A study of optimal solutions to resolve water quality problem from a small creature(larvae)

By

YOON, Jaehyuk

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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Committee in charge:

Professor Lee, Junesoo, Supervisor

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Abstract

This paper aims to find solutions to resolve water quality problem caused by small creatures(larvae). In the past, water quality accidents have been followed up with issues such as leakage of pollutants, improvement of water treatment method, and resolution of aging pipelines. A sand filtration method was introduced to remove turbidity, and chlorine disinfection was started to remove the virus. Activated carbon and ozone methods were introduced to prevent disinfection by-products, and membrane filtration was introduced to remove trace substances. However, the larvae incidents that have occurred nationwide since July 2020 in Incheon are different from existing accidents in that they meet the current tap water treatment standards such as turbidity and CT values.

In order to carry out this capstone project, the current standards for preventing and responding to the occurrence of tap water larvae and domestic and foreign research papers were examined through the literature review. The recent Guidelines for the treatment of larvae released by The Ministry of Environment were also reviewed. In addition, the two larvae accidents, which had become a major issue, were intensively analyzed to figure out what problems they had and what methods should be promoted as short-term and mid- to long-term solutions.

In this task, each five politic and technical solutions were suggested through data analysis and expert interviews. Among them, the tasks to be solved first were selected through AHP analysis. As a priority, in the policy field, the establishment of long-term financial plans for improving the water quality sector and the improvement of disproportionate budget allocation were selected as priorities. Technically, a plan to optimize the operation of the facility was confirmed as a priority.

Currently, the number of events and improvement status are insufficient to carry out quantified pilot research projects, and further research is expected to quantify the related content and lead to more reliable visualized results.

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1.Introduction

1.1 Objective of this study

The discovery of tap water larvae in Incheon from July 9, 2020 caused continuous problems with tap water following the red water accidents in Incheon and Seoul in 2019. In particular, in the previous water quality accidents, follow-up promotion measures were introduced with the issue of solving the outflow of pollutants or the old pipelines. However, the fact that the larvae occurred at a time when the current tap water treatment standards such as turbidity and CT value were satisfied is different from the previous accidents. In response to the accident in 2019, the Ministry of Environment announced the "Comprehensive Measures for Water Supply Safety Management" to correct the problem. In addition, regarding the detection of tap water larvae in Incheon, which occurred in 2020, the "Comprehensive Measures for Hygiene Management of Waterworks" was announced to correct the problem. However, unlike the red water case, the problem of the occurrence of larvae is a problem that cannot be solved by focusing on the replacement of old pipes, so it is necessary to approach from a different point of view. Through this Capstone project, I would like to approach the problem of larvae in tap water from different perspective and suggest multiple solutions.

1.2 Background overview

Water quality accidents that occurred in Korea have continued to occur since 1908 when tap water was first supplied. Until the 1980s, there were many issues about the supply and quantity of tap water, but from the late 1980s, the issue of water quality became a major issue.

1) The first domestic water pollution accident became an issue since 1989 when it was announced that heavy metals exceeding the standard were detected in tap water. At that time, the Ministry of Construction inspected and announced the nation's water quality under the special order of the president, and iron, cadmium, and phenol exceeded the standard at 10 water purification plants. E. coli, general bacteria, and ammonia nitrogen also exceeded the standard in 9 out of 46 inspected.

2) At the end of June 1990, the Board of Audit and Inspection revealed that the content of

trihalomethane (THM) in tap water at eight of the nation's 17 water purification plants exceeded the allowable standard.

3) For about 8 hours from the evening of March 14, 1991 to the dawn of the 15th, 30 tons of phenol undiluted solution leaked from Doosan Electronics in Gumi City into Okgye river Stream, a tributary of the Nakdong River. It was a problem caused by a crack in the pipeline supplying phenol, a raw material. Contaminated water flowed into the water source that supplied tap water in Daegu City, and citizens who drank it suffered from vomiting, diarrhea and abdominal pain. In particular, the cause of the problem was that phenol worsened the situation by continuing to inject disinfectants without knowing that chlorophenol, which increases the odor a lot when combined with chlorine disinfectants, was produced. Doosan Electronics resumed production again on April 22, but a small amount of phenol was leaked again. At that time, the Minister of Environment and the Vice Minister were dismissed, and Doosan Electronics' loss amounted to 3 billion won.

4) In June 1993, a doctoral dissertation in microbiology at Seoul National University was reported in the media, sparking controversy over the stability of tap water in Seoul. The paper said that from September 1991 to September of the following year, a large number of bacteria exceeding the standard were detected in water quality tests at five branches of the Seoul Metropolitan Government's water supply system. The Ministry of Environment, which denied the possibility of bacterial contamination in tap water, greatly added the microbial standard to the drinking spring water quality standard in 1996.

5) On January 4, 1994, the tap water treated and supplied by Dalseong Inlet Plant in Gyeongsangbukdo began to stink, and later expanded to Masan and Busan in Gyeongsangnamdo. The ammonia nitrogen concentration at the Dalseong Water Purification Plant in Daegu reached 2.52 ppm, exceeding the standard of 0.5 ppm for drinking water. Benzene and toluene were detected at the water purification plants in Masan, Haman, Mulgeum and Dalseong on the 11th. The reason why this situation occurred in the entire mid-to-lower part of the Nakdonggang River was that the flow rate of the Nakdonggang River decreased during the drought season, resulting in a significant decrease in

the ability to clean up chemicals from the outside. The problem is that excessive chlorine was added to remove the odor from the water purification plant, and trichloramine, which was produced by the reaction of chlorine and ammonia, was produced, and the chlorine and benzene combined to produce benzene chloride, which also produces odor. At that time, the ability to inspect organic chemicals was insufficient, and the water purification plant worsened the situation due to the lack of facilities or expertise to filter them out.

6) In February 2012, the aluminum of tap water in Gimhae exceeded the standard. This happened because the sediment accumulated in the settling basin was not discharged in time. In addition, tap water that cannot be drunk due to its strong sour taste was supplied at the Yongyeon Water Purification Plant in Gwangju in May of the same year. The acidity dropped to 5.5 due to excessive injection of flocculants. In August of the same year, tap water odor occurred in Incheon and Gyeonggi-do due to the rise in the water temperature of the Paldang water source. In particular, geosmin levels soared and were resolved by rain.

7) In November 2017, the Ministry of Environment announced that microplastics were detected in Seoul and Incheon. In the same year, the Ministry of Environment explained that compared to 4.3 per liter, which is a foreign detection level, Korea has only 0.6 per liter, which is not high. It was known in June of the following year that perfluorinated compounds were detected in tap water in Busan and Daegu in December of the same year. As the contamination became known, residents in Daegu had difficulty drinking due to distrust in tap water.

8) The Incheon Red Tap Water Incident, which began on May 30, 2019, occurred when tap water was supplied from an alternative water purification plant due to the suspension of operation of the Gongchon water purification plant. Normally, if the forward flow rate was 1700 tons per hour, 3,500 tons per hour, which was more than twice as much, was supplied in the reverse direction. As a result, wastes attached to the pipe wall floated with sediments and were supplied to the water receiving area, causing lots of problems.

9) On June 21, 2019, ocher-colored pollutants occurred in tap water in the area of Munrae-

dong, Yeongdeungpogu, Seoul. This was caused by an old drainage pipe buried in 1973, 46 years after construction, and was resolved only after the replacement of old pipes.

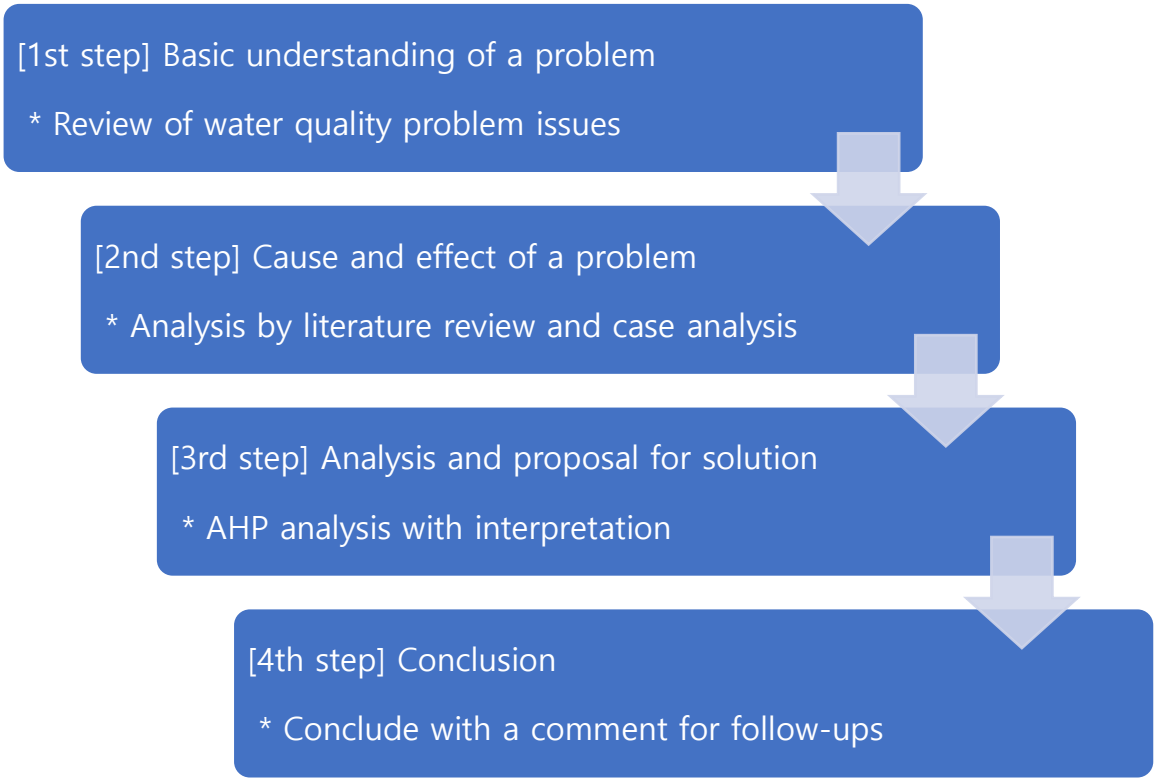
10) As discussed above, water quality problems in the past were often human made mistakes such as leakage of pollutants or failure to implement an appropriate disinfection process. However, the recent water quality problem has more environmental factors than the occurrence of direct pollutants. These include the aging of pipelines and the occurrence of algae due to high temperatures. However, in the case of larvae, there are a lot more diverse and complex factors than in the previous case.

2. Flow and methodology of study

2.1 Flow of study

In order to achieve the purpose of the study, the capstone research was prepared in the order shown in Figure 1.

Fig 1. Procedure of this study



2.2 Methodology of study

Three research methods were used to study the task. First, the analysis was made clear by utilizing logic tree, multi-dimensional matrix, and flow chart as the main analysis contents. We actively utilized LMF mainly for literature review and case-analysis.

Second, I calculated the priority of the contents derived from the capstone project using the AHP analysis method. The AHP analysis was divided into two parts: priority of politic solution and priority of technical solution, and the analysis was conducted separately according to the characteristics of the necessary tasks.

Third, professional opinions on the project were added through interviews with experts in the water supply sector. I got professional advice from experts who participated in the group work of actual larva accidents.

3. Literature review

3.1 "Prevention and Countermeasures for the occurrence of tap water larvae" (Ministry of Environment, 2021.8)

The following methods are proposed for each field to prevent the occurrence of larvae in tap water. The first is the installation and operation management of sanitation facilities. Install the tidal current barrier, water surface wave generator, sprayer at the intake source, and dredge sedimentary soil. Always inject the flocculant from the mixed flocculant and install a scum remover. Install an insect repellent room on the sedimentation basin, attach the wall and remove the lower sedimentation sludge, and install a fine filter net. Install double doors and air curtains at the entrance of the filter bed, and install fine screen and insect repellent. Maintain the effective diameter ratio of 1,000 or more, and back washing is carried out with water with residual chlorine as much as possible. Check for mud ball generation and pay attention to filter quality control. The activated carbon adsorption site is also equipped with a fine insect screen and checks whether it is evenly distributed during air washing. Clean and disinfect the reservoir at least once a year, and install micro strainers at the reservoir inlet

and outlet. Discharge water treatment facilities should be back-cleaned evenly for 24 hours and periodically inspected and cleaned. Reservoir should be cleaned twice a year in accordance with legal standards.

The second is the sanitary inspection section. Check the intake source for inflow of raw insects and attachment of foreign substances. Check for water puddles and prevent congestion. Check the air curtain and screen from the sedimentation area to the clean water reservoir. If necessary, install the micro screen at the inlet and outlet.

The third is the monitoring part. Check the raw water inlet once a week. Check the inflow of larvae from the filter bed outlet or the resin inlet every day.

3.2 "Guidelines on the Monitoring Method of Water Purification Plant Chironomid larvae" (Ministry of Environment, 2021.5)

This regulation stipulates matters concerning methods necessary for conducting monitoring to check the existence of rat larvae in water purification plants. The monitoring point is based on each inflow and outflow of water treatment. Make a filter net of 100 micrometers or less and check for larvae every day.

3.3 Manual for responding to 'water quality complaints' (Ministry of Environment, 2020.12)

It will be divided into "water quality abnormality" and "civil complaints from larvae problem". The larva civil complaint section presents the civil complaint management system and civil complaint response measures. In the event of a single complaint, a larval civil petition shall be actively responded to. If it is suspected that it is a factor caused by the tap water production system, the epidemiological investigation team shall be formed and investigated by expanding the situation. After that, a thorough epidemiological investigation will begin. Complaint response procedures include receiving complaints, field investigations, determining small organisms, self-investigating, determining the probability of inflow into the production system, terminating response, and reporting

accidents. The detailed investigation is conducted in the order of investigation of water supply and drainage pipes and water supply pipes, investigation of drainage water, and investigation of water purification and filter bed. First of all, a close examination of the acceptance price is conducted. After that, the detailed inspection of the supply system begins the detailed inspection of the production system. After that, water quality investigation, larva precision investigation, response and normalization, and response completion are carried out. The detailed investigation of the production system is conducted in more detail, consisting of drainage, wall investigation, surface layer precision investigation, core sampling investigation, and species identification.

3.4 Problem Organisms in Water: Identification and Treatment (AWWA, 2004)

In 1989 the organisms in water committee of the American Water Works Association (AWWA) conducted a survey to determine problems that water utilities encounter due to organisms in water. Midge larvae and other types of larvae were problematic, because it is the user who often find the problem. By increasing chlorination and filter backwash were marginally effective, but utilities found no “sure-fire” approaches to this challenge.

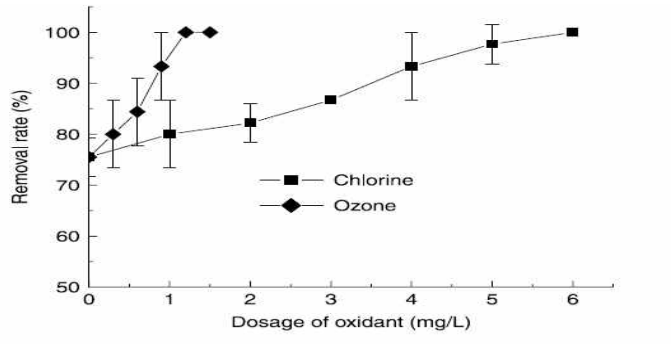
Since larvae are constantly moving perpetually, it has been reported that passing through filters such as filter bed is observed. And after increasing filter washing for every 8 hours, no larvae were observed.

3.5 Inactivation of chironomid larvae with ozone (water science & technology: water supply, Xing-bin sun and Fu-Yi Cui, 2008)

In this literature, removal efficiency of chironomid larvae was strengthened gradually with the increase of the dosage of oxidant regardless of the type of oxidant. Compared to that of the distilled water experiment, ozone inactivation efficiency is more effective. The chironomid larvae of the enemy are assumed in a different way. During the reaction at low doses, the inactivation rate of chironomid larvae was much lower than that. Although it occurs in distilled water experiments, the

gap in in inactivation efficiency gradually increased. It decreased as the ozone dose increased. And complete inactivation of chironomid larvae after 30minutes of contact time was achieved at higher dose of 2.0mg/l

Fig2. Removal effects of pre-oxidation combined with coagulation process on chironomid larvae in raw water (Xing-bin sun and Fu-Yi Cui, 2008)



3.6 Inactivation of Chironomid larvae from drinking water by ozone and its removal using ozone-GAC process. (Chemical industry and engineering v.57 no.3, SUN, Xingbin, 2006)

In the column experiment, 0.8 mg/L of post-ozone is injected and passed through the activated carbon filter bed. Through this process, the larvae were completely eliminated.

3.7 Water treatment manual: Filtration (USEPA, 2020)

In general, when groundwater is used as raw water, the back washing cycle is performed once for two to eight weeks, and when surface water is used as raw water, it is performed several times per week. Back washing shorter than the reproductive cycle of living things can be an effective control method.

3.8 Specialized and Advanced Water Treatment Processes (Twort's Water Supply: 7th Edition, 2017)

The frequency of reverse cleaning of activated carbon adsorption sites using groundwater as raw water is set to one time for two to eight weeks depending on the raw water quality. In the case of

using surface water as raw water, the back washing cycle is set once for 2~3 days so that low concentrations of bacteria are included in the filtered water. The growth of small organisms can be controlled by backwashing frequently shorter than the reproductive cycle of microorganisms.

3.9 Vertical distribution pattern of naidids in granular activated carbon filters and potential technology to control their penetration risk (Water science & Technology: Water Supply, Xiao-Bao Nie, 2018)

Small animals were not found when a 30cm sand filter layer was added under the GAC layer.

3.10 Removal efficiency of invertebrates in the filtrate of biologically activated carbon filter with sand bed (Journal of water supply, 2012)

When comparing activated carbon with activated carbon + sand (30 cm), rotor (40%) and copepod (80%) were removed, and the removal rate of large vertebrates increases as the depth of the sand layer increases.

4. Case analysis

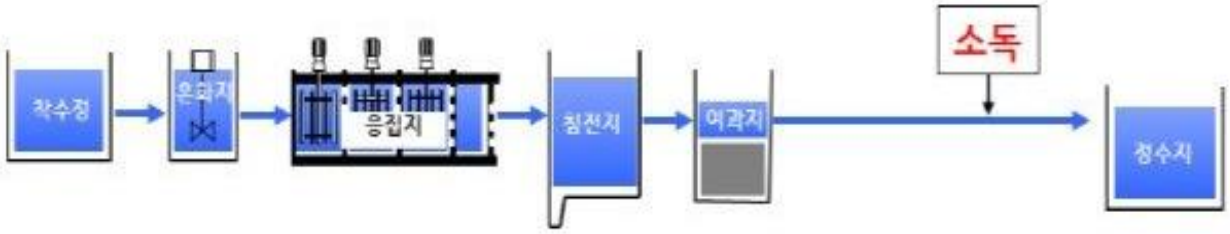
4.1. Larvae accident at K water treatment facility supply area

4.1.1 Circumstances of accident

<Supply system overview>

* Capacity of facility : 25,000m³/day
* Water treatment system: Rapid filtration
* Year of completion: 1987

Fig3. Water treatment procedure of K facility



Initially, it was recognized that larvae were reported in the shower filter at home, and a total of 77 complaints were reported as a result of the analysis of 107 complaints.

4.1.2 Causes of accident

The first reason is the occurrence of larvae due to external factors. Due to the increase in precipitation due to the rainy season and the influence of typhoons, non-point pollutants throughout the basin were brought into the river. Due to the excess of organic matter, a habitat environment was created in the water intake source. This can also be sufficiently examined in the detailed numerical data presented in the "Final Report on Epidemiological Investigation". The lack of pollution source blocking facilities in the water source protection zone and the fact that the appearance of larvae is higher than that of other rivers also played a role at the same time.

The second is the influx of larvae due to internal factors. The effective diameter to the length of the filter bed was below the standard, and functional problems of the facility were identified, such as uneven filter depth, lack of amount of back washing water, excessive back washing cycle, lack of back washing speed, and leakage of the lower collector.

The main content of the "Final Report of the Epidemiological Survey" is that the above two problems were combined to cause the inflow of larvae from the water intake source to the water treatment facility and lead to the discovery of larvae at the faucet.

4.1.3 Progress of accident response

First of all, for emergency response, the operation of the water purification plant facility was completely suspended and the entire volume was converted to an external water system. Since the K region has small-scale groundwater as a source of water and external wide-area sources were limited, emergency facilities were repaired to convert the entire supply chain to the water system conversion was possible.

After that, the facility was urgently improved, such as complete replacement of filter media,

replacement of auxiliary facilities to increase cohesion efficiency, installation of insect screen to block inflow of small organisms, painting, waterproofing and cleaning, installation of precision filter on supply network, dredging of soil and retaining walls.

4.1.4 Damage

Quantitative figures show that 1,430 tons (KRW 2 million) of water supply support, about 100,000 tons (KRW 107 million) of wastewater cleaning and drainage, and KRW 469 million of water supply reduction, resulting in a loss of KRW 578 million.

Qualitatively, 107 complaints caused administrative response works, and the group work by the Ministry of Environment, Jejudo Island, and K-water experts until normalization took 4 months. And it was worse than quantitative damage.

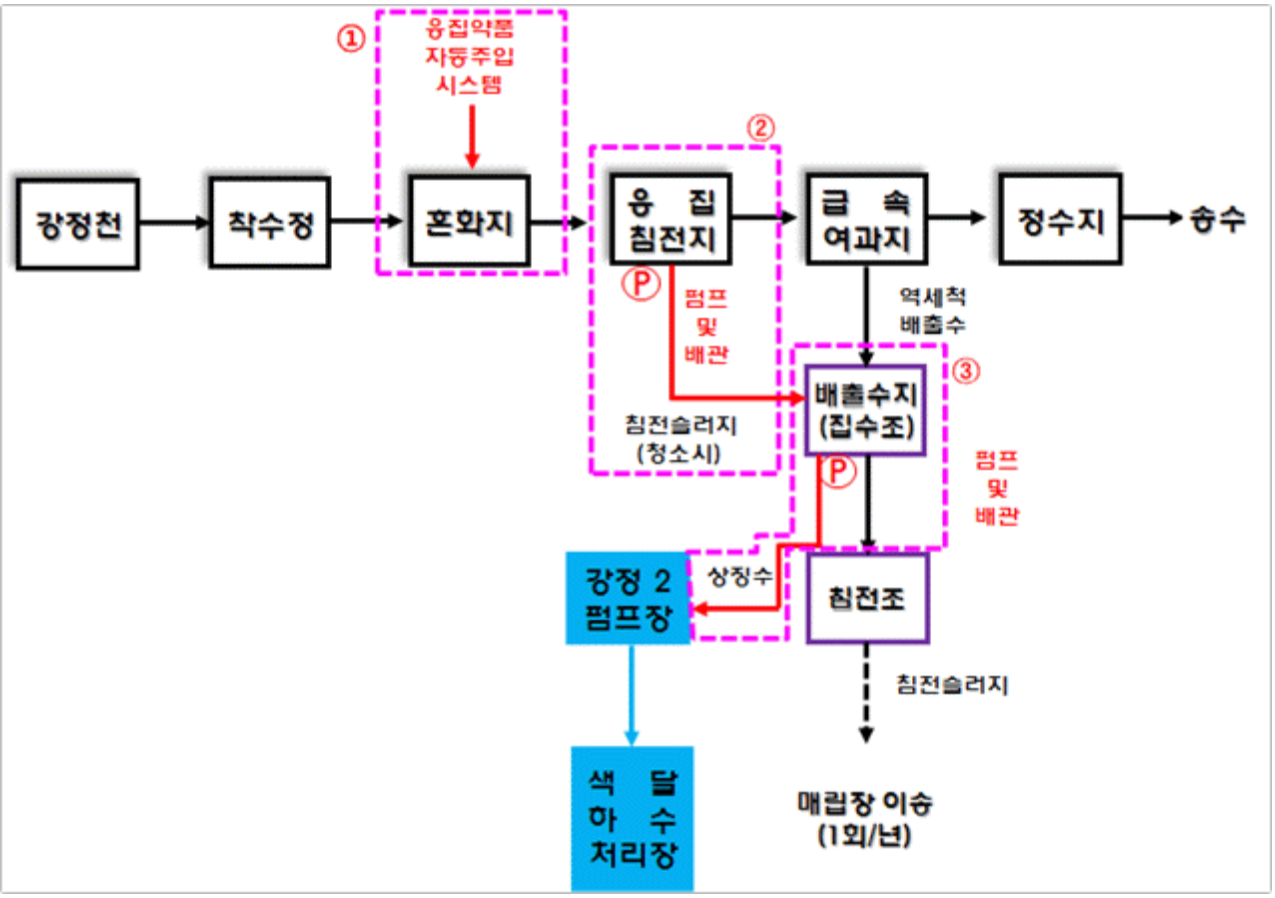
4.1.5 Future improvement plan

4.1.5.1 Short-term improvement

The short-term improvement was carried out in a total of two stages. The first step is to improve the environment to prevent the inhabitation of the larvae. The environment was improved to make it difficult for small creatures to enter through cleaning the intake tower facilities and cleaning nearby sedimentary soil. Insect screens were installed, insecticides were installed, double entrances to the building, and walls were sealed.

The second stage is the improvement of water purification plant facilities and operation plans. An automatic injection system and a change of the location of the flocculant in the mixed paper were introduced, the reverse detailed cycle of the fast filter bed was shortened, the filter medium was replaced, and the lower water collection device was improved. Facility operation improvement improved the regular injection of flocculant, shortening the cycle of filtration, and improving the discharge water treatment facilities as follows.

Fig4. An improvement plan overview of K water treatment facility



4.1.5.2 Mid to long term improvement

Table1. Mid to long term improvement plan of K water treatment facility

Classification		As-Is	To-be
System Improvement		(Water intake) When classifying water sources, 19 items of water quality are measured once a half-year by classifying underground water. (Manual) Insufficient operation management manual for water purification plant (Organization and manpower) 40% of the operation manager of the water purification facility compared to the statutory requirements.	The water source is classified as river water and strengthened by measuring 6 items once a month and 25 items once a quarter. (Manual) Reorganization of manual including regular inspection of water purification plant (Organization and Human Resources) Securing appropriate personnel for water purification facility operation managers and water quality managers
Tech nic	Facility Improve ment	Upper water intake through the intake tower (Filter bed) Poor drainage due to aging of strainer in the lower water collection system. (Emission water treatment facility) Insufficient capacity of 418.5 m	In-depth water intake through collecting and collecting (water intake facilities Improvement of the lower water collection system, and improvement of air supply pipes and fans. Supplementation and expansion of

		(Comprehensive Facility Improvement Plan) No improvement plan since the installation of facilities in the 1980s.	effluent treatment facilities in the water purification plant (discharge water treatment facilities) (Comprehensive Facility Improvement Plan) Establishing a long-term plan to improve the aging of structures
	Operation Improvement	(Filtration) one of six facility is water+air backwash (5 facilities are only by water wash)	(Filtration) All 6 sectors to be worked by water+air backwash

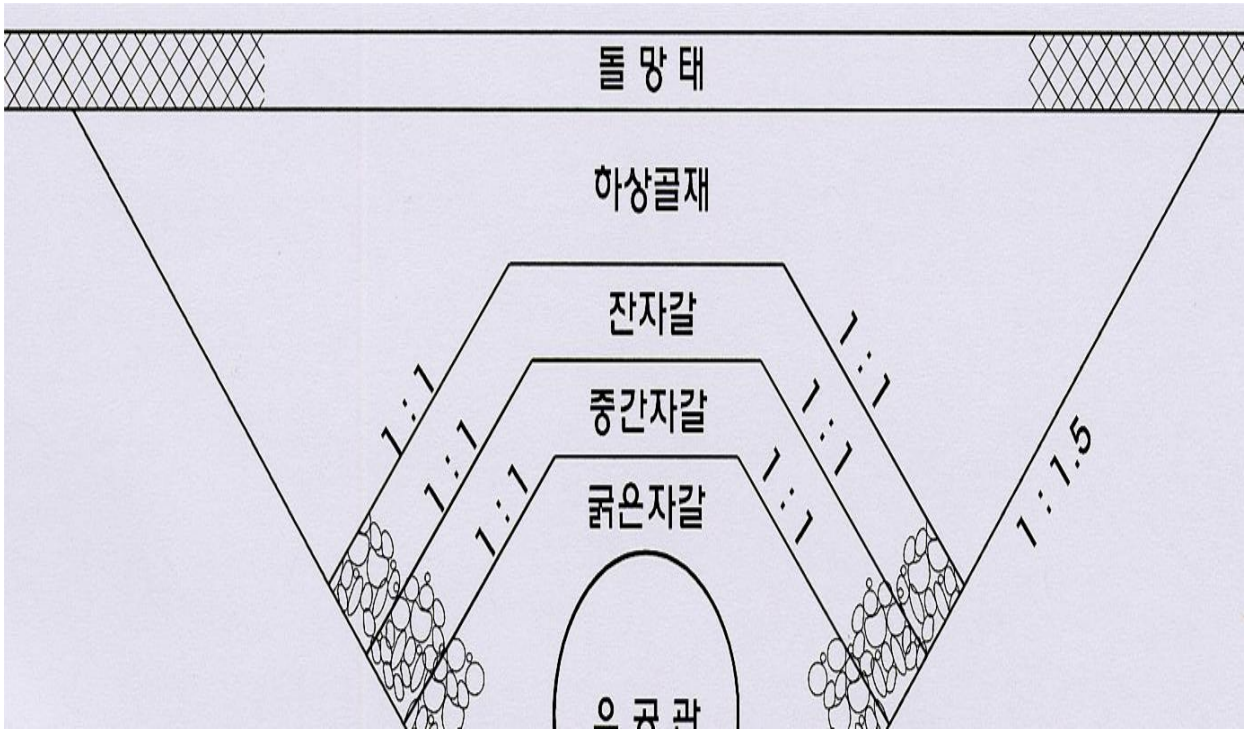
First, water intake management and facility improvement measures were prepared. The water quality measurement items of the water intake source classified as underground water should be changed to river water, and the water quality measurement should be carried out thoroughly.

Table2. Water source management rules [Attachment 6] Water quality inspection standards for raw water (Ministry of Environment, 2020)

Classification	Measurement times	Measurement items
River water, Back-flow water	Over 1 time every month (6categories)	Hydrogen ion concentration, biochemical oxygen demand, suspended mass, dissolved oxygen content, E. coli group (total E. coli group, fractional E. coli group)
	Over 1 time every quarter (25categories)	Cadmium, arsenic, cyanide, mercury, lead, chromium, anionic surfactant, organic phosphorus, polychlorinated biphenyl, fluorine, selenium, ammonia nitrogen, nitric acid nitrogen, carbaryl, 1,1,1-trichloroethane, tetrachloroethylene, phenol, carbon tetrachloride, 1,2-dichloroethane, dichloromethane, antichlorohexyl, antichlorohexyl, antichloroic acid, antichlorohexyl, antichloroic acid.
Lake water	Over once a month	Hydrogen ion concentration, chemical oxygen demand, suspended mass, dissolved oxygen content, E. coli group (total E. coli group, fractional E. coli group)
	Over once every quarter	Cadmium, arsenic, cyanide, mercury, lead, chromium, anionic surfactant, organic phosphorus, polychlorinated biphenyl, fluorine, selenium, ammonia nitrogen, nitric acid nitrogen, carbaryl, 1,1,1-trichloroethane, tetrachloroethylene, phenol, carbon tetrachloride, 1,2-dichloroethane, dichloromethane, antichlorohexyl, antichlorohexyl, antichloroic acid, antichlorohexyl, antichloroic acid.
Under Ground water	Over 1time every 6 month (19 categories)	cadmium, arsenic, cyanide, mercury, lead, chromium, anionic surfactant, diazinone, parathion, phenytrothion, fluorine, selenium, ammonia nitrogen, nitric acid nitrogen, carbaryl, 1,1,1-trichloroethane, tetrachloroethylene, trichloroethylene, phenol

Second, measures to improve facilities and operations were prepared. Considering the low underground water level, the water intake tower was reviewed to install a water collection store to prepare a plan for water intake in the deep.

Fig 5. Overview of collection and storage (based on water supply facilities, Ministry of Environment (2010)



In order to improve the operation of the rapid sand filter bed, it was reviewed that it was improved from some water + air backwashing to a total of six filter bed water + air backwashing, and the lower water collection device was improved. The drainage water treatment facility needs to be installed additionally to increase the capacity of the discharge resin due to the increase in the amount of back washing. The operation and maintenance manual for water purification facilities shall be reorganized. In order to improve water purification plant facilities that have been aged for at least 30 years, the results of precision safety diagnosis shall be reflected in the master plan for water maintenance to prepare the basis for future project implementation.

Third is strengthening water supply management capabilities. Appropriate manpower shall be secured due to a shortage of manpower due to strengthening water quality inspections, and in particular, an operation manager of a water purification facility, which is only 40% of the quota, shall be properly secured for the relevant facility.

Table 3. "A Study on the Establishment and Training of Appropriate Arrangement Criteria for Water Purification Facility Operation Managers" (Ministry of Environment, 2020)

Classification	Assigned staffs(A)				Insufficient Staffs (B)				Wanted Staffs (C=A+B)			
	Total	1st Class	2nd Class	3rd Class	Total	1st Class	2nd Class	3rd Class	Total	1st Class	2nd Class	3rd Class
Total	214	25	54	135	64	21	37	6	278	46	91	141
Seoul	71	11	18	42	-13	0	0	-13	58	11	18	29
Busan	24	4	7	13	6	1	3	2	30	5	10	15
Daegu	22	4	2	16	14	2	10	2	36	6	12	18
Incheon	31	2	8	21	7	4	4	-1	38	6	12	20
Gwangju	14	1	3	10	6	2	4	0	20	3	7	10
Daejeon	18	1	7	10	14	4	4	6	32	5	11	16
Ulsan	14	2	3	9	2	0	3	-1	16	2	6	8
Jejudo	**20**	**0**	**6**	**14**	**28**	**8**	**9**	**11**	**48**	**8**	**15**	**25**

4.2. I area larvae accident

4.2.1 Progress of accident

<Supply system overview>

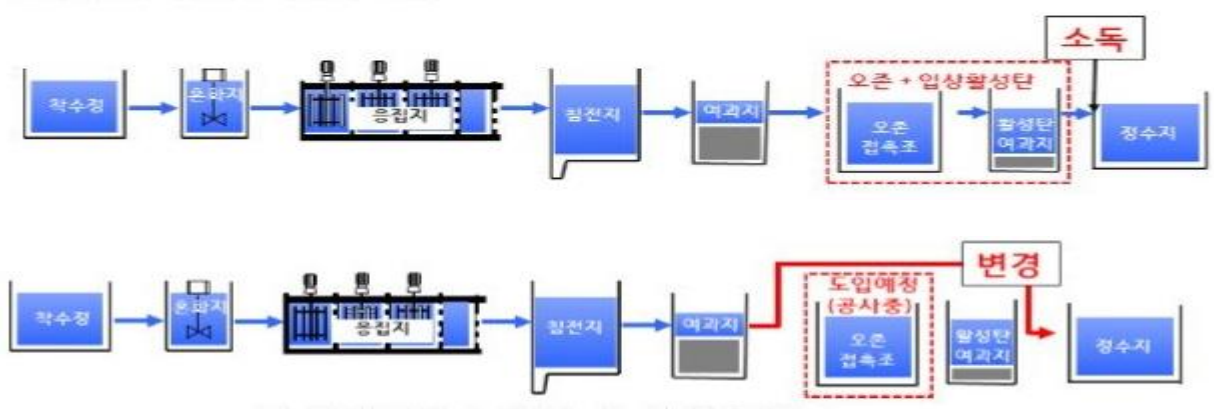
* Capacity of facility: 335,000m³/day (K facility), 325,000m³/day (B facility)

* Water treatment facility: Advanced water treatment

(K water purification plant did not introduce ozone contact tank and was introduced after accident)

* Year of completion: 2016(B), 2019(K)

Fig6. Water treatment procedure for K, B facility (I area, after accident)



The accident was recognized by the first complaints about the occurrence of larvae, and the investigation team confirmed the residence of larvae in the granular activated carbon adsorption site in the water purification plant.

4.2.2 Causes of accident

The causes of larvae in activated carbon paper are as follows. The building of the activated carbon filter bed has an open structure, and when the window is opened, the matting insects can flow in. In addition, the structure in which the upper layer is exposed provides an environment in which the biological membrane, organic matter, and proper temperature corresponding to 25 degrees Celsius can survive for the larvae. The causes of external outflow from activated carbon are as follows.

Chironomid eggs and larvae 1 to 2 years old show the characteristics of floating, but larvae 3 to 4 years old show the characteristics of moving to the bottom due to their benthic. The average particle diameter of activated carbon corresponds to about 1 to 2 mm, creating an environment in which the funnel larvae (0.1 to 1 mm) can pass through the strainer gap of 0.5 mm.

4.2.3 Progress of accident response

First, the granular activated carbon filtration process was bypassed to the standard process to exclude the inflow of larvae into the process. After that, group work members strengthened the disinfection process, shortened the filter area cleaning cycle, cleaned the resin, and installed a screen and insect repellent. On the pipe network, stabilization measures such as the installation of a blocking network for the inflow of drainage and water supply pipes were completed.

4.2.4 Damage

As a quantitative figure, KRW 880 million was lost due to 1.25 million tons of drainage (KRW 870 million) and water bill reduction (KRW 10 million). Qualitatively, 1806 complaints caused administrative response works, and the group work by the Ministry of Environment, Incheon city,

and K-water experts until normalization took 4 months. And it was worse than quantitative damage.

4.2.5 Short to long term improvement plan

Table4. Short to long term improvement plan of K&B water treatment facility

Classification		As-Is	To-be
Short	System	(Professional) The number of technical personnel in the region is insufficient compared to other regions. (Manual) Non-possession of larvae	(Professionals) Need to reinforce personnel related to technology, especially water quality. (Manual) Short-term supplementation and sharing
	Facility	(Structure) General screen and simple door structure (All) No filter installed in inflow and outflow pipes	Improvement to micro screen and double door structure (structure) Installation of backflow prevention filter in (all) inflow and outflow pipes
	Operation	(Activated carbon paper) Backwash cycle every 2 weeks (Measures to be taken upon discovery) Nothing in particular.	(Activated carbon paper) Within 7 days of back washing cycle (At the time of discovery) On-site check->Sample secured->Sample analysis is performed immediately.
Mid To Long term	System	(Monitoring method) No separate method (Professionals) Apart from the increase in the number of waterworks, the number of waterworks gradually decreases. (Communication with residents) No separation (Act) Multiple use of rooftop water tanks in multi-family housing and no standard for preventing larvae (Water bill) Supply below cost	(Monitoring Method) Construction of a permanent management system through insect netting, core collection, etc. (Professionals) Detailed classification when strengthening the recruitment of professional personnel and preparing water supply statistics. (Communication with residents) Cleaning of individual rooftop waterways at all times. (Act) It is necessary to expand the direct supply of multi-family housing and strengthen the standards of the Waterworks Act to prevent larvae of individual rooftop water tanks. (Water bill) Realized to more than 100% of production cost, fiscal consolidation
	Facility	Most of the (structure) water treatment processes are exposed to the ground. Defects such as (activated carbon paper) micro strainer not operated and cracks in the lower water collecting device.	(Structure) Completely sealed, covered, and undergrounded buildings for future renovations. (Activated Carbon Paper) Micro strainer installation, defect repair in lower water collecting
	Operation	(Activated carbon paper) No reverse cleaning cycle compared to larvae, thickness of lower support layer, etc.	Resetting the reverse cleaning cycle and thickness of the lower support layer compared to the larvae. Perform core sampling inspection during vulnerability period

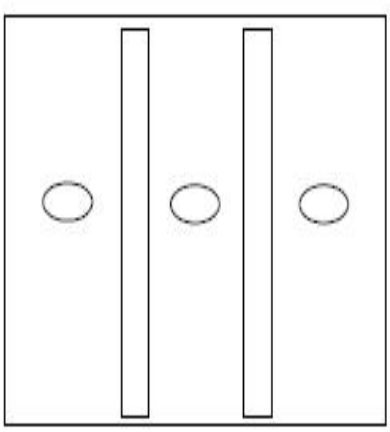
4.2.5.1 Short-term improvement plan

First, it improves the environment for the prevention of chironomid habitat. To prevent direct inflow into activated carbon paper, an air curtain, a double entrance door, and a fine screen are installed. In order to eliminate the possibility of passing through larvae, a backflow prevention filter shall be installed in both the inflow and outflow pipes of each supply system such as the static resin and the drainage resin.

Second, efforts are made to shorten the reverse cleaning cycle by conducting the reverse cleaning cycle within a week in the weak summer season.

Third, small organisms are added to the survey item for visual observation of the larvae of the chironomid, and if necessary, the existence of small organisms is checked by collecting samples through coring. After on-site confirmation, samples must be secured, morphological analysis within one day, and genetic testing within one week to determine exactly whether larvae have occurred.

Fig7. Manual on operation of water treatment facility (Seoul city, 2016)



<Activated carbon extraction point decision>

<Extraction>

<Extraction Device>

Fourth, in order to strengthen water supply management capabilities, it is necessary to actively invest the cost budget in stable maintenance and increase the number of technical and water quality-related personnel. It should be distributed to each local government through the maintenance of high-level water purification operation and management guidelines.

Table 5. Comparison of manpower engaged in the special and metropolitan water supply business (2018 water supply statistics)

Area	Population (person)	Staff (person)	Admin (person)	Tech (person)	Etc (person)	Staff per population	Ratio of tech	Tech staff per polulation
Busan	3,487,191	1093	241	649	203	0.313	0.594	0.186
Daegu	2,489,156	727	159	483	85	0.292	0.664	0.194
Incheon	**2,986,455**	**705**	**117**	**282**	**306**	**0.236**	**0.400**	**0.094**
Gwangju	1,480,864	373	74	169	130	0.252	0.453	0.114
Daejeon	1,506,903	487	76	187	224	0.323	0.384	0.124
Ulsan	1,157,532	252	56	186	10	0.218	0.738	0.161
Seoul	10,049,607	1826	529	1120	177	0.182	0.613	0.111

4.2.5.2 mid to long term improvement plan

First, there are measures to improve the design and construction of granular carbon filter bed. It is necessary to reset the existing design standards by reflecting the characteristics of the larvae. It is necessary to reset the design criteria for the material and thickness of the lower support layer. In addition, adjustment of trough spacing, and depth is required. Activated carbon basin shall be improved to the upper seal type. Defects in the lower collection device shall be investigated so that the reverse cleaning efficiency can occur equally. The treated water that has passed through the activated carbon basin should be considered for installation of microstrainers or the like at the front end of the inflow of the static resin.

The second part is measures to improve the operation of activated carbon. This is about improving the operation method of the reverse cleaning process, and in summer, the reverse cleaning cycle is performed every seven days or less, and a combination cleaning method of water and air is recommended. The optimal water backwashing duration shall be operated to ensure sufficient discharge of turbidity. Through monitoring of the lower water collecting device, it is continuously checked whether it is distributed evenly.

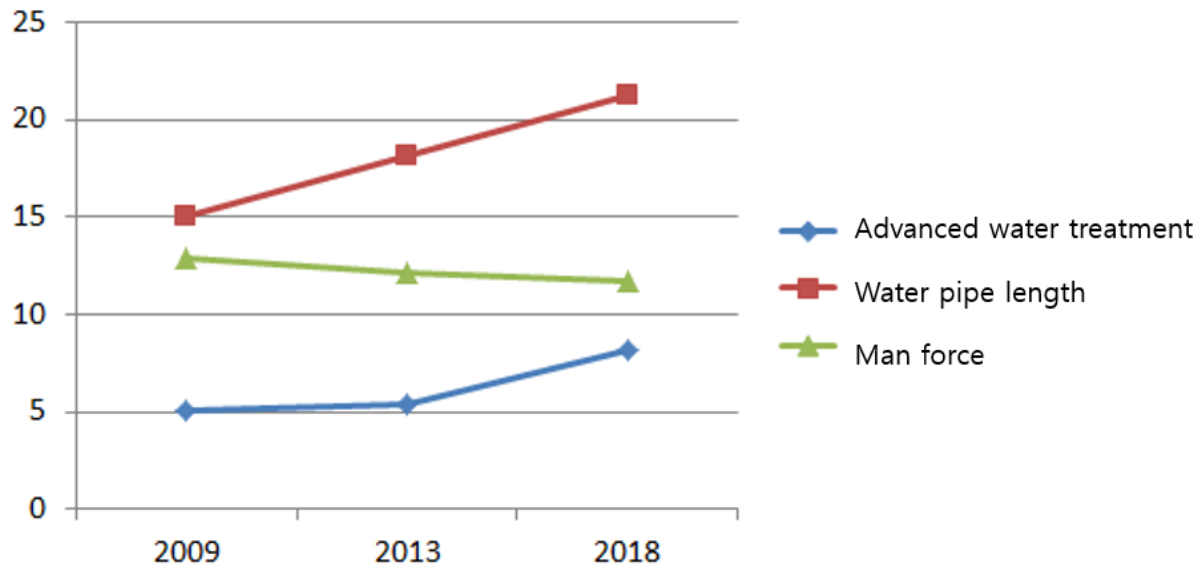
Third, it is the management improvement part, such as monitoring items and inspection methods of the chironomid larvae form. Activated carbon paper provides an environment in which the larvaes are habitable, so regular sample tests should be conducted on activated carbon paper

throughout the year. It should be possible to proceed continuously through the establishment of a standardization and regularization plan and monitoring system and the operation of staffs.

Fourth, there are improvement of water tank management and measures to communicate with residents. No matter how cleanly water is supplied to an individual, it is difficult to prevent larvae if the water storage tank is contaminated or foreign substances are easily introduced. There is a way to enforce the cleaning and management of water tanks by strengthening the water supply law. The management of water reservoirs and rooftop water tanks shall be kept clean through communication with residents.

Fifth is the specialization of management personnel. The manpower of water purification plants and waterworks offices is decreasing in contrast to the increasing trend of advanced water purification facilities.

Fig8. Change of members working for water treatment facility with scale of facilities



Over the past 10 years, the number of advanced water purification facilities has increased from 5.1 million tons/day to 8.2 million tons/day, while the number of water pipes has increased from 150,000 km to 210,000 km, while the number of staff in water field has decreased from 12.9 million to 11.7 million. Advanced operation of advanced water purification facilities through professional manpower reinforcement is required.

5. In-depth interview with experts

5-1. Selection of interviewees

The interviewee was selected mainly by experts in the water supply sector who worked as a task force to solve the larvae problem in the two regions that occurred in 2021. I selected two university professors and two people who worked as a K-water larva resolution team.

Table 6. In-depth interview list

4 experts of sanitary water management and civil engineering	
2 professors in University	1 full professor, 1 assistant professor
2 experts in K-water	1 senior manager, 1 manager

5-2. Interview result summary

The questions consisted of two main types, and opinions were summarized without classifying them by interview subject. The larva problem should be approached through complex solutions, not simple improvement.

Table 7. Summary of main comments from experts

Questions	**Opinions of experts**
Q1: Opinions on suggested political proposals	1. Since the water supply budget is concentrated on modernization projects to improve the pipe network after the Incheon red water crisis, it is necessary to improve the water purification plant through a balanced budget distribution. 2. In the case of qualifications for operating water purification facilities, policies are needed to induce them to be equipped because there are no special restrictions even if they are not equipped with qualified operators. 3. There are standards for disinfection and turbidity of water quality, but there are currently no standards for small foreign substances, so a new enactment is essential.

	4. In the case of existing problem areas, there is a high possibility that the problem will occur again, so separate management measures are required. 5. In the design for the renovation of the existing water purification plant, the main elements of the design evaluation are the determination of the appropriateness of improving the construction method due to increased capacity and deterioration of water quality. In response to the rise of the larva problem, measures to improve facilities should also be included to prevent this.
Q2: Opinion on suggested technical proposal	1. The occurrence of larvae is a social problem if it occurs at home. Assuming that the case found in the water purification plant is the first stage and the case found at home is the second stage, a countermeasure linking the number of larvae and the place found in the first stage will be necessary. When discovered in the second-stage assumption, a significantly expanded response should be included rather than the first-stage response. 2. It is important to analyze the species of larvae when discovering larvae, but it will be easier to respond through real-time monitoring if there is equipment capable of monitoring larvae such as particle counters. However, larvae are small and difficult to distinguish from general foreign substances, so it is judged that scientific development is needed. 3. Improvement through facility renovation is the most basic or most effective method. However, membrane facilities need a lot of financial input, so if basic measures such as installing a screen are not sufficient, it should be reviewed and applied first with good cost-effectiveness. 4. Response through operation method improvement should be implemented first rather than facility improvement. Since larvae have

	a strong response to chlorine, it is necessary to focus on the appropriateness of the filtration rate of the filter bed, the cycle of back washing, the effective standing diameter of the filter, and the damage to the lower collector. 5. Recently, many new technologies have been developed to solve the problem of larvae. Membrane filter technology is leading the main treatment measure. If the cost is economical without significantly interfering with the quantity and water pressure, the filtration filter technology will be preferred. In addition, a method of removing larvae through electrical stimulation is also being developed.
Q3: Extra opinions on solutions	1. Core labor force among public officials should be encouraged to work in the water supply field. The water supply sector is often treated as a underestimated job, but it is urgent to come up with policies to improve this so that talented people can continue to be invested in the water supply sector. 2. In the event of a water supply complaint, all information should be disclosed transparently. In the event of a local tap water accident, there is a need for a communication system that can be grasped without delay by the central government. 3. If the drainage or water tank is contaminated, there is a possibility that larvae may occur due to contamination of the drainage pipe due to reflux. To prevent this, the application of backflow prevention technology should be mandatory for customers who use water tanks. 4. Even if larvae occur in the water purification plant, water meter filtering equipment should be applied to prevent from leaking inside.

6. Solutions proposal

6.1 Political solutions proposal

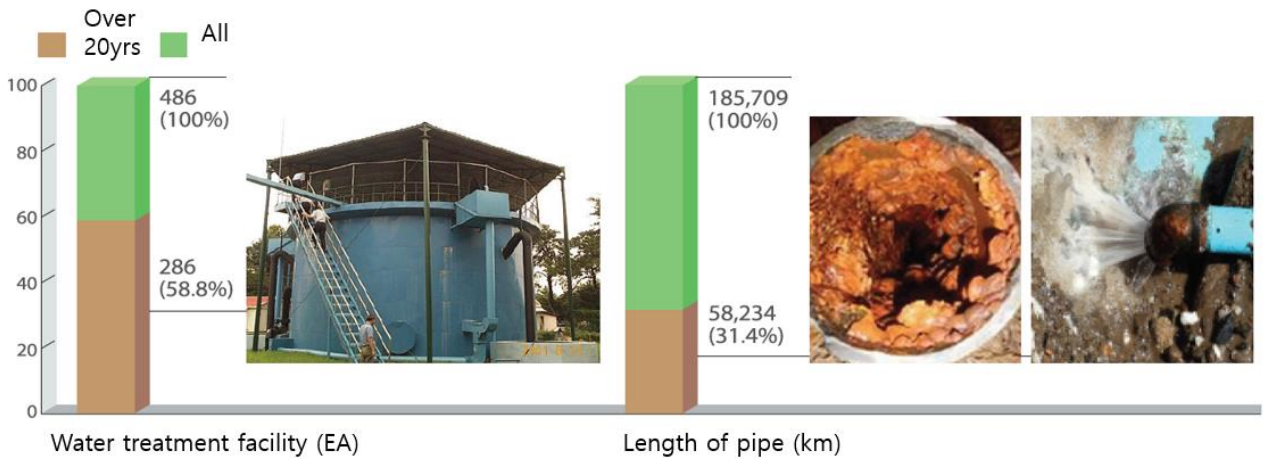
6.1.1 Items to approach political solutions

A total of five politic solutions were prepared through expert interviews and surveys, referring to the results of various water quality research, K-water's report, and the status of larvae response.

6.1.1.1 Establishing appropriate financial plans

The National Capital Framework is focused on quantitative allocation and expansion. Therefore, there are many problems to derive a solution to the water quality problem that has recently become a problem. Since the appropriate budget is not reflected in the mid to long term, the feasibility verification and budget allocation procedures for implementing it as a national project are very difficult. On the other hand, the water supply system adjustment project or expansion project in the National Capital Basic Plan is legally carried out through the basic plan, so even if it is somewhat less important, it is promoted as a national project first.

Fig9. Water facilities and age of facilities



Appropriate use of the reflected budget should also be improved. Of the 3.1 trillion won budget for the local water supply modernization project, 2.2 trillion won is being invested in improving the pipe network and 0.9 trillion won in improving the water purification plant facilities. The first modernization project, which was promoted on a large scale, is bearing the result of

increasing the water flow rate in areas with low water flow rates and modernizing water facilities. About 30% of the pipeline facilities that have been aged for more than 20 years, which are evaluated as a measure of the aging of water facilities, are managed as targets of aging. However, in the case of water purification facilities that have been aged for more than 20 years, about 60% of the total needs to be improved, but the budget input is less than half of the pipe networks.

This is why it is necessary to consider the aging of water purification plants when improving the basic national water supply plan and promoting the second modernization project in the future.

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6.1.1.2 Improvement of certification system for operation of water purification facilities and allocation of excellent human resources in the local water supply field

The water purification facility operation manager system has been promoted since 2007 to foster professional water purification facility operation managers. In 2007, 1,801 people applied and passed 531, or 29%, and 2,805 successful applicants were produced over 13 years. However, according to data from the Ministry of Environment in 2017, 817 people, or only 62% of the 1,332 people required by law, are working at 447 water purification plants nationwide. This shows that only 33% of the 2,805 successful applicants are active, and that more than 30% of the water purification plants do not meet legal requirements. Recently, the Ministry of Environment conducted a separate study on the appropriate arrangement of water purification facility operation managers and curing measures (2020), indicating that they are not being properly deployed.

Table 8. Pass rate of 'Water purification system operator certification exam' 2015~2019, MOE

Classification		2015	2016	2017	2018	2019	5yrs ave.
1st stage	Applicants	547	510	621	611	690	**596**
	Pass	209	212	216	328	350	**263**
	Pass rate	38%	42%	35%	54%	51%	**44%**
2nd stage	Applicants	350	432	377	438	506	**421**
	Pass	50	91	108	187	159	**119**
	Pass rate	14%	21%	29%	43%	31%	**28%**

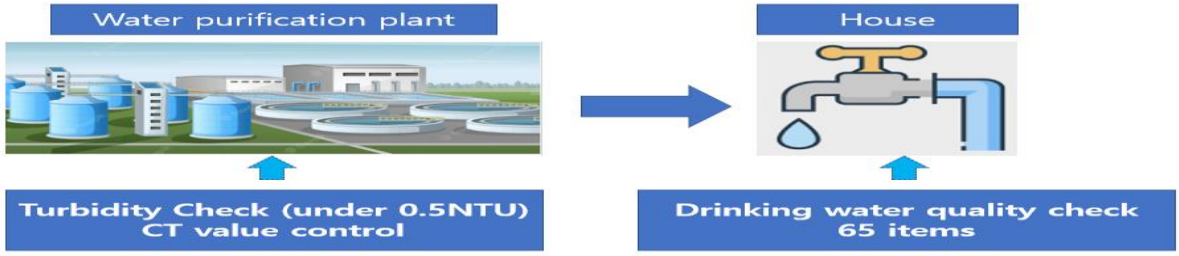
The lack of appropriate labor force disproves the fact that the successive red water accidents and larvae occurrence accidents were not just coincidences. Recently, the water supply business is developing into a smart water supply business through data construction, and remote meter reading and the introduction of smart systems are leading. However, on the contrary, the construction of water supply professionals is currently far behind.

Dr. Kim Donghwan of the Institute for Environmental Strategy pointed out that the water supply has already been advanced, but the related personnel remain analog. Due to the phenomenon of public officials avoiding the water supply department and the lack of incentives, the operation manager of the water purification facility, which has been in operation for more than 15 years, has been reduced to a mere system. There is a desperate need to come up with incentives for local working-level officials to acquire and work.

6.1.1.3 Adjustment of tap water treatment guidelines

According to Korea's Regulations on Water Treatment Standards, Waterworks Facility Standards (2010), and related design standards, the criteria for water treatment are turbidity and disinfection capacity (CT value)

Fig10. Figure of tap water quality control



In 1993, the U.S. city of Milwaukee suffered 430,000 casualties due to various germs of undead tap water. Since then, it has been based on managing CT values and turbidity in water purification treatment, and the same is true in Korea. However, the recent larvae incident suggests that we comply with another standard.

Until now, under the Waterworks Act, visible insects and larvae such as rugs were not included in

the violation of water quality standards. It is natural to put visible foreign substances from tap water that you drink every day into the water quality standard items.

6.1.1.4 Systematization of special mandatory management in areas where existing small biological problems occur

The nature of the larvae is the fact that they are affected by the environment. There is a high possibility that it will flow into tap water supply facilities when the temperature and living environment are adequate. Therefore, it is necessary to select the area where the previous incident occurred as a special management area and manage it separately. The status of larvae before and after facility supplementation shall be monitored and care shall be taken not to recur. In addition, the number of inspections should be strengthened more than in other regions and gradually eased if stabilized. Even when an improvement plan is established as a national project, priority reflection of the existing areas shall be reviewed.

6.1.1.5 Promotion of public notice of bidding for services and construction, including relevant information in task instructions and specifications;

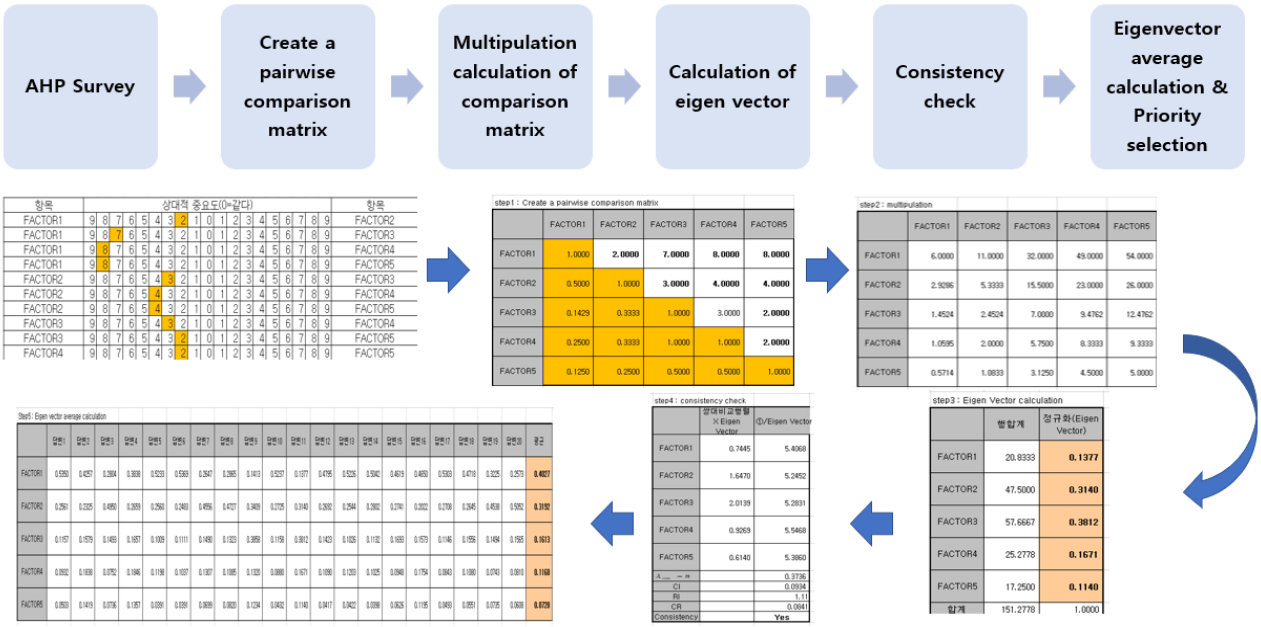
If laws and standards are improved, relevant subsequent procedures should also be improved accordingly. In the future, when improving facilities of an old water purification plant or constructing a new water purification plant, it shall include sufficient methods to prevent related accidents from basic planning to design and construction. When ordering a design or construction, the relevant task instructions and specifications must be thoroughly reviewed to ensure that facility improvement to prevent larvae is included in order to prevent overlapping budget input and promote efficient work.

6.1.2 AHP survey result

Priority was derived through AHP analysis of the survey results of five improvement measures. The survey was conducted on a total of 20 K-water water facility operation managers from November

to December 2022, and was conducted on those with more than 3 years of experience in operating water facilities. Priority was derived through AHP analysis of the survey results of five improvement measures. The process for deriving priorities is shown in the following figure.

Fig11. AHP survey & analysis flowchart



First, a total of 20 consistent survey results were obtained. The subjects of the survey were K-water's water purification facilities and water supply facilities managers and operators, and employees of grades 3 to 8. In order to make the AHP result reliable, valid results with a reliability of 0.1 or less and a result value with an acceptable value of 0.1 to 0.2 were used for the result. The results are shown in the following table.

Table 9. AHP analysis result showing priority sequence (political solution)

Content	Eigen Vector value	Priority
A Review of Financial Planning and Budget Allocation for the Improvement of Water Quality in Mid- to Long-term	0.4027	1
Improvement of water purification facility operation certification system and placement of outstanding human resources in the local water supply field	0.3192	2
Adjustment of tap water treatment guidelines (add foreign substances from the center of turbidity and CT values)	0.1613	3
Systematization of special mandatory management in areas where existing small biological problems occur	0.1168	4
Promotion of public notice of bidding for services and construction, including relevant information in task instructions and specifications;	0.0728	5

As a result of examining the above, the survey subjects consider the establishment of mid to long term financial plans and the reflection of the budget as the most important factors. In addition, it is judged that it is important to deploy an appropriately qualified water facility operation manager and to deploy excellent human resources for the work.

6.2 Technical solutions proposal

The following five technical solutions are proposed by referring to expert interviews, surveys, and response status.

6.2.1 Items to approach technical solutions

6.2.1.1 Development of larval warning parameters

Since 2012, the Ministry of Environment has conducted a seven-day water temperature forecast for water temperature and chlorophyll-a concentration at the four major river systems, and now operates an integrated water forecasting system and bird warning system. The criteria for issuing the water quality management stage are the predicted concentration of chlorophyll-a, and are divided into the level of interest to the serious level according to the number of algae cells. The purpose of introduction is to stably contribute tap water by issuing an alarm and preemptively taking necessary measures. The water quality forecasting system refers to a series of systems such as real-time linkage of vast observations and predictions such as weather, water quality, flow rate, water level, and pollutant sources for water quality forecasting, and generation of input data.

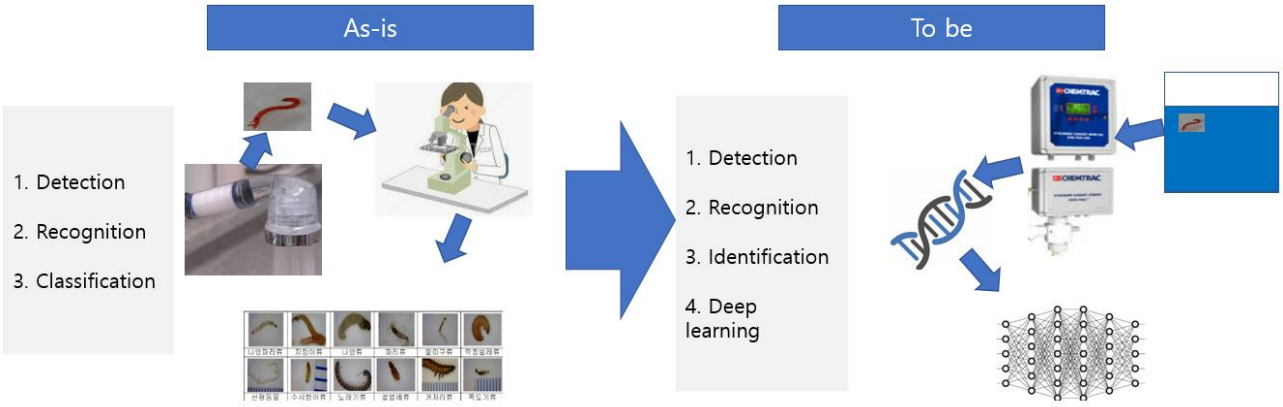
It is believed that a more preemptive response can be taken if the occurrence of larvae is also created and managed through a series of information such as temperature and water quality that can be observed or predicted.

6.2.1.2 Development and introduction of real-time monitoring equipment for larvae

In the past, Stream current detector for injecting the optimal amount of flocculant into the water purification plant has been developed to reduce the manual burden for water quality measurement

and lead the era of automation of material injection. As with water quality, larvae are also difficult to determine with the naked eye, so detector will be needed in the future. If a device that automatically monitors is installed as shown in the following figure, it will be useful for responding to accidents and establishing countermeasures.

Fig 12. Forecast for larvae genome detection technology development with deep learning



6.2.1.3 Prevention of occurrence by optimizing the operation method of facilities (adjustment of drug injection, etc.)

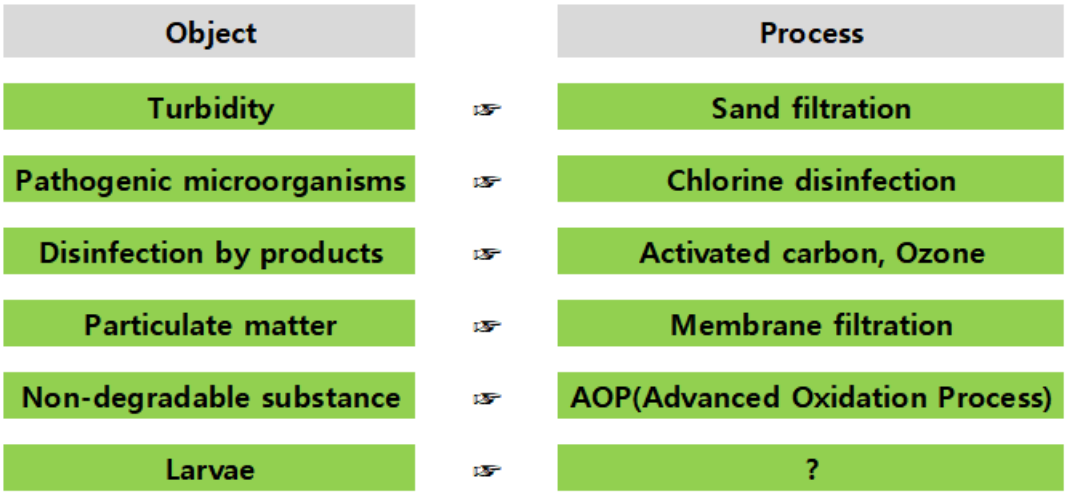
The installation of new facilities is limited by space and financial conditions. Therefore, the first thing to think about is the improvement of the operation method of the water purification plant. The injection concentration of disinfectant or ozone should be increased and the improvement effect should be checked. In addition, it is necessary to promote replacement with polymer aggregators and improvement of agglomeration efficiency. Supplement the lower collection device of the filter bed, enhance the reverse cleaning efficiency, and reduce the reverse cleaning cycle. It is essential to monitor whether the removal efficiency of larvae increases through such detailed process adjustment.

6.2.1.4 Prevention of occurrence by improving facilities (introduction of membrane filtration, etc.)

The process of new construction and introduction of the water treatment process for each material to be removed for water treatment is shown in the following figure. From the initial removal

of turbidity to the process of removing substances that generate taste and odor substances, the water treatment process has been developed repeatedly.

Fig 13. Water purification process by object



Currently, the most widely introduced filtration devices for the purpose of removing larvae are various, such as cartridge method, fiber ball method, automatic washing filter method, and automatic double filter method. The hole size also varies largely up to 100 micrometers, but there is a disadvantage in that the pressure at the rear end decreases after installation. In addition, active facility improvement methods such as air curtains, building and indoorization of water purification plants are also being reviewed for active facility improvement.

6.2.1.5 Development and introduction of new technology for eliminating larvae

Various technologies are needed to remove larvae. Typically, a method of removing larvae through electrical stimulation is also being reviewed. There is a manufacturer that proposes an efficient removal method by applying for patents in various ways for precision filtration devices.

6.2.2 AHP survey result

Priority was derived through AHP analysis of the survey results of five improvement measures. The process and results for deriving priorities are shown in Figure 11 in 6.1.2. The results of the

priority derivation are shown in the table below. Table 10. AHP analysis result showing priority sequence (technical solution)

Table 10. AHP analysis result showing priority sequence (Technical solution)

Content	Eigen Vector value	Priority
Prevention of occurrence by improving the operation method of facilities (adjustment of drug injection, etc.)	0.3989	1
Prevention of occurrence by improving facilities (introduction of filter, etc.)	0.3157	2
Development and introduction of real-time monitoring equipment for larvae	0.1977	3
Development and introduction of new technology for eliminating larvae	0.1101	4
Development and introduction of larval warning parameters	0.0878	5

7. Conclusion and limitations

7.1 Conclusion

Beyond the problems of water quantity and water quality, Korea supplies high-quality tap water to citizen. However, through the recent enemy accident in 2019 and larvae in 2020, the people are demanding higher water quality standards. Recently, pipelines have been actively improved to improve red water accidents, but it is difficult to satisfy the public's expectations for improvements related to larvae. Therefore, this capstone project presented how to solve this problem in the future by reviewing the Ministry of Environment's countermeasures related to the occurrence of small organisms, various guidelines, and domestic and foreign research data. Through task research and expert interviews, five politic solutions and technical solutions were selected, respectively. Priorities for these tasks were determined through AHP analysis. For reliable analysis, more than 20 consistent survey results were reflected each, and water facility operation experts were selected.

First of all, as a policy, it was suggested that the mid to long term financial plan be effectively implemented by reflecting the improvement of old water purification plant facilities in the basic national water supply plan. In addition, experts in the water supply field, such as water purification facility operation managers, were placed in the right place to suggest that the facility could be operated professionally.

Next, as a technical part, the task of optimizing the operation method of existing facilities was

presented. In addition, a plan to improve facilities (filtration of membranes, air curtains, and indoorization of water purification facilities) was proposed to solve small life problems.

In addition, there are next order tasks for each part which can be specifically reviewed on the main text. The comparative results showed that the policy and technical aspects were 46% and 54% respectively as a result of the survey. In order to solve the problem of small life generation, it is judged that it is necessary to approach not only a solution to one field but also a complex solution.

7.2 Limitations and suggestions for follow-up studies

The occurrence of larvae in Korea became an issue from the time of occurrence in region I and region J in 2020. Therefore, little research has been conducted to solve the problem of small organisms. The literature review for this capstone project was also investigated within limited data because there were not many research results. In the future, as water purification plant facilities and operation methods are improved, problems related to small organisms can be solved. Therefore for now, the quantitative result of how much small organisms are suppressed and the problem is solved through the above improvement method is unknown. In the future, more reliable research results can be derived if the degree of occurrence of small organisms can be confirmed by performing improvements through pilot tests.

However, the improvement of old water purification facilities should be dealt with importantly in the basic national water supply plan proposed as an institutional solution. In addition, water purification facility operation managers and pipe network facility operation managers should be deployed in the right place to create a foundation for professionally solving water quality-related problems. I hope that more specific measures will be proposed and implemented to improve the culture of avoiding working in the water supply department.

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#Appendix 1: Questionnaire for interview with experts

- This survey was created for the purpose of listening to water supply experts for related opinions to carry out research projects on solving larva problems.

1. In order to solve larvae, this study proposed five policy and technical solutions. Do you have any views on this opinion?
2. Is there any opinion you want to add or exclude?

   * 참고: 캡스톤 제안 내용

구분	정책적 제안 내용
1	관망개선사업에 편중된 예산의 재분배 (현대화사업 관망/정수장 개선 관련 예산 배분 총량 및 내용 분석)
2	정수시설 운영 자격증 제도 개선 및 지방상수도 분야 우수인력 배치
3	수돗물 처리 가이드라인 조정 (기존 탁도, CT값 만족 중심 -> 소형 이물질 발생 등 추가하여 수질기준 강화)
4	기존 소형생물 문제 발생지역 특별 의무관리 제도화 (필요시 실시간 모니터링 강화에 대한 기준 수립) (유충은 서식환경과 기존 발생지의 문제점이 깊게 연관되어 있음)
5	유충발견 사전 예방을 위한 신규 정수장 설계 및 리노베이션 설계시 설계 평가를 통한 유충 방지를 위한 시설물 보완 점수화하여 체크할 수 있도록 의무화

구분	기술적 제안 내용
1	조류경보 수치 등 사례를 참고로, 유충발생 위험도 parameter를 신규로 만들어 관리하도록 함 (parameter가 높아질수록 유충발생 위험도 증가/ 사고발생 선제적 대응)
2	particle counter 등의 원리와 같이 유충의 발생 정도를 사전에 예측할 수 있는 발생 모니터링 장치(ex. 유전자 분석장치)를 통한 관리
3	시설물 리노베이션을 통한 예방 (멤브레인 등 시설물 도입, 시설물 실내화를 통한 외부유입 원천 차단) (간이개선: 필터 추가)
4	시설물 운영방식 개선을 통한 예방 (약품투입 강화, 약품 접촉시간 증대, 정수시설 여과과정 이중화 등)
5	신기술 도입 (전기파동 발생을 통한 살충 등)

#Appendix 2 : Paper for AHP survey

<Survey for AHP Evaluation>

- This AHP survey is to evaluate priorities of proposals dealt in this capstone project research. Please read carefully and answer these questions with your consistent opinion.

1. Write a number of the recent larva accidents that you think are important to respond to or prevent.
   - Please answer within Scope of weight calculation
   - Accident recovery: Accident prevention = _____ : _____

     * Scope is from 0~50, Sum is 100

2. There are a total of five policy solutions proposed in this study. Mark in a consistent position which of these you think is more important.

Factor 1: 적정한 재정계획 수립 (수질개선 관련 중장기 재정계획 및 관망예산조정)

Factor 2: 정수시설 운영 자격증 제도 개선 및 지방상수도 분야 우수인력 배치

Factor 3: 수돗물 처리 가이드라인 조정 (기존: 탁도, CT값 중심 -> 변경: 소형 이물질 등 추가)

Factor 4: 기존 소형생물 발생지역 특별 의무관리 제도화

Factor 5: 과업지시서와 시방서에 관련 내용을 포함한 용역 및 공사 입찰공고 추진

Evaluation item	Relative importance																			Evaluation item
	Absolutely important				Imprtant					Eqaul					Important				Absolutely important	
	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	
Factor 1																				Factor 2
Factor 1																				Factor 3
Factor 1																				Factor 4
Factor 1																				Factor 5
Factor 2																				Factor 3
Factor 2																				Factor 4
Factor 2																				Factor 5
Factor 3																				Factor 4
Factor 3																				Factor 5
Factor 4																				Factor 5

2. There are five technical solutions proposed in this study. Mark in a consistent position which of these you think is more important.

Factor 1: 유충발생 예보 parameter를 신규로 도입하여 조류경보와 같은 기능 추진

Factor 2: Particle counter 등의 원리와 같이 유충의 발생 정도를 정확히 모니터링 할 수 있는 장치로 관리 (예-유전자 분석 장치)

Factor 3: 시설물 운영방식 최적화를 통한 예방 (약품투입 강화, 여과지 역세척 시간 준수, 여과과정 이중화 등)

Factor 4: 시설물 리노베이션을 통한 예방 (에어커튼 등의 원리와 같이 전체 정수공정 지붕화, 멤브레인 등 시설개선 적극 도입)

Factor 5: 신기술 도입 (전기파동 발생을 통한 살충 등)

Evaluation item	Relative importance																		Evaluation item
	Absolutely important				Imprtant					Eqaul					Important			Absolutely important	
	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	
Factor 1																				Factor 2
Factor 1																				Factor 3
Factor 1																				Factor 4
Factor 1																				Factor 5
Factor 2																				Factor 3
Factor 2																				Factor 4
Factor 2																				Factor 5
Factor 3																				Factor 4
Factor 3																				Factor 5
Factor 4																				Factor 5

3. Please list the numbers which areas you think should be pursued more urgently, policy solutions or technical solutions.

- Please answer within Scope of weight calculation
- Politic solution: Technical solution = _____ : _____

  * Scope is from 0~50, Sum is 100