Water Safety Plans in Tokyo Metropolitan Waterworks

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Abstract

Tokyo Metropolitan Waterworks (TMW) has introduced a water quality management system called Tokyo High Quality Management Program (the Tokyo version of the Water Safety Plan) to all the water treatment plants (WTPs) and distribution systems since 2008. This paper explains, after introduction of the concept of Water Safety Plans (WSPs), how WSPs have been integrated in the Guidelines for drinking-water quality by WHO and how the WSPs was introduced to the water utilities in Japan. This paper also explains concretely how TMW has integrated the WSPs into its water supply management and operation systems. The challenges in implementation of the WSP in TMW are also elucidated based on the 7-year experience of the WSP in TMW.

Keywords

Water Safety Plans (WSPs), water quality management system, ISO (International Organization for Standardization)

1. Introduction

Now that the water supply system has extended its service coverage in every nook and corner in Japan, almost all the people living in Japan can utilize tap water with high safety. However, there are still some risks that water supply outage may occur because of a large-scale contamination of the source waters. One such example is the incident that happened in the Tone River system in May 2012, which was caused by an industrial material that transforms into formaldehyde by chlorination. There are high risks of water resource contamination in Japan because of high dependence on surface water such as river water. That is the reason why we have to realize the potential causes of contamination incidents, and thus we need to take a comprehensive water-quality-control approach. TMW had introduced WSPs antecedent to the other water utilities in Japan. Since 2008 we have implemented Tokyo High Quality Management Program (the Tokyo version of the Water Safety Plan) in all the WTPs and distribution systems. In this paper, after a brief introduction of the concept of WSPs, the introduction steps and the operational processes of the WSPs in TMW are reported.

2. Water Safety Plans (WSPs)

2.1 What are the WSPs?

2.1.1 The circumstances surrounding water quality management and the necessity of comprehensive water-quality-control measures

The safety of tap water is secured by regular monitoring of water quality to meet the national drinking water quality standards stipulated in the Water Supply Law. The high quality of tap water is maintained by the following procedures: monitoring the water quality at a higher frequency than that required by the Water Supply Law, monitoring the tap water quality continuously, checking water quality of raw and purified water at the WTPs, monitoring water resources, and controlling the processes of water treatment according to water quality. The quality control of examination has been improved in order to secure the accuracy of the water quality monitoring, to publish how quality of examination is secured, and to facilitate understandings of the customers about the safety of tap water. However there are still various risks in the water supply systems, such as occasionally reported contamination incidents and offensive tastes and odors. In addition, there are other problems, such as the aging of the water supply systems and the decreasing numbers and aging of engineers.

Regardless of these adverse circumstances, we have to maintain uninterrupted supply of safe and delicious water by securing the safety of tap water. Hence, we need a comprehensive management approach of water supply from the catchment to the customer tap.

2.1.1 The proponent of water safety plans

In the Guidelines for drinking-water quality (the 3rd edition) published in 2008, WHO proposed water safety plans as water quality management approach, while the values of water quality standards were also updated. The WSPs are water quality management approaches to supply safe drinking-water continuously based on HACCP (Hazard Analysis and Critical Control Point, a hygienic control method in the food processing industry). By the WSPs, it is possible to indentify all risks from the catchment to the customer's tap comprehensively and control them. In the Guidelines for drinking-water quality (the 4th edition) published in 2011, WHO emphasized the importance of introducing WSPs. Furthermore, the statements on the relationship of each section WSPs were added, and the importance of WSPs was further emphasized.

In Japan, it was recommended to improve the level of water quality management by developing WSPs in *the Vision for Water Supply* announced by Ministry of Health, Labor and Welfare in 2013. Afterwards, it was recognized as an important approach to improve the level of water quality management by a comprehensive approach using

WSPs in *the New Vision for Water Supply* published in 2013.

2.1.3 The concept of HACCP

WSPs are the approaches of water quality management using the HACCP systems. In the HACCP, the probability of hazards caused by food is analyzed, and the safety of foods is secured by controlling processes that can control risks as an important control point from production to delivery. The concept of HACCP is shown in Figure 1.

If the products are inspected only in the process of shipping, which was the ordinal method of hygiene management, the number of inspections needs to be increased in order to make absolutely sure for the safety of products, which leads more costs. On the other hand, an occurrence of hazard can be prevented effectively if we control intensively some processes which are the critical control points to lead to food poisoning, for example stewing process and cooling process.

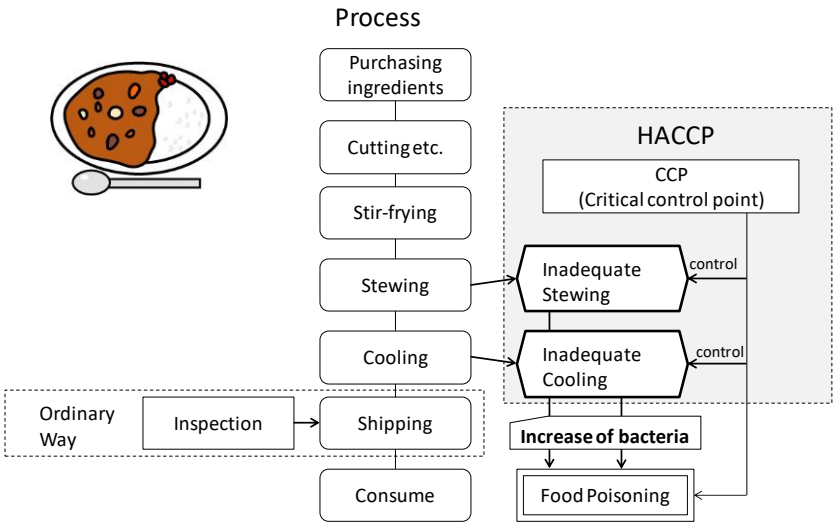

Figure 1. Process management by HACCP.

2.1.4 The concept of WSP

In the Guidelines for drinking-water quality (the 4th edition), WSPs are defined as follows: "*The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from catchment to consumer. In these Guidelines, such approaches are termed water safety plans (WSPs).*" The main components of WSPs are follows:

1) *A system assessment* to determine whether the drinking-water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets identified targets. This also includes the assessment of the design criteria of new systems;
2) Identifying control measures in a drinking-water system that will collectively control identified risks and ensure that the health-based targets are met. For each

control measure identified, an appropriate means of operational monitoring should be defined that will ensure that any deviation from required performance is rapidly detected in a timely manner;

3) Management and communication plans describing actions to be taken during normal operation or incident conditions and documenting the system assessment, including upgrade and improvement planning, monitoring and communication plans and supporting programs.

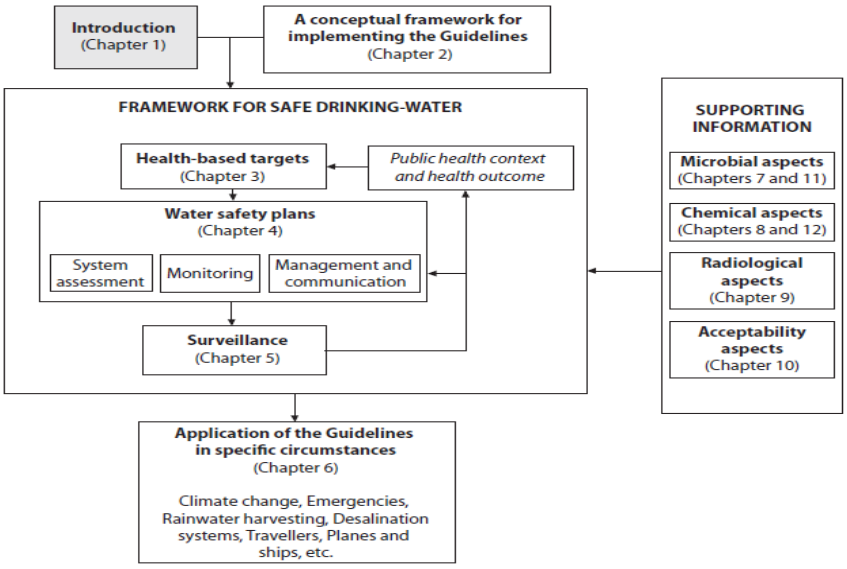

Figure 2 The outline of the Guidelines of drinking-water quality

WHO recommends water suppliers to develop WSPs. Water suppliers have to analyze the hazards of each process from the catchment to the customer tap, and implement control measures, by which contaminations are reduced or eliminated in WTPs. Hence it is possible to undertake the systematic water quality management for supplying safe drinking-water continuously.

2.2 WSPs in Japan

In Japan, the importance of WSPs has been recognized from the time when the Guidelines for drinking-water quality (the 3rd edition) were being developed. WSPs were evaluated as an important approach to be promoted in *the New Vision for Water Supply* published in 2013, updating *the Vision for Water Supply* in 2004. In *the New Vision*, the three pillars for the management of the future water utilities were proposed: Sustainability (the assurance of sustainability of waterworks services), Safety (assurance of water safety), and Resilience (the thorough measures for crisis). The WSPs was explained as a measure to achieve Safety. It will be needed to enforce

consistent management of water quality from the catchment to the customer's tap, and to develop WSPs which are comprehensive approaches of water quality management. In *the Roadmaps to promote the Waterworks New Vision* published in 2014, developing WSPs in all water suppliers was set as one of the goals: the WSPs will be implemented in 100% of water utilities in 10 years; hence, the WSPs should be in operation in 5 years for water utilities with more than 50,000 of service populations.

However, only 9% of the water utilities developed the WSPs by the end of FY 2011 (*the New Vision for Water Supply* published in 2013). It has increased slightly to 13% by the end of FY 2014 (Office memorandum about the simple tool which assists to develop WSPs from Ministry of Health, Labor and Welfare 02/06/2015). WSPs are hard to be developed in Japan.

Ministry of Health, Labor and Welfare published some tools to help the development of WSPs considering the situation of Japan. (Table 1)

Table 1 Document related to WSPs published by government

Date	Related document by government
May 2008	The guideline for development of WSPs
September 2008	The case studies for WSPs
December 2008	The assisting tool to develop WSPs
June 2015	The simple tool to assist development of WSPs

3. WSPs of TMW

3.1 The outline of the TMW

The outline of TMW is in Table 2 and Figure 3. At present, TMW owns 11 large-scale WTPs and a total length of 27,000 km of the distribution network; and it has a service population of 13 million.

Table 2 Summary of Tokyo Metropolitan Waterworks facilities.

Service area	1235.0 km^2
Population served	12,948,000
Total length of distribution network	26,613 km
Total production capacity	6,860,000 m^3/day
Number of main water treatment plants	11

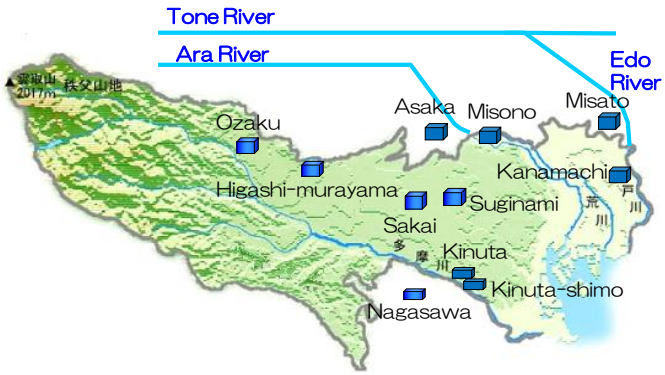

Figure 3　Location of water treatment plants

3.2 The flow of development of WSPs

3.2.1 The schedule of development of WSPs

We developed a WSP previously for one model WTP, and expanded the WSP to other WTPs. Misato WTP was selected as a model plant because it took water from the Tone-River system that supplied 80% of the total water supply in TMW. The Misato WTP has both the rapid sand filtration treatment and advanced water treatment then. So we had developed a WSP at Misato WTP previously in FY 2006.

After that, we developed WSPs for other WTPs in FY 2007 based on the WSP of Misato WTP.

The schedule is shown in Figure 4. We had developed WSPs for all the WTPs by FY2008, and we have operated them from FY 2009.

	FY 2005	FY 2006	FY 2007	FY 2008
Misato WTP	Information gathering	Development	Opreation	
Othre WTPs		Information gathering	Development	Opreation

Figure 4　The schedule of development and operation of WSPs

The developments of WSPs were undertaken as follows; firstly, we conducted *hazard analysis* about all the risks that were supposed to occur from the catchment to the customer tap according to risk evaluations. Next we determined *the control measures* to prevent or minimize hazards when they would occur. Furthermore we documented

control measures in the manuals.

3.2.2 Hazard Analysis

3.2.2.1 Hazard Identification

We researched the cause of all potential hazards that could affect water quality throughout the water supply system from the catchment to the consumer tap. We collected information of the past reports of water pollution at first. Next we collected statistical data such as the population of the target basin, the sewage coverage, the number of domestic animals, and the situation of land use. Then, they were correlated to pollution loads from household wastewater and animal husbandry. We also collected statistical data about the amount of transportation of specified chemical substances. According to these data, we estimated the concentration at the intake points when a water pollution substance might flow into rivers, and estimated the potential of water pollution. Furthermore in case of incidents in the waterworks facilities, we collected the information of the facilities, equipments, and chemical products that were used in WTPs and the distribution systems. The data was also collected about some hazards against groundwater based on the past reports of the WTPs utilizing groundwater in the Tama distinct and other areas. Based on the above-mentioned information, we indentified hazards from the catchment to the customer's tap except the disaster by armed attack and radiological accidents. We now indentify 93 kinds of hazards for WSPs, as shown in the separate sheet.

3.2.2.2 Identification of the items of water quality

Subsequently we determined the items of water quality considered in the WSPs. The items of water quality in WSPs were determined to include national drinking-water quality standard items, complementary items for water quality management, items needed investigation, and our own water quality targets for delicious water. Furthermore we add items concerned with the past incidents and the pathogenic microorganisms. Finally about 120 items shown in the separate sheet are identified for WSPs.

3.2.2.3 Prioritizing hazards

We established operational limits of each water quality item in order to judge when to reinforce water quality management. Operational limits were established individually based on 10 – 50% values of the national standards.

Next we classified the risk levels into five steps on every item of water quality by using the classification list (Table 3). The frequency of occurrence and the degree of damage are estimated by the result of water quality examinations and the expected

concentrations of pollution substances and the specified chemical substances.

Table 3　The classification list of risk level

Frequency of occurrence	Degree of damage		
	Lower than operational limit	Operational limit ～ Water quality standard	More than Water quality standard
once a week or more	**2**	**4**	**5**
less than once a week ～ once a month or more	**1**	**3**	**5**
less than once a month ～ once a year or more	**1**	**3**	**5**
less than once a year	**1**	**3**	**5**

3.2.2.4 Identification of control measures

Next we determined the control measures in case of hazards. Control measures are determined for each process of WTP, distribution, and supply system. The outlines of control measures are defined according to the risk levels. (Table 4) We implement urgent measures such as closing the water intake valves if the risk level is 5. We reinforce management and monitoring such as optimizing injection of chemicals if the risk level is 3 or 4. As for Level 1 or 2, which are below the operational limits, we continue the ordinary management. for the risk level becomes either Level 2 or 4 when the frequency of occurrence is once a week or more; in such cases, we have to consider permanent measures such as maintenance of facilities and equipments because the frequency of occurrence is high. In order to notice fluctuations of water quality and ensure the effectiveness of the control measures, we monitor and check water quality. Finally, we made *the lists of control measures*, in which we described the cause of hazard, risk level, control measure, item to monitor, method to monitor, and operational limit for each item of water quality. (Figure 4)

Table 4　Risk level vs Control measures

Risk level	Control measures
5	Stopping water intake or water supply as a general rule
4	Reinforcing of management(Proper injection of chemical, Drainage at distribution pipes, etc) In addition, undertaking permanent measures
3	Reinforcing of management (Proper injection of chemical, Drainage at distribution pipes, etc)
2	Continuing ordinary management In addition, undertaking permanent measures
1	Continue ordinary management

The lists of control measures　　Residual Chlorine　　Misato WTP

Cause	Manual	Risk Level	Water Resource	Intake	WTPs						
					Receiving well	Coagulation basin	Flocculation basin	Sedimentation basin	Intermediate chlorination	Rapid sand filtration	Post chlorination
Discharge without treatment from sewerage	For disorder of chlorination after sedimentation or filtration	3	*Occurrence of hazard*	**check point*	**Proper Chlorination**	**check point*		**check point*	**Proper Chlorination**	**check point*	**check point*
Item: Residual Chlorine Point of monitoring: shown by * Operational limit: 0.10-0.40mg/l after sedimentation						**monitoring consistently*		**monitoring consistently*		**monitoring consistently*	**monitoring consistently*
Item: Ammonium nitrogen Point of monitoring: shown by * Operational limit: None				**monitoring consistently*							

Figure 4　A example of the lists of control measure

3.2.3 Documentation of procedures

We documented control measures and procedures as unified manuals for Level 3 or higher. We have to reinforce management about hazards of Level 3 or higher, while we continue ordinary operation at hazards of Level 1 or 2. As unified common manuals, we prepared about 50 kinds of manuals. (Table 5)

Table 5　List of the manuals

Process	Target of control measures
Raw water	Water-tank for detection of contamination, Zinc and Copper, Musty odor（Geosmin or 2-MIB）, pH, Odor, Turbidity, Oil
After sedimentation	pH, Odor, Residual Chlorine
After filtration	Turbidity (rapid sand filtaration, menbrane filtration, slow filtration), Residual chlorine
Purified water	Water-tank for detection of contamination, By-product by chlorination, Choric acid, Bromic acid, TOC, pH, Odor, Turbidity, Residual chlorine, Contaminations from equipments, Tri-chloramines
Raw and purified water	Toxic substances(Cadmium, Mercury, Lead, Arsenic, Cyanide, Chromium, Selenium, Boron, Fluoride, Choric and Perchlonic acid, VOC), Pathogenic microorganism
Groundwater	Turbidity, Pathogenic microorganism, Dumping of poison, Toxic substances
Distribution	Turbidity, contamination from equipments, Odor, Residual chlorine, Foreign matter
Supply	Turbidity, Odor, Residual chlorine, cross-connection of pipe, Foreign matter, Zinc

3.2.4 Establishment of methods for reviewing and recording WSPs

We decided to undertake regular review of implementation of WSPs under PDCA cycles. As a regular review, we describe and record the conditions of control measures toward hazards, and regularly collect the disorders when control measures are implemented in practice. Their conditions and problems are summarized at the meetings by concerned members. It enables us to review WSPs regularly.

3.3 Tokyo High Quality Management Program (the Tokyo version of the Water Safety Plan)

In addition to the risk management by WSPs, we undertake, in the ordinary times, the quality control measures according to ISO9001, which is the international system of quality control. Additionally, we examine water quality according to ISO/IEC 17025, which is the international standard to certify the objective reliability of water examination. We implement the three systems integrally as Tokyo High Quality Management Program (the Tokyo version of the Water Safety Plan) since 2008.

3.3.1 Risk management by WSPs

The hazards of water resources can be discovered immediately by our own inspection and other information from networks of waterworks. After the discovery of hazards, we comprehend the situations by exchanging information and inspection. We can incorporate them into WTPs immediately.

In the WTPs, water quality from raw water to purified water is being monitored consistently so as to discover hazards in advance. If a hazard of Level 3 or higher would occur at the water resources or the WTPs, we implement control measures to prevent the harmful influence to water quality. Control measures at the WTPs are to optimize injection of chemicals such as powdered activated carbon and poly aluminum chloride, to decrease the amount of treated water, and to stop treatment according to situations.

In the distribution systems, we monitor and detect disorder of water quality immediately by automatic measuring instruments, which are equipped at water supply stations and 131 sites in the supply-coverage area. If the hazard of Level 3 or higher would occur, we implement measures such as changing supply routes etc.

In the water supply system, we judge whether a real disorder would occur by manuals for inquiry from the customers, and implement measures immediately in case of real disorder.

3.3.2 Improvement of quality management in ordinary times by the method according to ISO9001

At WTPs, we undertake more precise management of operation and water quality in ordinary times by the method according to ISO9001 when the risk level is under 3. Furthermore we undertake PDCA cycles each WTP to improve water quality management consistently.

3.3.3 Identification of high levels of safety and good taste by water examination with high accuracy based on ISO/IEC 17025

In our laboratories for the examination of water quality, we undertake water quality examination with high accuracy based on ISO/IEC 17025 according to *water quality inspection plan* which is determined each fiscal year. It enables us to guarantee high levels of safety and good taste that are ensured by systematic water quality management.

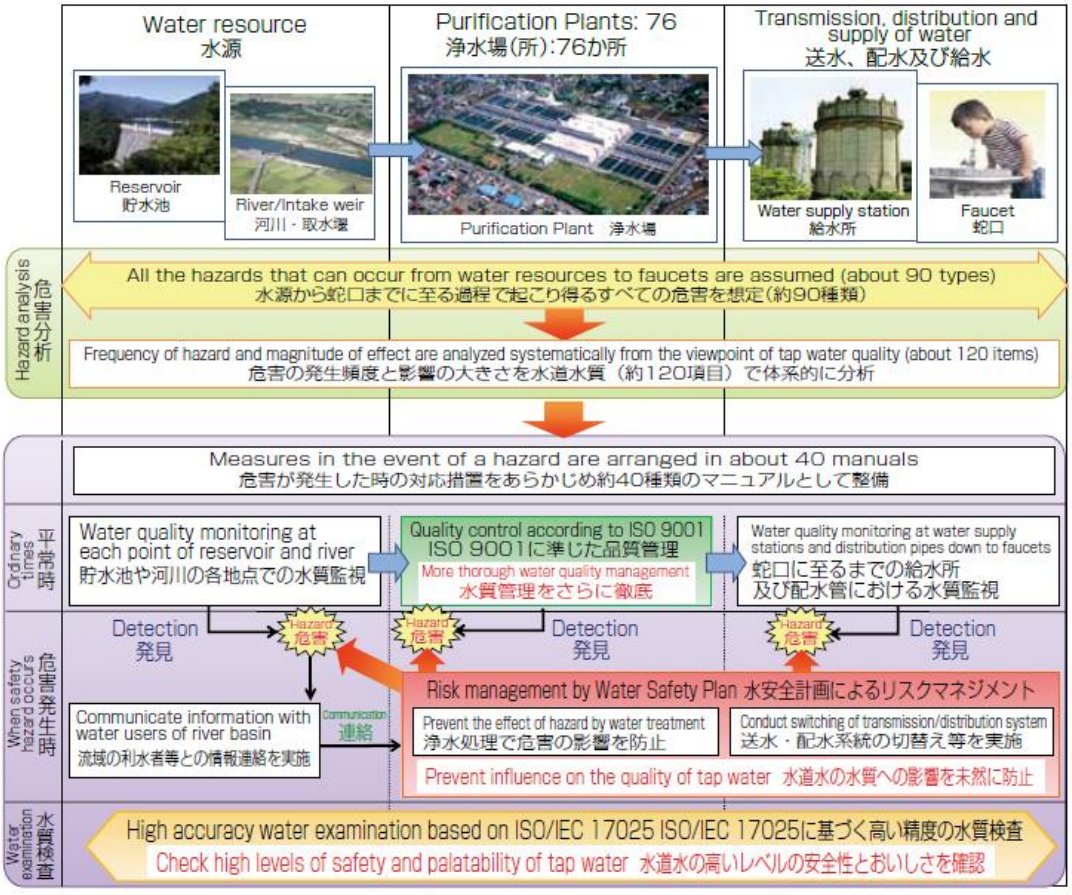

Figure 5　The outline of Tokyo High Quality Management Program

4. Future task

Until now, the Tokyo High Quality Management Program has been operated for about 7 years. Because various data that had been used for the hazard analysis to classify the risk levels are still the same as the first ones, renewal of the data is needed now. However there are many kinds of data used for WSPs. The number of manuals which were developed in TMW was more than that of the first set of manuals, and the workload of renewal will be increased. Now our future task is to maintain and update the WSPs properly.

On the other hand, there are other tasks that we continue our efforts to inform properly the contents of the WSPs to our new staffs regardless of regular personnel changes.

There are sometimes unexpected incidents of water quality changes. If the incident beyond our expectations would occur, we have to determine whether the WSPs should include detailed accounts of those incidents, or the WSPs should be established flexibly to some extent. It is a big challenge to make our system more user-friendly and easy to update, while maintaining consistency of other relevant documents.

5. References

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