# A Study on water shut off period and countermeasure for effective water supply maintenance

By

**LEE, Seung-Ho**

**CAPSTONE PROJECT**

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

**MASTER OF PUBLIC MANAGEMENT**

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Approval as of May, 2022

## Executive Summary

Since the 1960s, Korea's water supply has been rapidly expanded through state-led facility investment along with economic development, with 99.4% of the people receiving water supply services as of 2020. Korea's water supply has reached the world's highest level in terms of facility capacity and supply rate, but as of 2020, 34.8% of Korea's buried water pipes have passed more than 20 years and their performance is rapidly decreasing.

In 2019, 630,000 citizens were damaged by the supply of discolored tap water for up to 67 days due to inappropriate work procedures, and waterworks business operators suffered more than KRW 6.6 billion in financial losses due to compensation for citizens' damage. It is time to pay attention to maintenance to preserve stable functions so that this situation does not occur again, and the Ministry of Environment recently enacted ‘Detailed Standards for Maintenance of Waterworks Network Facilities’ to require water supply businesses to conduct regular water pipe cleaning. However, like other maintenance tasks such as emergency construction and altering waterworks system, cleaning of water pipes will cause shut off of tap water supply unless it is under special conditions such as double track supply.

Accordingly, measures to improve the efficiency of maintenance work and reduce citizens' inconvenience were investigated through interviews with experts in consideration of loss, such as civil inconvenience, and benefits from regular maintenance of water facilities. Based on the experience of experts, the results of analyzing the optimal time and interval for maintenance work to the level of dissatisfaction of citizens according to water shut-off and finding out promotional and support measures to minimize dissatisfaction in the event of water shut off are as follows.

If there is sufficient prior notification of water shut off, citizens should not sensitively complain of discomfort until the water shut off duration of 12 hours and should perform it during late night time (23:00-05:00) when water consumption is low. In addition, detailed work schedules for each time period should be established in consideration of citizen inconvenience such as noise from excavation work at night, and maintenance work needs to be carefully planned at intervals of at least one month to prevent citizen inconvenience caused by repeated water shut-off. As a way to minimize inconvenience to citizens in the event of water shut-off, it is most important to notify citizens in advance, and it is desirable to notify them about a week in advance by various ways, such as sending individual SMS and posting banners. On the other hand, frequent guidance should not cause inconvenience to citizens due to the burden of fatigue. In addition, it was suggested that if water shut-off is to be carried out for a long time, a plan to support bottled water and water-tank trucks to be provided to the victims should also be set up.

# Table of Contents

1. **Introduction** ..... 1

2. **Literature review** ..... 4

*2.1. Increasing the demand for water quality improvement from citizens* ..... *4*

*2.2. Maintenance-related regulations and research data such as pipe cleaning* ..... *5*

*2.3. A case of research on the benefits and inconvenience costs of maintenance work* ..... *9*

3. **Research questions and method** ..... 13

*3.1. Research topic* ..... *13*

*3.2. Research method* ..... *13*

4. **Research results** ..... 15

*4.1. Maintenance working hours and optimal water shut-off period* ..... *15*

*4.1.1 Water shut-off duration experience* ..... *15*

*4.1.2 Water shut-off duration that citizens can endure* ..... *16*

*4.1.3 Time interval between water shut-off operations* ..... *16*

*4.1.4 Time suitable for performing water shut-off operations* ..... *16*

*4.2. Measures to minimize inconvenience to citizens* ..... *18*

*4.2.1 The most effective medium and duration of guidance among water shut-off notice methods* .... *18*

*4.2.2 Effective measure of reducing civil inconvenience among planned water shut-off* .... *19*

5. **Policy or Administrative Recommendations** ..... 21

6. **Conclusion** ..... 24

**Bibliography** ..... 26

## List of Tables

Table 1 Pipe cleaning article in 'Detailed Standards for Maintenance of Water Supply Network Facilities' ... 5

Table 2 Cleaning methods introduced through 'Standard Specifications for Waterworks'..... 6

Table 3 Interview target experts..... 14

Table 4 Punishment articles in 'Special Act on the Safety Control and Maintenance of Facilities'..... 21

## 1. Introduction

From the afternoon of May 30, 2019, reports of colored water coming out instead of tap water were received in some areas of I city. The colored water incident occurred in the process of altering waterworks system to supply tap water without water shut-off when conducting a legal inspection of electric facilities in the area. According to the analysis results of the investigation team after the accident, the direct cause was excessive waterworks system conversion. It is usually supplied in a natural flow method, but when the water system was switched at the time of the accident, it was pressurized and supplied in the opposite direction. In the case of reverse waterworks system alternation, the flow rate shall be gradually increased unless the impurity is generated in good condition with sufficient time, considering the effect of pipe vibration, water shock load, etc., but the flow rate was doubled and supplied deposits on pipe lining to citizens at that time. In addition, when the water purification plant was restarted after 5 hours, tap water was supplied in the existing supply direction, and water mixed with suspended impurities in the pipeline was supplied to the end of the water pipe network.

As described in the announcement by the Ministry of Environment, the direct cause may be inappropriate waterworks system alternation, but another causes that cannot be overlooked is impurities in pipes accumulated over a long period of time. The main cause of contamination in the process of supplying tap water is particles generated during the water treatment process or sedimentation in the pipe network. Soluble or particulate materials present in a small amount in raw water treated below Standards for drinking Water Quality flow into the raw water and adhere to pipe's lining for a long time. New particulate materials are also generated in water purification facilities such as mixed aggregation, corrosion inhibitors (calcium, etc.), back washing (sand, etc.), and disinfection processes (manganese dioxide formation). During

construction or maintenance (boring, etc.), impurities may enter from the outside, or paint or scale particles peeled from lining may be contaminated due to aging pipeline. The inflow or newly generated particles into the pipe are precipitated and accumulated along the pipeline, and some of them repeatedly move precipitation (agglomeration) and flotation according to hydraulic fluctuations, causing various colors such as orange, red, and black (Ministry of Environment, 2020). In other words, pollutants occur in the process of producing tap water, such as water treatment, and in the process of moving through the water pipeline, so it is impossible to fundamentally block them and inevitably occur over time. Therefore, measures are needed to remove stagnant water in water quality vulnerable areas where various substances are floating and deposited due to stagnation of tap water in drainage and water pipes such as end of pipelines, highlands, and low-flow velocity areas, and bacteria are likely to reproduce due to reduced residual chlorine.

The water supply in Korea began in 1908 when the Ttukdo water purification plant was built and supplied 12,500m3 of tap water per a day in the central part of Seoul. The period when water supply was installed in earnest at the current level has been rapidly distributed since the 1960s due to quantitative expansion through state-led facility investment along with economic development. Since the 1990s, qualitative maturity has continued, such as the introduction of advanced water treatment, and recently, water supply has been expanded to rural areas, with 99.4% of the people receiving water supply services as of 2020. Korea's water supply has reached the world's highest level in terms of facility capacity and water supply rate, but Korea's water supply facilities, which have a history of 100 years, are rapidly aging with time (Ministry of Environment, 2016). As of 2020, 34.8% (79,461km) of 228,323km of water pipes nationwide are old facilities that have passed more than 20 years, and it is time to pay attention to maintenance to maintain stable functions.

Measures to prevent inconvenience to citizens due to the occurrence and transport of impurities in old pipeline described through I city cases include structural reinforcement measures such as replacement, repair, and rehabilitation, and temporary measures to solve aesthetic water quality problems such as pipe cleaning. Structural reinforcement involves a large budget and takes a long time from plan to work, so many local governments manage old pipelines through regular pipe cleaning. Flushing (one of the cleaning methods) of water pipes in Korea has been used in earnest since 2009, and new methods such as the Air Scouring method using compressed air injection have been applied on a trial basis since 2015 to improve cleaning effects and efficiency. In addition, in 2017, the Ministry of Environment enacted the ‘Detailed Standards for Maintenance of Waterworks Network Facilities’ to ensure that waterworks business operators perform regular pipe cleaning. However, pipe cleaning work, like other maintenance work such as emergency work and waterworks system alternation, causes water shut-off unless it is under special conditions such as double track supply. Therefore, I seek ways to improve the efficiency of maintenance work and reduce citizens' inconvenience in consideration of losses such as citizens' inconvenience due to water shut-off and benefits from regular maintenance of water facilities.

## 2. Literature review

### *2.1. Increasing the demand for water quality improvement from citizens*

In 2021, the Ministry of Environment announced the results of the 2021 Tap Water Drinking Survey conducted for the first time under the revised ‘Water Supply and Waterworks Installation Act’ on October 27, 2021. According to the results of the ‘Tap Water Drinking Survey’ of 72,460 households in 161 cities and counties nationwide, 71.1% said yes, 25.4% said neutral and 3.5% said no to the need to systematically strengthen water pipe management. In the previous ‘2017 Tap Water Drinking Survey’, 41.7% of respondents did not drink tap water, followed by "because there would be a problem with water tanks or old water pipes," 22.7% "because of smell and impurities," and 3.9% "because of negative media reports." In 2013, the Tap Water Satisfaction Survey conducted by the Ministry of Environment, the Korea Water Resources Corporation, and the Seoul Metropolitan Government on 15,000 adults aged 20 or older showed 30.8% of the reasons for not drinking tap water said "there would be a problem with the water tank or old water pipe.", 28.1% said "because raw water would not be clean" and 24% said "because of impurities and odors."

Over the years, many local governments have spent a lot of money on tap water production and facility maintenance, but citizens' distrust in tap water quality has not disappeared. Tap water experts said, "At least Seoul's tap water quality and management are second to none in the world, but old water pipes may be a problem," and some experts pointed out, "We need to make more efforts to improve old water pipes." This means that the cleanliness of water facilities such as water pipes and water tanks for supplying clean tap water is becoming more important. Through technical diagnosis, pipe cleaning implementation plans,

target revenue water ratio and achievement plans were established, and discharge water treatment was planned and implemented as a pipe cleaning implementation plan, including provisions that operation and maintenance plans such as inspection maintenance and information management plans. In addition, it was stipulated that waterworks system alternation was implemented by water utilities to establish a plan and report it to the head of the Basin Environment Agency if necessary.

### *2.2. Maintenance-related regulations and research data such as pipe cleaning*

Among the efforts to resolve distrust in the cleanliness of water pipes and reservoirs that citizens are concerned about in the 'Tap Water Drinking Survey' and the 'Tap Water Satisfaction Survey', the most direct and reliable way is to clean the reservoir and pipe cleaning. This is why the Ministry of Environment included the pipe cleaning mandatory clause in the 'Detailed Standards for Maintenance of Water Supply Network Facilities'.

< Table 1. Pipe cleaning article in 'Detailed Standards for Maintenance of Water Supply Network Facilities' >

| |
|---|
| Article 5 (Pipe cleaning implementation) (1) When waterworks business operators implement pipe cleaning, they should check and analyze the internal condition of the pipe by endoscopy or specimen collection, etc., and apply a method to minimize the generation of discharged water generated during pipe cleaning.<br>(2) The cleaning section should be divided into blocks or water supply areas and a plan should be established so that it can be implemented step by step.<br>(3) In order to prevent civil complaints and minimize inconvenience to residents during pipe cleaning, it is necessary to promote and notify the residents of the jurisdiction about water supply and impurities discharge in advance. |

(4) Pipe cleaning is terminated if the criteria for turbidity (0.5 NTU or less) and residual chlorine (0.1 mg/L or more and 4.0 mg/L or less) are satisfied when the cleaning part is conveyed.

(5) Cleaning results, discharge water treatment methods, and results, such as pipe cleaning method, quantity required, pipe condition before and after cleaning, and step-by-step water quality measurement, should be recorded and managed.

(6) The amount of discharged water is measured using a portable flow meter, etc. or a block flow meter, and a management ledger according to attached Sheet No. 1 is prepared, recorded, and managed.

In 2012, the Ministry of Environment newly established detailed provisions such as water tank installation standards, water tank hygiene inspection standards, water tank cleaning personnel and equipment standards, and administrative disposition standards for water tank cleaners and published the 'Tank cleaning (disinfection) manual'. On the other hand, the detailed standards for pipe cleaning were introduced through the 'Standard Specification for Waterworks' in 2017 and the application method of each construction method, but it is not yet as sophisticated as the water tank cleaning. There is a total of four cleaning methods introduced through the Standard Specifications for Waterworks.

< Table 2. Cleaning methods introduced through 'Standard Specifications for Waterworks' >

| | |
|---|---|
| Flushing | There is conventional cleaning by opening one or more fire hydrants to simply clean them, unidirectional flushing to properly adjust valves and separate specific pipeline sections to allow water to flow in one direction, and continuous discharge to flow low flow rates in many tubular areas or in small water supply systems. |

| | |
|---|---|
| Air Scouring | It is a cleaning method that injects compressed air into running tap water inside a water pipe at regular intervals to generate 'water slug' and removes deposits or biological films weakly attached inside and discharges them to the outside. |
| Swabbing Pig | It is a method of cleaning by removing various impurities deposited on the pipe's lining without damage to the pipe's lining and slime and biological films formed on the inner surface using a swap pig with low hardness, good elasticity, and excellent adhesion in the pipe. The method of launching the pig by water pressure and recovering it again. |
| Ice Pigging | It is a pipeline cleaning method in which tap water is frozen to be prepared in the form of a slush, and it is pressed and pumped into the pipeline to remove sediment, slime, or biological film inside the pipe. Ice slurries, which act as pigs, quickly pass through bent pipes or joints of different diameters without clogging to remove impurities. |

In addition to the flushing method, which was originally widely used, new methods were introduced, and studies comparing the cleaning effects of each method were conducted. Bae C. et al. (2015) compared air scouring cleaning and swabbing pig cleaning. Air scouring cleaning is a technique in which when compressed air is intermittently injected into a pipeline, the volume thereof is temporarily expanded while being mixed with water, and precipitates and adhesive impurities weakly attached to the pipe's lining are discharged to wash the pipe. An air scouring device referring to the air injection device guidelines proposed by Ellison et al. (2003) was manufactured and used for field application evaluation, and an experiment was conducted by injecting appropriate compressed air for each diameter of the pipes. In the comparison target swabbing pig cleaning, a launcher injected with pigs into the target section and a receiver

discharged are installed in a check port or fire hydrant on the drain pipe in advance, a pig made of polyurethane is inserted into the pipeline through the launcher, and then a gate valve immediately before the launcher is opened. As a result of the cleaning, pig cleaning had a greater cleaning effect than air injection cleaning, but unlike swabbing pig cleaning, air scouring cleaning can be cleaned regardless of constraints such as changes in diameters and valves, so it is expected to be useful for water pipe network cleaning in the future.

Seo J. et al. (2011) conducted an experiment to compare the effects of unidirectional flushing and air scouring cleaning. The cleaning effects of each cleaning method according to water pressure, diameter, and burial period were compared and analyzed using cases in S city 1,040 flushing and 277 air scouring in washing data before, middle, and post-cleaning water quality measurement data and pipeline status data. Based on the results of measuring the water quality of flushing and air injection washing performed on 42 pipes with similar conditions such as pipeline length, diameter, buried year, and water pressure, the cleaning effect was compared and analyzed by analyzing the water flow. Both methods are carried out using underground fire hydrants or drain valves, and the air inlet is carried out by installing a 20 mm saddle joint in the pipe in gate valve manhole and injecting compressed air using an air injection device (air compressor). As a result of comparing and analyzing the cleaning effect by applying correction factors for the length of the pipe to be tested, flushing and air scouring cleaning in the forward direction through field experiments can improve the removal effect of turbid substances through air injection. In particular, in the case of air scouring cleaning, it was observed that reverse cleaning is more effective in removing turbid substances and reducing iron concentration during forward and reverse cleaning, and statistically verified that it is necessary to actively use it when reverse cleaning and air injection are possible in field conditions.

However, if you look at how actively pipe cleaning is performed, it is greatly compared to water tank cleaning. According to a study commissioned by the Ministry of Environment to the Korea Water and Sewerage Association in 2008, the number of facilities is subject to water tank cleaning nationwide was about 51,000, with 97.5%, and 4,081 water tank cleaning companies in operation. On the other hand, pipe cleaning is a level in which flushing is performed on some of the end of pipeline in the event of a civil complaint, and as of 2018, it was investigated that about 1.0% of all pipes were cleaned or improved.(Ministry of Environment, 2020) Unlike water tank cleaning, which requires fines for violating cleaning obligations due to local government ordinances, the implementation rate of pipe cleaning is low because there was no separate obligation for pipe cleaning and improvement before the revision of the Water Supply and Waterworks Installation Act.

### *2.3. A case of research on the benefits and inconvenience costs of maintenance work*

In order to compare the benefits of maintenance work for water quality management with the water shut-off inconvenience of citizens, studies conducted in the past were investigated on the benefits of water quality management.

Chae S. & Kang K. (2011) derived the economic value of avoiding water shut-off situations. In addition to the use value for the economic benefits of the wide-area waterworks construction project, the economic value of avoiding water shut-off situations was derived using the conditional value measurement method to measure the non-use value caused by resolving the water shut-off situation. The survey targets 803 households using tap water from local governments in southern Gyeonggi Province, which benefited from the wide-area

waterworks construction project. As a result of the survey, only about 10.46% of the total samples had water shut-off experience, so it was not significant at the 5% level, but it was estimated that the willingness to pay would be high if there was water shut-off experience. According to the economic analysis results, consumers' payments per ton of water to avoid water shut-off situations were about KRW 175.4/m3, an increase of about 23-34% from existing water rates.

Kwak S. et al. (2012) applied the conditional value measurement method to derive the willingness of respondents to improve tap water quality in Ulsan. A household survey was conducted on 400 households in Ulsan Metropolitan City, and through one-on-one individual interviews, the willingness to pay for the tap water quality improvement program was asked. As a result of the study, it was found that the willingness to pay was significantly affected by household characteristic variables such as education level and income level, and each household had an average monthly willingness to pay KRW 1,611.

Pyo H. et al. (2011) estimated the willingness to pay for the improvement of domestic water quality in Busan using the conditional value measurement method using the nonparametric estimation method. In this study, 665 samples were selected through the individual interview method using the random sampling method, and as a result of the analysis, the average monthly willingness to pay per household in Busan was estimated to be KRW 3,190 to KRW 3,331 as of 2009.

K-water (The Korea Water Resources Corporation) estimated the benefits of improving tap water quality in 2014 to solve side effects such as expanding water quality improvement projects and delaying investment due to a lack of practical experience in improving tap water

quality. The G water purification plant of the Hangang River water system with advanced water purification facilities and the G water purification plant of the Nakdonggang River water system under installation were selected, and the results of the introduction of advanced water purification facilities were estimated. The average monthly additional payment intention per household calculated by the avoidance cost technique was KRW 20,983 at the G water purification plant in the Hangang River water system and KRW 12,855 at the G water purification plant in the Nakdonggang River water system. Meanwhile, the conditional value measurement technique was KRW 5,905 and KRW 13,188, respectively, and the selective experimental technique was calculated as KRW 10,871 and KRW 19,382, respectively.

The results of the case review on the costs of water supply and water quality deterioration as well as the analysis of the willingness to pay according to the water supply maintenance benefits are as follows. The 2019 I City accident incurred a total of KRW 33.175 billion in compensation costs, including KRW 6.669 billion in compensation for citizens' damage and KRW 23.665 billion in exemption from water and sewage charges in the affected area. The details of compensation for damages include KRW 922 million in school drinking water compensation, KRW 1.063 billion in daycare center alternative meals, childcare fees, and filters, KRW 674 million in water tank cleaning, and KRW 282 million in water quality inspection materials (Tap Water Citizen Network, 2020). The inconvenience experienced by 630,000 households and 153 school students in 260,000 households in the tap water supply suspension area during the 67 days of normalization of supply cannot be compared to the amount of compensation, but it is clear that huge social costs were involved.

As another example, 160,000 households in the nearby area were not supplied with tap water for two to five days due to a water shut-off accident in G City, Gyeongsangbuk-do, in

May 2011. More than 170,000 citizens who suffered water shut-off damage filed a lawsuit against the water supply business. In 2013, the first trial court ruled that KRW 20,000 should be paid per victim, but in the final trial, the Supreme Court refused to accept the demands of the victims by reversing and returning them (Lim Y., 2018). However, for the large-scale water shut-off incident in C city, Chungcheongbuk-do in August 2015, C city, a waterworks business operator, cited a court ruling on compensation for the 2011 G City water shut-off accident and paid KRW 20,000 per victim as compensation. The total amount of compensation was around KRW 750 million for about 5,000 households (Namgung H., 2017).

In the case of a study on the amount of willingness to pay for improving tap water functions, such as avoiding water shut-off situations or improving water quality, the amount is between KRW 1,000 and KRW 20,000 per month. However, there was a large difference of about 20 times due to differences in research purposes, target areas, and survey timing. The water service provider's damage compensation fee was small in the number of cases paid and the scale of the number of victims and the duration of damage in each case varied, so no consistent pattern could be found.

## 3. Research questions and method

### *3.1. Research topic*

Citizens' stress on the shut-off of tap water supply due to water maintenance work, necessity of working-level perspective on water shut-off work, situation-specific (emergency recovery, pipe cleaning, waterworks system alternation, etc.), and effectiveness of each medium were reviewed to minimize citizen's dissatisfaction.

1) Maintenance work hours and optimal water shut-off period.

Q1. Water shut-off duration experience value (normal time required for each type of work)

Q2. Water shut-off time that citizens can endure (time elapsed due to the rapid increase in civil discomfort based on the level of civil complaints)

Q3. Time interval between water shut-off operations (weighted discomfort according to continuous operation intervals)

Q4. Time appropriate for performing water shut-off operations

2) How to minimize inconvenience to citizens.

Q5. The most effective medium and duration of guidance among water shut-off notification methods.

Q6. Effective method of reducing civil inconvenience among planned water shut-off.

### *3.2. Research method*

Interviews were conducted with quasi-manager-level public water service workers with experience in maintaining the waterworks in direct contact with citizens at the fields.

The interviewees were selected as five incumbent people with more than five years of experience in creating water shut-off events and listening to customers' voices directly while performing the task of maintaining the wait-and-see network of local waterworks. <Table. 3> The interview method was carried out by sending a questionnaire in writing (e-mail, etc.), granting a two-week answer period, because of COVID-19 pandemic in November 2020.

In addition, open descriptive answers were requested for qualitative analysis, considering that they were interviewees working at different waterworks sites and that they were not sufficient samples, and that specific quantitative analysis results could not be derived.

< Table 3. Interview target experts >

| Case | Work site | Field work experience | Total work experience |
|---|---|---|---|
| A | P city in Gyeonggi-do, N city in Jeollanam-do, etc. | 9 years | 24 years |
| B | S city, S city in Chungcheongnam-do, etc. | 8 years | 14 years |
| C | General manager of 5 waterworks in Gyeonggi-do | 5 years | 13 years |
| D | J city in Jeollabuk-do,<br>General manager of 23 waterworks nationwide. | 9 years | 12 years |
| E | T city in Gyeongsangnam-do,<br>D city in Gyeonggi-do, etc. | 10 years | 10 years |

## 4. Research results

### *4.1. Maintenance working hours and optimal water shut-off period*

#### *4.1.1. Water shut-off duration experience*

It is a common opinion that it depends on maintenance work, and in the case of pipe cleaning work, the interviewees are not the same as their experiences with pipe cleaning methods of different sizes and timing, but they generally had a little more than 4 hours, in the case of flushing and air scouring, which are pipe cleaning methods that are usually used in the field, However, there was a response that it took 14 hours when the cleaning method was applied while the cleaning section was completely emptied. It was judged that it took a long time to discharge all tap water in the pipe network and fill the empty pipe body again after direct pipe cleaning. Emergency recovery takes about 1 to 2 hours if the recovery site and waterworks facility is exposed in advance, and the waterworks system alternation usually takes less than 6 hours, but it tends to depend greatly on the time to secure the standard turbidity after work. Although the water shut-off time differs depending on the leak type, leak point, pipe materials, pipe diameter, buried environment, and recovery method, 227 cases were analyzed in 2018, and on average, small pipeline with a diameter of 50mm or less had 0.63 hours and 1.24 hours for pipeline recovery exceeding 50mm. They suggested that most of the waterworks system alternation for the purpose of building and operating the block system were about 6 hours. Therefore, it was possible to draw a conclusion that the singular time required for maintenance of the water pipe network was within 6 hours. It is important to note that this is a case of normal work, and it may take more time if abnormal situations occur during work or if a special construction method is applied.

*4.1.2. Water shut-off duration that citizens can endure*

This is the result of asking opinions from experts and hearing answers to find out the maintenance work plan time that entails appropriate water shut-off. The biggest factor that causes direct differences is the presence or absence of prior notice, although the area where water shut off occurs varies greatly depending on whether the area is urban or rural, or whether the time zone occurs is the commuting time of ordinary office workers. There was an opinion that the number of inconvenience reports surged immediately after the suspension of emergency water shut off due to water facility accidents that were not notified in advance, but if the notice was sufficient, the number of inconvenience reports would increase after about an hour from expected resuming time. Three out of five interviewees said they had the longest water shut off time of about 12 hours, and they had about three days of water shut off work experience, but they also had experience working without many inconvenience complaints with support for water shut off victims such as drainage to reservoir using tank trucks. It is concluded that even though the areas where the interviewees worked were different in urban and island areas with different populations, they do not complain of discomfort until 12 hours if sufficient prior notice is made.

*4.1.3. Time interval between water shut off operations*

When planning the maintenance work of the water supply network, water supply operators often focus on the work for a certain period of time. Moreover, in Korea, field work is often concentrated in a specific period due to the lack of field work such as early summer flood season, hot weather in summer, and cold weather in winter, but this is the result of asking experts' opinions on how much time interval they have between work in the same area. Most

experts said they had no experience in continuous work in the same section because they tried to complete the water shut off work on a one-time basis, and one expert said that if he did not complete the work during the week, he had experience in creating a water shut off situation at night. In addition, there was an opinion that although there was experience in performing water shut off work in the same section with a two-week time interval, it was desirable to set a time interval of more than three weeks to prepare promotional and support measures. Another expert said that in experience, there is an opinion that citizens' discomfort does not increase only when there is an interval of more than one month. Taken together, it was found that the continuous implementation of singular work should be avoided as much as possible in the same section, and if necessary, more than one month of interval should be placed to alleviate citizens' inconvenience.

#### *4.1.4. Time suitable for performing water shut off operations*

When asked about the appropriate time zone to perform maintenance work involving water shut off, all experts presented a common opinion. The opinion was that late-night hours from 23:00 to 05:00 the next day, which are the least used water during the day, and that it was reasonable to do noise-causing tasks such as breaking road pavement and digging to expose water pipes in the ground in advance during the daytime. In addition, in the case of water shut off work within 3 hours, there was an opinion that citizens would not feel much inconvenience due to water shut off from 14:00 to 17:30 during the daytime when water consumption is low in consideration of work efficiency.

The results of collecting the opinions of experts on the usual time required for water shut off work are as follows.

- Maintenance work involving water shut off generally takes 6 hours.
- Citizens do not complain of discomfort dramatically until 12 hours if there is sufficient prior notice of water shut off.
- It is recommended to avoid continuous water shut off operations within the same section and not cause single water within one month.
- It is recommended that the water shut off operation be performed during the late night period (23:00-05:00) when the amount of water used is preferably performed.

### *4.2. Measures to minimize inconvenience to citizens*

The common opinion of experts on various questions about water shut off time for maintenance work was that there should be sufficient prior notice. If so, I asked how much preparation period should be given before the event to make the pre-announcement effective. If it is guided too early, citizens' preparedness for water shut off may be insufficient or information may be forgotten due to sufficient preparation time, whereas if it is given too short, it is difficult for citizens to be prepared for water shut off, so we tried to find out the optimal pre-announcement and time interval between water shut off event. Considering the differences in the conditions of the area where experts worked and the quantitative imbalance of experience, it is the result of receiving a reply by requesting an open descriptive answer like an inquiry about water shut off time.

#### *4.2.1. The most effective medium and duration of guidance among water shut off notice methods*

Although not all experts agreed, the personal SMS transmission method and banner installation were effective, and the announcement effect was good mainly using two or more

complex media, not a single method. In addition, in the case of the SMS transmission method, there was an opinion that complaints of fatigue due to frequent notifications were received if the same content was sent several times. Most experts answered that the pre-announcement period is a week before the planned water shut off notice period specified in the "K-water Water Supply Operation Management Standard," and that attached promotional media such as banners were posted two weeks before water shut off event. In addition, in the case of sending information several times, it is an opinion that notifications were made at regular intervals from the first guide a week before water shut off. However, experts did not provide special opinions on the period specified in the criteria applied at the site, and the answer to the singular time can be measured by the intensity of complaints, but the effectiveness of the announcement is not an area that can be judged by the intensity of citizen's complaints.

*4.2.2. Effective measure of reducing civil inconvenience among planned water shut off*

Various answers were given due to various cases, such as the number of water shut off victims and water shut off period, but experts generally answered that it was the most effective to pay bottled water and support water-tank trucks. As for the support for bottled water, if it is not a business site or a large-scale customer, it is mainly supported with bottled water, and the amount of payment is about 1 to 2 boxes per request acceptance (350/500ml × 20 bottles, etc.). In addition, the main opinion reaffirmed the importance of prior notice by answering that sufficient prior notice and minimization of water shut off time are more important than support measures after water shut off. As a result of citizens asking how they mainly handled water shut off damage, they said that water shut off damage was mainly done in accordance with local government ordinances, and there were cases where they paid actual costs such as water filter replacement and apartment water tank cleaning same as I city case in 2019. However,

water rate reduction or compensation was applied to rare events where the damage was severe, and some experts answered that there were no actual compensation cases.

As a result of reviewing the contents of pre-announcement, water supply support, and damage compensation, which are measures to minimize civil inconvenience to water shut off phenomena involved in maintenance work.

- It is desirable to notify about a week in advance in complex ways such as sending SMS and posting banners for individuals, and be careful not to burden fatigue due to frequent guidance.
- If water shut off is to be carried out for a long time, a plan to support bottled water and water-tank trucks to be provided to the victims should be established together.

## 5. Policy or Administrative Recommendations

Through various media, citizens' expectations and demands for clean tap water were high, and experts with a lot of field experience were able to examine the level of inconvenience and efforts of citizens to reduce water supply operations. As a result, if sufficient prior notice is made, citizens do not feel much inconvenience in water shut off time due to normal maintenance. Therefore, the maintenance work for supplying clean tap water should not be neglected for fear of water shut off inconvenience to citizens.

Although belatedly, the ‘Detailed Standards for Maintenance of Water Supply Network’ was enacted in 2021 to establish detailed operation and maintenance plans, including annual implementation plans for water pipe cleaning. However, there is no punishment clause for non-fulfillment of maintenance work, so it is questionable for its ability to execute. Since the collapse of large facilities in the 1990s, Korea has enacted the ‘Special Act on the Safety Control and Maintenance of Facilities’ and has regularly managed regular safety inspections and performance evaluations. In addition, punishment regulations are prepared for violations to secure business bases such as registration of inspection agencies, and the maintenance of facilities is properly carried out.

< Table 4. Punishment articles in ‘Special Act on the Safety Control and Maintenance of Facilities’ >

Article 63 (Penalty Provisions) (1) Any of the following persons shall be punished by imprisonment with labor for not less than one year but not more than 10 years:

1. A person who endangers the public by conducting a safety inspection under Article 11 (1), a full safety examination under Article 12 (1) or (2), or an emergency safety inspection under Article 13 (1) or failing to conduct such inspection or examination in good faith, thus causing serious damage to an establishment; ...

Article 67 (Administrative Fines) (1) Any of the following persons shall be subject to an administrative fine not exceeding 20 million won:

1. A person who fails to conduct a full safety examination, in accordance with Article 12 (1) or (2); ...

(2) Any of the following persons shall be subject to an administrative fine not exceeding 10 million won:

1. A person who fails to conduct a safety inspection in accordance with Article 11 (1) (excluding where the head of a Si/Gun/Gu shall conduct an inspection in accordance with the proviso to Article 6 (1); ...

(3) Any of the following persons shall be subject to an administrative fine not exceeding five million won:

1. A person who fails to formulate an establishment management plan or fails to report or submit an establishment management plan in accordance with Article 6 (1), (4), or (5); ...

Water pipes are also subject to safety management under the above laws and are inspected for poor jointing, damage to pipes, deformation, and corrosion, but are limited to structural safety checks against facility damage. However, in the current generation, which requires sufficient quantitative expansion and qualitative improvement of water supply

facilities, it is necessary to consider ways to manage water safety under strong legal binding force, including safety inspections.

Waterworks business operators should thoroughly plan measures in advance to minimize the inconvenience of citizens' suspension of water supply in a single operation to supply clean water to citizens. The ‘Detailed Standards for Maintenance of Water Supply Network facilities’ say, "In order to prevent civil complaints and minimize inconvenience to residents, water supply and foreign substances should be promoted and notified in advance," but detailed information is insufficient. In addition, it is desirable to eliminate citizens' distrust of the suspension of tap water supply by making manuals and managing tap water emergency supply plans (payment methods, preparation by water size, etc.) and pre-announcement plan (type of information medium, pre-announcement period, etc.) that can be practiced by local governments in consideration of different service conditions.

In addition, if each local government conducts proper publicity to understand that regular water shut off phenomena occur to maintain clean tap water supply, it will be possible to remove a major obstacle to active water maintenance.

## 6. Conclusion

In addition to cases where many citizens had great difficulty using tap water due to inappropriate waterworks system alternation in the old water supply network, several surveys of citizens confirmed that citizens' demand for clean tap water is increasing. Since impurities inevitably occur during the water purification process and transfer process of tap water, regular water tank cleaning and pipe cleaning are required, and the Ministry of Environment has established detailed standards for water pipe network facility maintenance and inserted water tank cleaning and pipe cleaning obligations. However, specific procedures for maintenance work involving water shut off or details of measures to minimize water shut off damage are insufficient.

This study identified the optimal time and working interval of water supply maintenance work, such as pipe cleaning accompanied by water shut off, and sought pre-announcement measures and water supply support measures to minimize inconvenience in the event of water shut off. As a result of the interview, experts say that citizens would not complain of discomfort until 12 hours and should perform it during late-night hours (23:00-05:00) when water consumption is low if there is sufficient prior guidance on water shut off. In addition to water shut off, detailed work schedules for each time period should be established in consideration of citizens' inconvenience, such as noise from excavation work, and maintenance work needs to be carefully planned at intervals of at least one month to prevent citizen inconvenience caused by repeated water shut off.

As for the question of minimizing inconvenience to citizens in the event of water shut off, the first thing to do is to inform citizens of the occurrence of water shut off in advance, and

it is desirable to promote it about a week ahead in complex ways such as sending individual SMS and posting banners. In addition, precautions were proposed not to cause inconvenience to citizens due to the burden of fatigue due to frequent guidance. In addition, it was confirmed the necessity of establishing a water-tank truck support plan and bottled water to be provided to the victims if the water supply is scheduled to proceed for a long time.

### *Limitation and Future research*

The study investigated time plans, pre-announcement plans, and supply support measures to minimize civil inconvenience in water maintenance work involving water shut off, but failed to obtain consistent answers because the interviewees' experienced workplaces were different. Still, a common opinion was also drawn that the importance of prior notice and that it is effective only by using complex media. And it was confirmed that citizens did not feel much inconvenience in water shut off time due to normal maintenance. In addition, it is expected to help establish an appropriate maintenance work plan by analyzing water shut off pre-announcement methods and measures to reduce inconvenience to residents in a short period of time that are not covered in detail in related regulations and guidelines. However, although it was chosen as an interview with water service operators as a way to estimate citizens' satisfaction, it may be a different opinion for citizens who directly experience water shut off. It is thought that more effective results can be derived if more surveys are conducted on the satisfaction of pre-announcement measures and support measures during the suspension of tap water supply for citizens who have experienced water shut off inconvenience. Based on the results of a study conducted on water supply operators, it is hoped that better water supply service standards will be established by reviewing measures to minimize inconvenience to citizens through follow-up studies of citizens with water shut off experience.

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