Tap Water Inspection: Multi-Check Quality System

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Background to Management of Tap Water Quality

Ttukdo Arisu Water Purification Center, the first modern facility of its kind in Korea, commenced operations in September 1908. From then until Korea was liberated from Japanese colonial rule, water quality was examined in accordance with 14 parameters, such as turbidity, pH level, hardness, and dissolved solids.

On March 11, 1963, Regulations on Health Diagnosis & Hygiene were passed, setting new standards for water quality. New criteria for inspections and additional parameters were set to include ammonium nitrate and 28 other items.

However, the quality of tap water became the subject of controversy. In August 1989, it was reported by the media that tap water was contaminated with microorganisms and heavy metals. In 1990, trihalomethane and other disinfectant byproducts were found. In the following year, phenol leaked from Doosan Plant in Gumi, contaminating the source water for the Nakdong River, where odor was detected in 1992. This succession of reports on contaminated tap water created profound distrust in the general public, who were convinced that all tap water was contaminated and unfit for consumption. To reverse this distrust, efforts were made to prevent contamination, expand the scope of water quality inspection, and establish a systematic framework for those inspections. From July 1997, Seoul instituted 2 more of its own inspection criteria on top of the statutory parameters. Today, the city has 104 monitoring and 59 statutory inspection parameters. Beginning in 2014, new items are added each year, such as disinfectant byproducts and trace contaminants. Arisu, Seoul's tap water, is monitored and inspected in accordance with WHO (World Health Organization) guidelines and announced to the public as evidence of its safety.

Seoul instituted an algae alert system in 2000 to respond effectively to an increase of odor-generating algae at the water source. However, there have been cases where odor was detected in the tap water even though the algae alert was not activated. So, in addition to the algae alert system, Seoul introduced an odor alert system in 2012 to monitor geosmin and 2-MIB to react preemptively and proactively to odor-generating particles in order to keep tap water free of odor and bad taste.

As of 2014, there are 59 parameters in the statutory water quality inspection.

Introduction to the Policies

① Water source management ⇒ Ensures safety and quality at source (intensive management during dry and other vulnerable seasons).

② Purification management ⇒ Maintains the best possible purification quality (turbidity kept below 0.06NTU on annual average).

③ Supply-level management ⇒ Provides proactive administrative services (Arisu Quality Certification, etc.).

④ Inspection at faucet and supply level ⇒ Improves acceptability and quality of the tap water as felt by residents (inspection at faucet in 450 different locations).

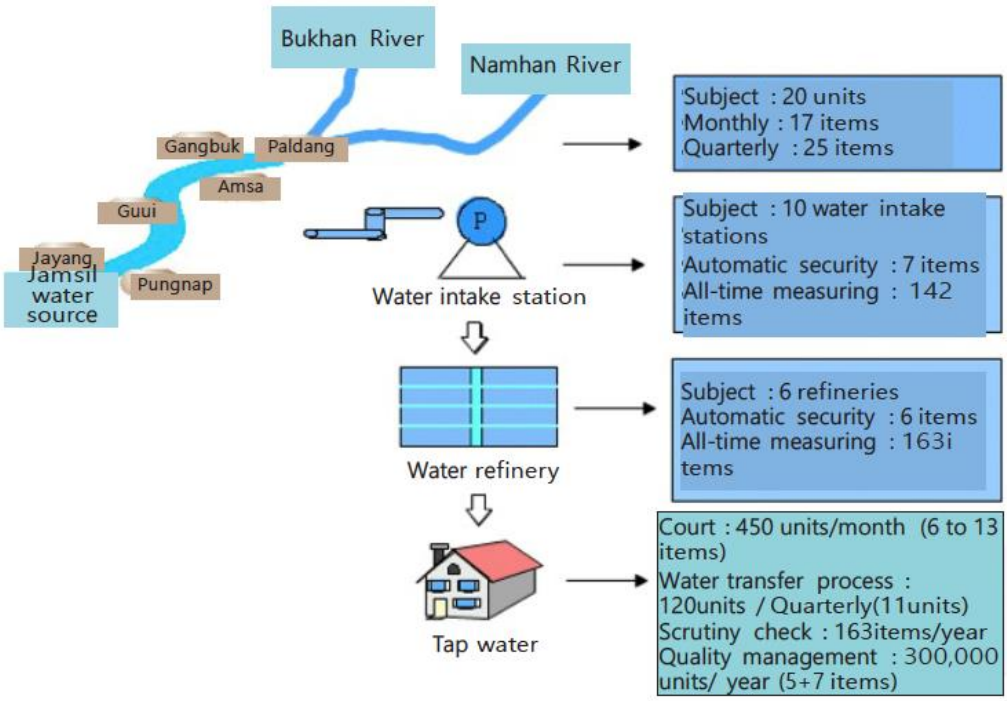
⑤ Reduction of chlorine residue at faucet ⇒ Removes odor from tap water (chlorine residue maintained within the range of 0.1 - 0.3mg/L).

Process of Tap Water Management

Multi-check Quality Inspection System for Tap Water

: Management at Water Source, Purification & Supply Process

<Figure 1> Water Quality Inspection at Water Source Purification & Supply Process



Water Quality Management at Source & Intake

Of the 6 purification centers in Seoul, Gwangam is the one that takes raw water from the Paldang Reservoir Protected Area (157.3 km^2). The rest take their water from the Jamsil Reservoir Protected Area (6.45 km^2). Inspections are conducted on the main Han River stream and tributaries that affect intake points. Water quality is then forecast to ensure aggressive and proactive response to the source of any contamination and to safeguard the water.

Major water quality inspections at source and at intake are carried out by Seoul's Waterworks Research Institute (WRI) and purification centers. Water measurements for such contaminants as phenol and ammonium nitrate are done automatically in real time. The intake points at Gangbuk, Amsa, and Pungnap (Yeongdeungpo) operate a bio alert system, constantly monitoring for contaminants such as heavy metals and domestic sewage.

<Table 1> Water Quality Inspection at Source & Intake

	Target	Total Parameters	Inspector	Inspection Frequency
Water Source	20 points (Namhan River: 5, Bukhan River: 5, Gyeongancheon Stream, tributaries from Paldang: 9)	42	WRI	Monthly: 17
				Quarterly: 25
Water Source	8 points: tributaries (6), main Han River branch (2) - Tributaries: Gungchoncheon Stream, Doshimcheon Stream, Wolmuncheon Stream, Deoksocheon Stream, Hongneungcheon Stream, Sangokcheon Stream - Main Han River branch: Amsa, Gueui	57 - tributaries: 42 -Main Han River branch: 15 (15 overlapping)	WRI	Monthly: 42
			Amsa, Gueui	Daily: 4
				Monthly: 11
Intake Point	3 points - Gangbuk: Green algae (closterium) (heavy metals, agricultural pesticide) - Amsa: Electrically active microorganisms (domestic sewage) - Pungnap: Water fleas (pesticide, heavy metals)	Bio alert	Gangbuk, Amsa, Yeongdeungpo	Real-time
Intake Point	6 intake points: Cyanide, phenol, NH3-N, TOC, temperature, pH, turbidity (chlorophyll-a)	Automatic water quality monitoring device (7 parameters)	Purification Center	Real-time
			WRI 135	Weekly: 21

<table>
<tr><th></th><th>Target</th><th>Total Parameters</th><th>Inspector</th><th>Inspection Frequency</th></tr>
<tr><td rowspan="5">Intake Point</td><td rowspan="5">10 points (intake points: 6 / Han River convergence: 4)
- Namhan River: Bukpo-ri, Shinwon-ri
- Bukhan River: Sambong-ri, Jinjung-ri</td><td rowspan="5">142
- Statutory: 31
- Seoul: 111
(15 overlapping)</td><td rowspan="3"></td><td>Monthly: 12</td></tr>
<tr><td>Quarterly: 73</td></tr>
<tr><td>Yearly: 29</td></tr>
<tr><td rowspan="2">Purification Center: 22</td><td>Daily: 10</td></tr>
<tr><td>Weekly: 12</td></tr>
<tr><td colspan="5">Source: Internal data, Seoul Metropolitan Government</td></tr>
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Water Quality Management at Purification Centers

With an aim of managing the quality of purified water, turbidity is kept at 0.06NTU or lower (flood season: 0.1NTU or lower), and the chlorine residue goal of each purification center is ±0.04mg/L. The turbidity of purified water at the processing level aims to achieve 0.3NTU or lower for 95% or more of the monthly measured sample. Goals for tasteless, odorless water are achieved through odor alerts and powdered activated carbon, etc.

Source water is inspected for quality to enable effective management at the purification processing level while ensuring sufficient disinfectant concentration and management of filtered water turbidity, with the utmost effort made to produce tap water of the highest quality even in the most undesirable conditions.

Turbidity is one of the most important parameters in tap water inspection, and is managed 24 hours a day at each step of the process from injection of chemicals for purification. Management is adjusted according to season (dry weather, flooding, winter, etc.) to ensure optimal conditions for processing. The quality of tap water is inspected according to 163 parameters (59 drinking water parameters, 104 monitoring parameters), as strict as WHO guidelines. The inspection agency is the WRI, the highest tap water inspection authority in

South Korea, and 6 purification centers, classifying the parameters daily, weekly, monthly, quarterly, and yearly. Results are disclosed to the public as evidence of tap water safety.

<Table 2> Water Quality Management at Purification Centers

	Target	Total Inspection Parameters	Inspection Agency	Inspection Frequency
Water Source	6 purification centers	22	Purification Center	Daily: 10 Weekly: 12
Purified	6 purification centers	23	Purification Center	Daily: 10 Monthly: 13
Purified	6 purification centers 10 points (bottled water 1)	163 (59 statutory, 104 monitoring)	WRI	Monthly: 63 (Statutory: 59 / Monitoring: 4) Quarterly: 61 Yearly: 39
Purified	Inspection for new trace materials -Residual pharmaceutical compounds (3), industrial chemicals (3)	130 (2014: 6)	WRI	Yearly

Source: Internal data, Seoul Metropolitan Government.

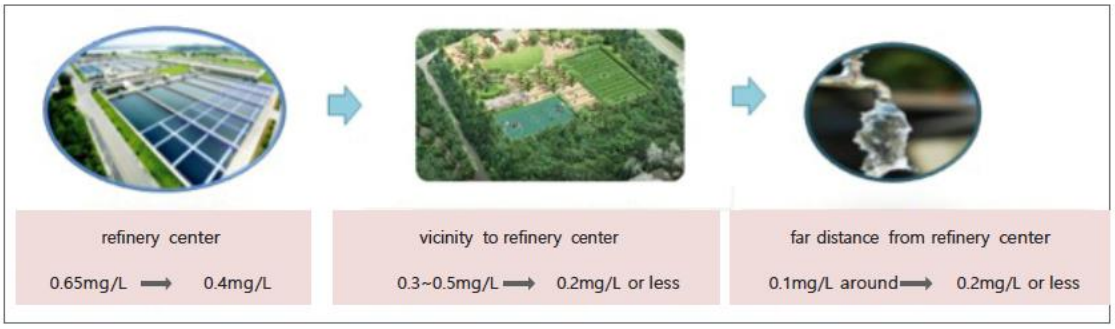
From Purification Center to Faucet

In the past, chlorine, one of the most influential factors on people drinking straight from the tap, was injected intensively at the purification centers. This resulted in complaints about the odor in the vicinity; there was also the issue of meeting the chlorine residue standards at faucet. To resolve these issues, injected chlorine was reduced at Gangbuk and Amsa Purification Centers, which supply to wider areas, and a system introduced to inject it at the distributing points (17 locations) from 2012. The plan is to introduce the system in phases and maintain 0.1~0.3mg/L at the faucet.

The pipes in use are deteriorating and range from cast iron to galvanized steel to non-corrosive materials. They frequently leak and develop rust inside. The long use of uncoated cast iron and steel pipes has left the inside of the pipes covered in rust, interrupting flow and reducing chlorine concentration. In April 1994, galvanized steel pipe was no longer permitted for waterworks. The City of Seoul plans to replace all pipes with a corrosion-resistant network by 2018.

Rooftop water tanks at apartments are a byproduct of the time-restricted water supply system of the past due to poor infrastructure. Because tap water was supplied only at certain hours, most of the water for domestic use was pumped, not directly, but from the underground tank to the rooftop tank. The water would stay in the tank for a prolonged period of time, resulting in the loss of chlorine residue. This could lead to degradation of water quality, including unhygienic storage. The city decided to take the direct supply approach without going through the water tanks. This increased the amount of chlorine residue (0.18mg/L) at the faucet, enhancing the quality and safety of the tap water.

<Figure 2> Reducing Disinfectant Odor(Chlorine)



Water Quality Management at Distribution/Supply Level

Several inspection and management methods are adopted at distribution level to ensure that the quality and safety of the water produced at the purification centers is maintained when it is delivered to users. These include statutory inspections, inspections at each distribution and supply process, Arisu Quality Certification, and other such tests that involve resident participation. The city takes various measures to enhance satisfaction and reliability, and to encourage more to drink the tap water.

<Table 3> Water Quality Management at Distribution/Supply Level

	Target	Total Inspection Parameters	Inspection Agency	Inspection Frequency
Faucets	450 points (419 statutory + basic inspection points)	6 (4 according to guidelines, 2 independent)	WRI	Monthly
Deteriorating Pipes	20 points	13	WRI	Monthly
Distribution & Supply Process	120 points (8 purification centers, 26 before and 26 after going through the distribution reservoir, 26 feeding points into the supply, 8 pumping stations, 26 pipe-ends)	11	WRI	Quarterly
Arisu Quality Certification	300,000 households	12 (5 Phase 1, 7 Phase 2)	Office of Waterworks	Constantly

	Target	Total Inspection Parameters	Inspection Agency	Inspection Frequency
Pumping Stations, Distribution Reservoirs	113 points (104 distribution reservoirs, 9 manned pumping stations)	Chlorine residual	Office of Waterworks	Daily
	Automatic water quality measurements at 188 points	Turbidity, pH, chlorine residual, temperature, conductivity	Office of Waterworks	Real-time (Disclosed on SWN)
Distribution Reservoirs	104 points	12	Office of Waterworks	Quarterly
Before Release (After Construction)	Distribution reservoir, pumping station, water pipe	4 (2 pipe repair works)	Office of Waterworks	Constantly
Water Pipes & Tanks	1,079 points (water pipes)	7	Office of Waterworks	Yearly
	12,089 points (tanks)	6	Private drinking water quality inspection body	Yearly

	Target	Total Inspection Parameters	Inspection Agency	Inspection Frequency
Arisu Drinking Fountains	2,674 points (30,807 fountains)	5	Office of Waterworks	Monthly: metro/subway
				Quarterly: schools, government office buildings
Monitoring Parameters	25 locations (1 per *gu*-district)	163 (59 statutory + 104 monitoring)	WRI	Yearly (September)
Chlorine Residual Monitoring	By water system of the purification center, at 90 faucets (2013)	Chlorine residue	Office of Waterworks	Weekly
Source: Internal data, Seoul Metropolitan Government				

Multi-check Quality Inspection for Major Particles: Trace Particles & Algae Alert System

Trace Particles

In addition to the 163 parameters, Seoul set 130 parameters for other items (6 more added in 2014), mostly comprised of endocrine disruptors, unregulated chemicals, agricultural pesticide, and carcinogenic substances, to identify any new trace particles in the annual inspection.

Algae Alert System

To reduce the source of odor in tap water, an algae alert system is activated when blue-green algae is identified at the water source, after which the water can be treated accordingly. In 2012, the algae alert was activated for a total of 15 days at Upstream Point 1 of Jamsil Reservoir. From 2000 to date, 6 algae warnings have been issued at Han River segments in Seoul. The effects of green algae include odor, water toxicity, and damage to water purification devices, etc. Along with the algae alert system at Jamsil, Seoul introduced an odor alert system for odor-generating substances – geosmin and 2-MIB – in 2012. The city has been able to respond proactively to such substances, thereby effectively reducing odor before the water reaches the tap. When an alert is issued due to significant amounts of algae and odor-generating substances, water inspections increase in frequency from weekly to daily, accompanied by various purification measures (injecting powdered activated carbon, stopping the injection of chlorine before the intake points and injecting it after PAC treatment at the purification centers), in order to minimize odor before the tap water goes into the supply pipes.

<Table 4> Algae Alert System (Issued after 2 Parameters are Breached Twice Consecutively)

	Algae Warning	Algae Alert	Serious Algae Alert
Chlorophyll-a Concentration (mg/m3)	15 or above	25 or above	100 or above
Blue-green Algae Cell Count (Cell/mL)	500 or above	5,000 or above	106 or above

<Table 5> Odor Alert (Reflects Purification Process Effectiveness)

Odor-Generating Substances	Odor Warning	Odor Alert	Serious Odor Alert
Geosmin (ng/L)	20	500	1,000
2-MIB (ng/L)	20	50	100
Source: Internal data, Seoul Metropolitan Government			

Multi-check Quality Inspection System: Arisu Quality Certification, Selection & Management of Water Quality Monitoring Parameters, Private-Public Monitoring, General Monitoring

Arisu Quality Certification

Seoul inspects tap water quality at production and supply level. At major points the inspection is conducted automatically, sending the results in real time to the Seoul Water-Now System and website for public disclosure. While the safety of tap water is thus proven, some citizens who drink from the tap are anxious about rust from old piping. Seoul therefore offers the Arisu Quality Certification service by visiting citizens at home where they can take part in the water quality inspection. This system helps them identify the problems and the service is provided until a solution is found. It has successfully earned the public's trust in the quality of tap water in Seoul.

Selection & Management of Industry-Best Water Quality Monitoring Parameters (104

Parameters)

The Ministry of Environment and relevant institutions work together to build a legal framework and institutional measures to ensure tap water quality and aid in management of purification, such as the Water Supply & Waterworks Installation Act. In addition to water quality inspections as required by this Act, Seoul adopted 104 of its own water quality monitoring parameters based on the relevant City of Seoul Ordinance, actively improving its activities based on the necessary legal and government systems.

Private-Public Water Quality Monitoring

Pursuant to Article 30 of the Water Supply & Waterworks Installation Act and the City of Seoul Ordinance, an advisory group – the Seoul Tap Water Assessment Committee consisting of external city councilors, professors, and environmental experts – is organized for monthly meetings. Samples are taken directly from 10 points – from intake points to the faucet of 2 purification centers – and sent to a private inspection body appointed by the Committee, where they are analyzed in accordance with the 59 statutory parameters, and the results disclosed on the Seoul Metropolitan Government and Committee websites to earn the public's trust.

Monitoring at Major Points

Chlorine residue level is checked daily at 113 distribution reservoirs and pumping stations. There are automatic measurement devices at 188 points to ensure adherence to 5 parameters, including turbidity and chlorine residue, in real time. The results are disclosed on the Seoul Water-Now (SWN) System.

Major Achievements

Supply of Healthy, Safe Water

Seoul's water quality inspection and management is a systematic process that covers start to finish, from water source to production to supply at the faucet. The city delivers tap water that is safe and healthy, and complies with WHO guidelines with the 163 parameters in water quality inspections as well as with the 130 parameters concerned with unregulated trace particles in annual inspections. The city is aware that odor is the biggest reason people avoid drinking from the tap and has therefore adopted algae and odor alerts that are activated upon detection of odor-generating substances or algae at the water source, a preemptive action that has helped the city detect and remove such substances. To reduce chlorine and disinfectant odor, Seoul injects chlorine at the distribution reservoir, limiting it to the guideline range of 0.1 – 0.3mg/L. When more advanced water purification facilities are completed and adopted by all 6 purification centers in Seoul by 2015, the city will be able to drastically reduce odor and taste-generating substances in the tap water.

Implications & Applicability in Developing Countries

Seoul endeavors to maintain safety of raw water at its source at Paldang Reservoir and constantly monitors for contaminants at intake points. Raw water is analyzed by the purification centers in accordance with various parameters as stringent as WHO guidelines. Seoul's odor alert, the first in South Korea to respond proactively to increases in algae, as well as at-faucet inspections known as the Arisu Quality Certification, distributed chlorine injection, and monitoring and analysis of trace particles are all part of the multi-check approach adopted by the city to supply safe, healthy tap water to its residents. Each year, research topics are selected and studied by each purification center, and the outcome presented in workshops where the issues and improvements are examined to which other cities and developing countries can refer.

Q&A

- Why take a multi-check approach to producing tap water?

Paldang Reservoir, Seoul's water source, is not algae- or contaminant-free, making it necessary to conduct statutory inspections and monitor water quality across the whole process, from source and intake points to purification centers and distribution and supply points, so as to ensure safety of the tap water supplied to some 10 million people.

- How were the quality standards developed for Arisu?

In South Korea, the drinking water standards govern the amount of microbes, harmful inorganic and organic substances, disinfectants and disinfectant byproducts allowed, as well as other substances for aesthetic considerations. The parameters are usually determined by the amount that would not be detrimental to health for an ordinary person drinking 2L of water daily for 70 years, with the additional consideration of a safety factor of 1/100 - 1/1,000. This means that drinking water that meets the standards will not be detrimental to human health.

- How are the water quality monitoring parameters selected and what is their basis?

Pursuant to Article 26.3 of the Water Supply & Waterworks Installation Act, tap water quality inspections are reinforced by selecting specific parameters on such contaminants as: i) trace particles that are harmful and highly likely to be detected in annual inspections or the city's inspections; ii) those that have become the subject of social controversy and need to be tested; and iii) those that have caused problems in the international community and may be found in South Korea as well. The inspection standards, methods, etc. are in compliance with WHO regulations and examples from other countries (30 parameters selected by the Ministry of Environment and 104 parameters by the City of Seoul [including the monitoring parameters from the Ministry of Environment]).

- How were the Healthy, Taste-Free Water Guidelines developed?

Since May 2010, various activities have been undertaken such as studies by research institutes, tasting events, public polls, public hearings, and expert advisory meetings, etc. The Guidelines were developed and completed in December 2010.

<Table 6> Healthy, Taste-Free Water Guidelines

	Substance/Measurement	Unit	Drinking Water Standard	Guidelines	Why Selected
Health	Minerals (Ca,Mg,Na,K)	mg/L	-	20 - 100	. Vital for human health
	Total Organic Carbon	mg/L	5.0 (Seoul's monitoring parameters)	1.0 or lower	. Disinfectant byproducts removed to protect health
	Turbidity	NTU	0.5	0.3 or lower	. Microbes (protozoa, viruses, etc.) removed to protect health
Taste	Chlorine Residue	mg/L	4.0	0.1 - 0.3	. Disinfectant odor
	2-MIB	ng/L	20 (Ministry of Environment's monitoring parameters)	8.0 or lower	. Generates moldy odor
	Geosmin	ng/L	20 (Ministry of Environment's	8.0 or lower	. Generates dusty odor

	Substance/Measurement	Unit	Drinking Water Standard	Guidelines	Why Selected
			monitoring parameters)		
	Copper	mg/L	1.0	0.05 or lower	. Gives a bluish tinge to water
	Iron	mg/L	0.3	0.05 or lower	. Gives a reddish tinge to water and gives off metallic odor
	Temperature	℃	-	4 - 15	. Fresh, crisp drinking temperature

References

The Office of Waterworks, Seoul Metropolitan Government, http://arisu.seoul.go.kr/

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Ministry of Environment, 2008, The 100-Year History of Waterworks in Korea.