Amsa and Pungnap (Yeongdeungpo) purification centers to constantly monitor and test for the inflow of contaminants such as heavy metal and domestic sewage.

<Table 1> Inspection of Water Supply Sources & Raw Intake Water

	Inspection Targets	Total No. of Inspection Items	Inspecting Agency	Inspection Cycle
Water Supply Source	20 Locations (South Hangang 5, North Hangang 5, Kyeongancheon <Stream>, Tributaries on the Paldang Downstream 9)	42 Items	Water Supply Institute	17/Month
				25/Quarter
Water Supply Source	8 Places: Tributaries (6), Main Stream of Hangang (2) - Tributaries: Gungchoncheon, Dosimcheon, Wolmuncheon, Deoksocheon, Hongneungcheon, Sangokcheon (Stream) - Hangang Main Flow: Amsa, Guui	57 Items - Tributaries: 42 Items - Hangang Main Flow: 15 Items (15 Items Overlap)	Water Supply Institute	42/Month
			Amsa, Guui	4/Day
				11/Month
Water Intake Source	3 Locations - Gangbuk: Green Algae, Closterium (Heavy Metal, Agricultural Pesticides) - Amsa: Electric Active Microbes (Domestic Sewage) - Pungnap: Water Fleas (Insecticide, Heavy Metal)	Biological Warning System	Gangbuk, Amsa, Yeongdeungpo	Real Time

Water Intake Source	6 Water Intake Stations: Cyan, Phenol, NH3-N, TOC, Water Temperature, pH, Turbidity (Chlorophyll-a)	Automatic Water Quality Monitoring System (7 Items)	Water Purification Center	Real Time
Water Intake Source	10 Locations (6 Water Intake Stations, 4 Hangang Confluences) - South Hangang: Bogpo-ri, Sinwon-ri - North Hangang: Sambong- ri, Jinjung-ri	142 Items - Legal: 31 - Add'l: 111 (15 Items Overlap)	Water Supply Institute (135 inspections/year)	21/Week
				12/Month
				73/Quarter
			Water Purification Center (22 inspections/year)	29/Year
				10/Day
12/Week				
Source: Internal Data of the Seoul Metropolitan Government.				

Management of Water Quality at Water Purification Centers

The goals of purified water quality management are to maintain turbidity levels at 0.06 NTU or less (purified water turbidity 0.1 NTU or less in the rainy season) and to maintain residual chlorine at $\pm 0.04\text{mg/L}$ of for each purification center. Another goal is 0.3 NTU or less of turbidity in 95% of the purified water measured every month. The goal in terms of taste and smell is to produce tasteless and odorless water (through the odor warning system, input of powdered activated carbon, etc.).

To manage water quality during the purification process, analysis begins with raw water, sufficient disinfectant concentrations are used and turbidity managed in purified water. Seoul produces and supplies high quality tap water which meets the purification processing standards even in the worst conditions.

One of the most important aspects of water quality is management of turbidity, and the system in Seoul automatically monitors for it during each treatment process from the point of disinfectant injection and into the following 24 hours. The optimal operating conditions for purification are also analyzed and determined for each season (periods of water shortage, rain and winter). Inspections of tap water quality are performed by the Water Supply Institute, the top inspection agency in Korea, and each of the 6 water purification centers, and are in accordance with the WHO's 163 inspection items (59 items to ensure drinking water quality and an additional 104 items required by the SMG). Daily, weekly, monthly, quarterly and yearly inspections are done on various items, and the findings are made available to the public as evidence of tap water safety.

<Table 2> Water Quality Inspections at Water Purification Centers

	Inspection Target	No. of Total Inspection	Inspection Agency	Inspection Cycle
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		Items		
Raw Water	6 Water Purification Centers	22 Items	Water Purification Center	10/Day
				12/Week
Purified Water	6 Water Purification Centers	23 Items	Water Purification Center	10/Day
				13/Month
Purified Water	6 Water Purification Centers 10 Locations (Including 1 Bottle Water)	163 Items (59 Legally-required, 104 Monitored)	Water Supply Institute	63/Month (59 Legally-required, 4 Monitored)
				61/Quarter
				39/Year
Purified Water	Research on the Real Status of New Micro-pollutants - Residual Pharmaceutical Compounds (3), Industrial Chemical Materials (3)	130 Items (2014: 6 Items)	Water Supply Institute	Yearly
Source: Internal Data of the Seoul Metropolitan Government.				

From Water Purification Center to Faucet

Chlorine levels have the most influence on whether or not people drink water directly from the tap. Previously, chlorine was added mainly at water purification centers. As a result, complaints about the chlorine smell were raised by people living nearby, while the concentration of residual chlorine was below the standard at faucets far from the centers. To resolve these problems, in 2012, the amount of chlorine added at the Gangbuk and Amsa purification centers, which provide tap water to the largest areas in the city, was reduced while chlorine was added at places like water distributing reservoirs (17 places) during water transportation. It planned to the system more to the other places to maintain a chlorine level within 0.1~0.3mg/L.

Time-worn water supply pipes made of gray cast iron, galvanized steel and steel non-resistant to corrosion were vulnerable to water leaks and inside rusting. Especially for cast iron pipes and steel pipes without cladding, the inside became covered with rust after long use and accordingly, reduced both water flow rate and the concentration of residual chlorine. The use of galvanized steel pipes was prohibited in April 1994 for water supply. Seoul is planning to change the entire pipe system with corrosion-resistant pipes by 2018.

Water tanks on apartment rooftops were installed in the past to handle water supply restrictions. Due to the insufficient infrastructure of those days, water was available for a limited time only. In most cases, the water for personal use was supplied after pulling it up from an underground water tank to a rooftop tank to store for a time it would be needed. Because this water was stored for a long time in these water tanks, the residual chlorine decreased, potentially deteriorating water quality if the tanks became contaminated.

To address these problems, the city began supplying water directly to households to increase the amount of residual chlorine (0.18mg/L) and to ensure cleanliness and safety.

<Figure 2> Reducing Disinfectant Odor (Chlorine)



Water purification center / Areas a short distance from the purification center / Areas a long distance from the purification center

Management of Water Quality During Distribution & Supply

Several programs and many inspections are conducted to inspect and manage water quality to keep Arisu, Seoul’s name for the water produced in the water purification centers, clean and safe through arrival to households. These include legally-required and other water quality inspections during each stage of the supply process and the Arisu quality confirmation system (which includes participation from citizens), thereby enhancing user confidence and satisfaction and raising the rate of people drinking water directly from the tap.

<Table 3> Inspections of Water Quality in the Water Distribution & Supply System

Classification	Inspection Target	No. of Total Inspection Items	Inspection Agency	Inspection Cycle
Faucets	450 Locations (419 Legal + Basic Inspection Places)	6 Items (4 according to Guidelines, 2 Self-initiated)	Water Supply Institute	Monthly
Old Water Pipes	20 Locations	13 Items	Water Supply Institute	Monthly
During Water Supply Stage	120 Locations (8 at Purification Centers, 26 Before Reservoir, 26 After Reservoir, 26 at Inflow Points into Water Supply)	11 Items	Water Supply Institute	Quarterly

	Area, 8 at Booster Stations, 26 at End of Pipe)			
Arisu Quality Confirmation System	300,000 Households	12 Items (5 Primary, 7 Secondary)	Water Supply Office	Frequently
Reservoir Booster Stations	113 Locations (104 at Reservoir, 9 at Manned Booster Stations)	Residual Chlorine	Water Supply Office	Daily
	Auto Measurement of Water Quality at 188 Locations	Turbidity, pH, Residual Chlorine, Water Temperature, Electrical Conductivity	Water Supply Office	Real Time (Open via SWN)
Distributing Reservoirs	104 Locations	12 Items	Water Supply Office	Quarterly
Water Pipes (After Construction)	Reservoir, Booster Station, Water Pipe	4 Items (2 Plumbing)	Water Supply Office	Frequently
Water Pipes & Water Tanks	1,079 Locations along Water Pipes	7 Items	Water Supply Office	Yearly
	12,089 Water Tanks	6 Items	Private Drinking Water Quality Inspection Agency	Yearly
Arisu Drinking Fountains	2,674 Locations (30,807 Units)	5 Items	Water Supply Office	Monthly: Subways
				Quarterly: Schools, Public Offices
Monitoring Items	Faucets at 25 Locations (1 per District)	163 Items (59 Legally-required + 104 Monitored)	Water Supply Institute	Yearly (September)
Residual	Watershed-based Faucets	Residual Chlorine	Water	Weekly

Chlorine Monitoring	at Water Purification Center (90 Locations in 2013)		Supply Office	
Source: Internal Data of the Seoul Metropolitan Government.				

Water Quality Management Using Multiple Checks for Major Items: Micro-pollutants & the Algae Warning System

Micro-pollutants

Seoul selected 130 inspection items (6 added in 2014) in addition to the original 163 and performed research on the actual situation of endocrine disruptors like non-regulatory chemicals, pesticides, and cancer-causing toxic substances, etc. every year.

Algae Warning System

To reduce the occurrence of substances causing odor in tap water, an Algae Warning System has been introduced, which issues warnings when blue-green algae is present in large amounts in the raw water. A warning was issued in section 1 of the upper region of Jamsil Underwater Dam for 15 days in 2012, and 6 in the Seoul area of the Hangang since 2000. Algae creates odor and toxic substances, and causes water purification facilities to malfunction, etc. Together with the Algae Warning System, an odor warning system was established for geosmin and 2-MIB in 2012 to respond preemptively to the presence of odorous substances and thereby reduce the smell of tap water. In cases when warnings are issued due to the significant generation of algae and odorous substances, water quality inspections which would normally be carried out once a week are done once a day or more often, and powdered activated carbon is added at the purification centers, followed by interchlorination. Prechlorination at water intake stations is also done to remove as much of the odorous substances as possible.

<Table 4> Algae Warning System (Warnings issued if 2 Items exceed standard 2 times consecutively)

Items of Algae Warning	Algae Watch	Algae Warning	Significant Algae Alarm
Chlorophyll-a Concentration (mg/m3)	Over 15	Over 25	Over 100
No. of Blue-Green Algae Cells	Over 500	Over 5,000	Over 106

(Cell/mL)			
<Table 5> Odor Warning System (Reflecting purification process efficiency)			
Items of Odor Warning	Odor Watch	Odor Warning	Significant Odor Alarm
Geosmin (ng/L)	20	500	1,000
2-MIB (ng/L)	20	50	100

Multiple-Check System for Management of Water Quality: Arisu Quality Confirmation System, Selection & Management of Water Quality Monitoring Items, Water Quality Monitoring through Public-Private Partnership, Monitoring

Arisu Quality Confirmation System

Seoul inspects water quality during every step of tap water generation and supply and automatic measurement of water quality also takes place. The findings are made available to the public via the Seoul Water Now system and the Seoul City website (http://english.seoul.go.kr/?SSid=101_01&tr_code=foreign) as evidence of the safety of the city's tap water. However, people remain skeptical about drinking city water in their own homes because of rust on the insides of old water pipes in buildings. Seoul visits designated places (to which they are invited) to understand the situation and inspect the water quality according to the Arisu Quality Confirmation System. The causes of unpleasant odors, taste, or appearance are identified and a process implemented to reduce these issues and gain the confidence of the public.

Selection & Management of Items for Monitoring of Water Quality in the World Best Class (104 Items)

The SMG cooperated with the Ministry of Environment and related government organizations in legislating and revising related laws and regulations to set up a management system for tap water quality and water purification standards. In addition to the legally-required water quality inspection items prescribed in the Water Supply and Waterworks Installation Act, the SMG designated 104 more that it felt would lead to better monitoring through its related ordinances, while establishing regulations related to water supply.

Water Quality Monitoring through Public-Private Partnership

In accordance with Article 30 of the Water Supply and Waterworks Installation Act and SMG ordinances, Seoul organized the Seoul Tap Water Evaluation Committee, which consists of external city council members, professors and experts in environmental groups. Specimens are collected at 10 points within the water transportation route from intake source to the faucets of 2 water purification centers and an external private inspection agency designated by the Seoul Tap Water Evaluation Committee inspects the water for the 59 legally-required items, releasing the findings on the SMG and Seoul Tap Water Evaluation Committee

websites.

Major Aspects of the Monitoring System

Residual chlorine is checked every day at 113 locations, including reservoirs and booster stations. Automatic water quality measuring systems are installed at 188 points to monitor for 5 items, including turbidity and residual chlorine, in real time, with the findings open to the public via the Seoul Water Now system (SWN).

Achievements

A Safe, Healthy Supply of Water

The SMG provides its citizens with safe, healthy water through systematic quality inspection and management of the process of production and distribution from water source to faucet. It also has proven the safety of tap water through water quality inspections which include the 163 items recommended by the WHO and annual research on the actual conditions of a total of 130 additional non-regulatory micro substances. In order to remove biological and disinfectant odor, the main deterrents for people when considering drinking the water directly from the tap, algae and odor warning systems have been established which issue warnings when the algae and odors increase in the raw water, reacting preemptively to odor-causing substances. In order to reduce the chlorine odor, Seoul has introduced a system that inputs chlorine at the water reservoirs in the middle of the water supply process, maintaining residual chlorine in the range of 0.1~0.3mg/L at faucets, in accordance with the guidelines on clean-tasting water. Once the installation of advanced water purification facilities is completed at 6 purification plants in Seoul by 2015, algae-related odors will decrease noticeably.

Implications & Applications for Developing Countries (Ripple Effects)

Seoul manages the quality of raw water in the Paldang water supply source and constantly monitors water intake stations for the inflow of pollutants. In accordance with WHO recommendations, Seoul inspects and analyzes water for many items. It has also introduced the first odor warning system in Korea to preemptively respond to increases in algae. In addition, the Arisu quality confirmation system is used to inspect water quality at the tap, a distributed chlorine injection system reduces tap water odor, and monitoring and research is done on micro toxic substances. Water quality inspections using a multiple check system contributes to the supply of safe, healthy water. Seoul also selects topics for research for each water purification center and holds workshops where findings, problems and cases of improvement are presented. Such findings and improvements are used as benchmarks for other cities and provinces in Korea and developing countries overseas.

Q&A

- Why do you use a multiple check system to manage tap water quality?

The Paldang water supply source is not perfectly free from algae and sources of point pollution. To provide safe, healthy water to its more than 10 million citizens, Seoul requires water quality inspections and monitoring for various items at multiple levels throughout the entire process of tap water production and distribution, including at water supply sources, water intake stations, water purification centers, and distribution and supply systems.

- What are criteria used to determine the water quality of Arisu?

The criteria for determining drinking water quality in Korea include the level of microorganisms, harmful inorganic substances, harmful organic substances, disinfectants, disinfection by-products and substances with aesthetic impact. The reference values in determining water quality are set by the amount of water that is not harmful to health for the average person drinking 2 liters of water per day for 70 years and in consideration of a 1/100~1/1,000 of safety rate. Therefore, water that falls within the reference drinking water quality values is harmless to humans.

- What are the bases for selection of items for water quality monitoring and inspection?

In accordance with Article 26, Paragraph 3 of the Water Supply and Waterworks Installation Act, the SMG selected for water quality monitoring highly detectable items based on research of the actual situation of micro toxic substances, etc. and self-initiated inspection results, the necessary items that would allow better handling of related social issues, and the items that were tap water issues in other countries which seemed to also be detectable in Korea. The inspection standards and methods are made and implemented after taking into account the related regulations of the WHO and in other nations. (Thirty items recommended by the Ministry of Environment included in the 104 items determined by Seoul)

- What are the guidelines for clean-tasting, healthy water?

Research has been conducted in Seoul and service agreements carried out with specialized organizations, water tasting events hosted, opinion surveys distributed, and public hearings, meetings with advisory committees held, etc. since May 2010 to aid in setting the guidelines for ensuring pure, healthy water, guidelines which were completed in December 2010.

<Table 6> Guidelines for Healthy, Clean-tasting Water

Classification	Item	Unit	Standards of Drinking Water Quality	Guideline	Background
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Items Related to Health	Minerals (Ca, Mg, Na, K)	mg/L	-	20~100	. Essential elements for health
	Total Organic Carbons	mg/L	5.0 (Monitoring Items of Seoul)	1.0 or less	. Disinfection by-products removed to protect health
	Turbidity	NTU	0.5	0.3 or less	. Microorganisms (Protozoa, virus, etc.) removed to protect health
Items Related to Taste/Appearance /Smell	Residual chlorine	mg/L	4.0	0.1~0.3	. Disinfectant odor
	2-MIB	ng/L	20 (Monitoring Items of the Ministry of Environment)	8.0 or less	. Substance causing moldy odor
	Geosmin	ng/L	20 (Monitoring Items of the Ministry of Environment)	8.0 or less	. Substance causing earthy odor/taste
	Copper	mg/L	1.0	0.05 or less	. Substance causing bluish tinge
	Iron	mg/L	0.3	0.05 or less	. Substance causing reddish color and rusty odor/taste
	Temperature	°C	-	4~15	. Feeling of refreshment and good to drink