Operation of Tap Water Quality Management System to aim at securing the Highest Level of Safety and Security: Continuous Verification and Review of Tokyo High Quality Management Program

E. Omori*, K. Tominaga**

* Bureau of Waterworks, Tokyo Metropolitan Government, 1-3-1, Miyado, Asaka-city, Saitama,

** Bureau of Waterworks, Tokyo Metropolitan Government, 2-8-1, Nishi-Shinjuku, Shinjuku-Ku, Tokyo,

Abstract: Tokyo Waterworks Bureau has steadily operated and reviewed the “Tokyo High Quality Management Program”, as the Tokyo version of the Water Safety Plans since it was formulated ten years before. However, in recent years, massive water quality accidents that we never experienced so far have occurred by radioactive substances and substances out of water-related laws and ordinances. We have summarized extensive knowledge of these water quality accidents and have collected information on Japanese chemical substance quantities in use and water quality accidents inside and outside Japan in order to enhance the content of the Water Safety Plan. Thus, we have been able to widely expand the adaptable range of hazards through the program.

Keywords: Water quality management; water safety plan; ISO 9001 standard; ISO/IEC 17025 standard; the PDCA cycle

1 Introduction

Tokyo Waterworks Bureau has always endeavored to supply safe and delicious water from water resource to tap at every stage of the process. Furthermore, domestically for the first time in 2008, we formulated the Water Safety Plan to conduct risk management from water resource to service faucet because of potable water quality needs and demands to refine safety and taste. We have added ISO/IEC17025 standard to this plan; they guarantee highly reliable water quality inspections and quality control that conforms to the international standard of ISO 9001. We have operated and continually reviewed the plan in the form of the “Tokyo High Quality Management Program”.

However, in recent years, due to the detection of radioactive substances through the nuclear power plant accidents arising from the Great East Japan Earthquake, and owing to substances out of water-related laws and ordinances, massive water quality accidents that we never experienced so far have occurred. In addition, further countermeasures are essential in order to appropriately deal with the risk of water quality accidents caused by many factories in river basins, and support the capital functions and the lifestyles of citizens because of increasing threats of terrorist attacks in line with the upcoming 2020 Tokyo Olympic and Paralympic Games.

In order to completely handle an adaptable range of hazards, we have carefully re-investigated the factors (hazards) that can affect the quality of tap water, and have newly incorporated into hazards that have not been presumed up until now. As well as summarizing knowledge obtained from water quality accident case studies unprecedented at the time, we have also selected chemical substances with high risk of accident at water resources, and have collected information on water quality accidents both domestically and internationally. Based on these results, we will report the intensively reviewed Water Safety Plan.

2 An overview of the Tokyo High Quality Management Program

2.1 The Tokyo High Quality Management Program

This program is a comprehensive water quality management system that operates through the unification of three elements: risk management of the water safety plan advocated by the World Health Organization (WHO), high level quality control conforming to ISO 9001 standard, the international standard of quality management systems; and ISO/IEC 17025 standard, the international standard that guarantees the objective reliability of water quality inspections.

Tokyo Waterworks Bureau always verifies and reviews the program by the PDCA cycle, such as by conducting operation meetings regularly every year. At these operation meetings information is shared about case studies of handling hazards at particular purification plants about the program's operating status, and discussions are also held concerning the necessity of reforms etc. Through these efforts we implement the maintenance and improvement of high technological levels in the future, and, based on this, provide the supplying of even safer and more delicious water. Also by conveying information on the water quality management of this program, we seek to increase further reliability in tap water. An overview of the program is shown in **Figure 1**, and the operation of the program is shown in **Figure 2**.

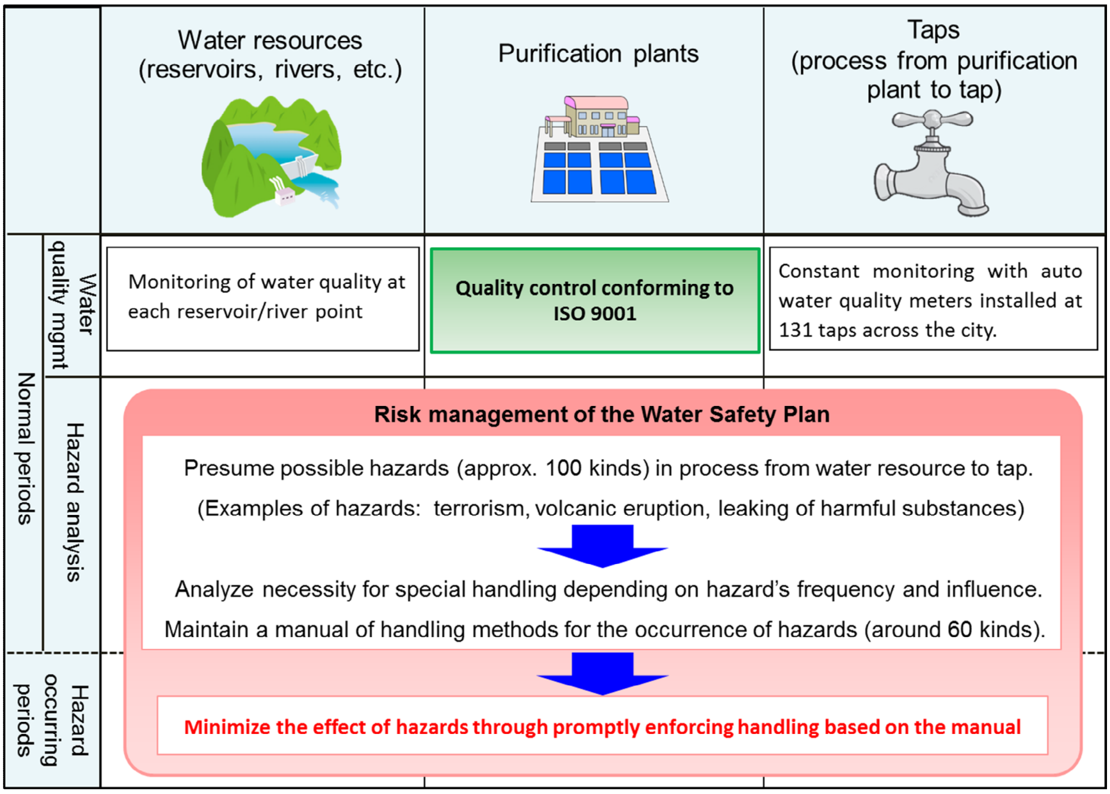


Figure 1 An overview of the Tokyo High Quality Management Program

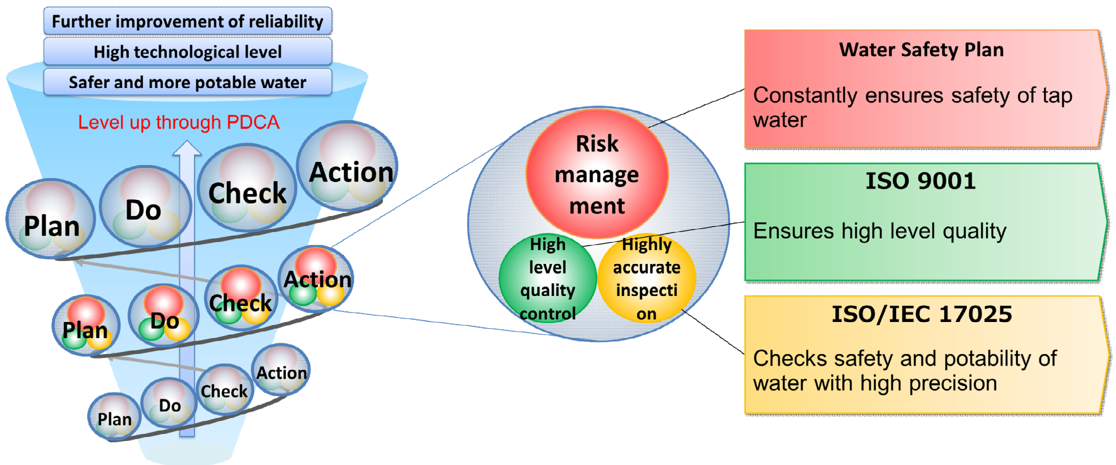


Figure 2 The operation of the Tokyo High Quality Management Program

2.2 The Water Safety Plan

This plan is adopted to the ideas of a food hygiene control method called the "Hazard Analysis and Critical Control Points" (HACCP) system, which is a risk management technique where hazards are analyzed in the water system, from water resource to tap, and control methods are decided upon in advance.

Tokyo Waterworks Bureau owns more than 70 purification plants and stations, which have diverse types of water resources such as surface water, subsoil water and ground water. In accordance with raw water quality, we adopt water treatment systems such as rapid filtration systems, slow filtration systems, advanced water treatment systems that add ozone and biological activated carbon treatments to rapid filtration systems, and membrane filtration systems. The scale of these purification plants is also various from large-scale facilities where the capacity exceeds 1 million m^3 per day to small-scale facilities whose capacities are less than 100 m^3 per day.

The Tokyo High Quality Management Program has presumed hazards based on the problems and properties of purification plants. However, after the review, we presumed around 100 different kinds of hazards such as terrorist attacks, volcanic eruptions, and the leakage of harmful substances. Every hazard has been analyzed based on its frequency of occurrence and extent of damage, and the "hazard level" that indicates the importance of hazard has been evaluated on a 5-scale index (**Table 1**). For those risks of higher hazard levels (from 3 to 5), their methods have been pre-organized as around 60 kinds of manuals.

Table 1 Hazard level evaluation table

			Extent of damage			
			Below control enhance level※		Control enhance level – below quality standard	Exceeding water quality standard
			Under 70% of level	Over 70% of level		
			a	a'	b	c
Frequency of occurrence	Over (1 time per week)	D	1	2	4	5
	Less than (1 time per week) – over (1 time per month)	C	1	1	3	5
	Less than (1 time per month) – over (1 time per year)	B	1	1	3	5
	Less than (1 time per year)	A	1	1	3	5

※ The control enhance level is set as a standard for judging early the risk of exceeding the water quality standard and enforcing stronger handling of control.

These manuals are utilized in order to minimize influence when accidents occur. The manuals include to reinforce purification through chemical dosing, modifying raw water systems, suspending purification plants, and modifying water distribution systems in order to back up areas that suspended purification plants cover.

2.3 ISO 9001 standard

In regards to overall water treatment work, including the operation of purification plants and the maintenance of facility and equipment, we enforce quality control that conforms to ISO 9001 standard, the international standard of quality management. This consists of maintaining quality manuals for the overall water treatment work in every purification plant, and performing water treatment standardization. Furthermore, we seek continuous improvement of quality control by enforcing verification and reviewing at each purification plant in accordance with the PDCA cycle.

2.4 ISO/IEC 17025 standard

In order to check the quality obtained from ISO 9001 quality control system and the risk management of the Water Safety Plan, our water examination department acquired ISO/IEC 17025 standard, which is the international standard guaranteeing objective reliability of water examinations of metals and volatile organic compounds. Also as for other analysis items, we maintain educational training and relevant documents that conform to ISO/IEC 17025 standard in order to implement water quality inspections of high precision and reliability.

3 Accident case studies related to the reviews of the Tokyo High Quality Management Program

3.1 Radioactive substance accident

With the nuclear power plant accident caused by the large earthquake that struck Eastern Japan in 2011, the effects of radioactive substances reached even Tokyo. Before the incident, atomic disasters had not accounted for hazards in the Water Safety Plan; however, the disasters caused a situation beyond the plan’s presumptions. In eastern Tokyo’s Edogawa River, which we utilize as a water resource, radioactive iodine became highly concentrated. The quantity of measurement in the Kanamachi Purification Plant’s purified water, which took in raw water from the river’s downstream basin, temporarily exceeded 100 Bq/kg, as the national provisional index concerning potable water for babies. Thus, in the space of around one day, we announced to the public that they should not allow babies to drink tap water, and provided approximately 240,000 pet bottles as a 500mL drinkable water bottle to babies instead.

3.2 Hexamethylenetetramine accident

In 2012, a massive water quality accident occurred due to hexamethylenetetramine (HMT) which was unregulated by water-related laws and ordinances. HMT is a substance that reacts with the chlorine injected through water treatment process to create formaldehyde (FA), which is a water quality standard item. An industrial waste disposal company commissioned by chemical plants didn't fully dispose of waste that included HMT, and resulted in the water quality accident of leakage in the Tonegawa River, the upper stream of Edogawa River (**Figure 3**). This was an unprecedented accident where a substance of low toxicity changed into a highly harmful substance in the purification plants.

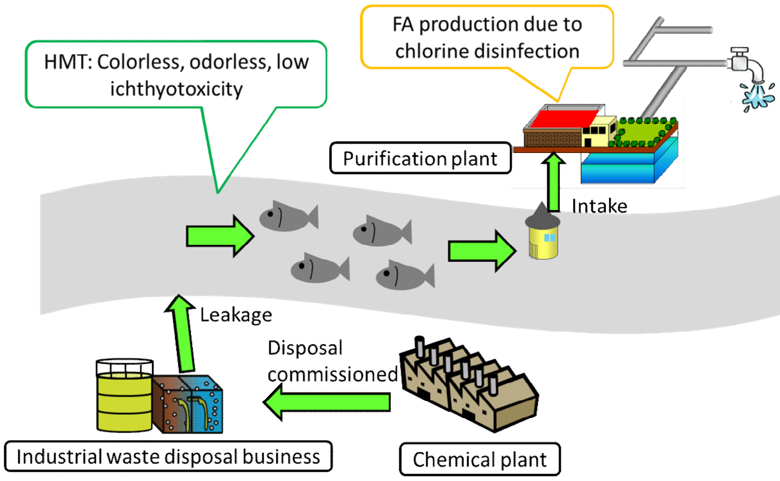
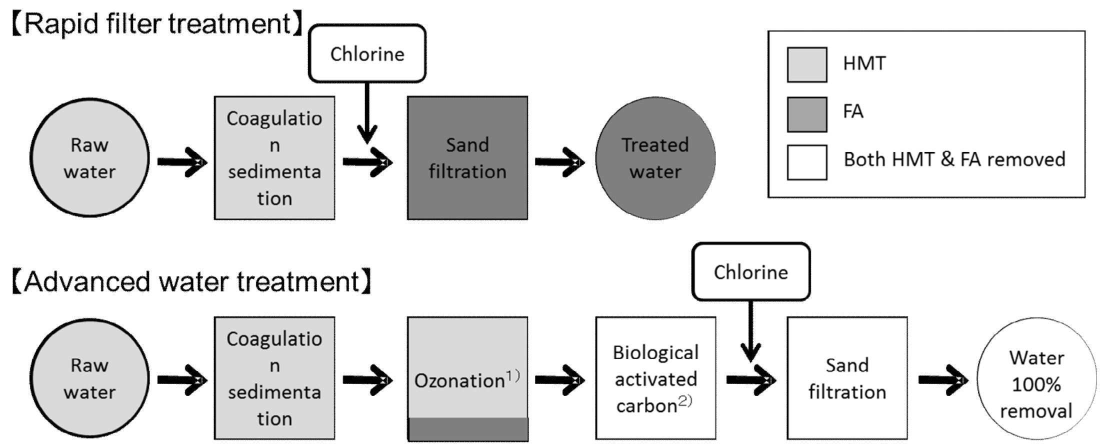


Figure 3 An outline of the water quality accident caused by HMT

The removal of both HMT and FA was achieved through advanced water treatment (**Figure 4**). However, at Misato Purification Plant, which takes in raw water from Edogawa River, these treatments were suspended because of construction. As a result, FA in purified water exceeded the water quality standard 0.08 mg/L, and also suspended water intake and transportation for around three days. During this period, by following the Water Safety Plan's manual and implementing backup distributions from other purification plants, we were able to avoid reductions or interruptions in the water supply.



1) Even in ozonation around 10% of HMT changes to FA.
2) Through ozonation and biological activated carbon treatments, HMT and FA are 100% removed.

Figure 4 The HMT and FA removal mechanisms in the water treatment process

4 Reviewing Tokyo High Quality based on the accident case studies

4.1 Handling of the radioactive substance accident and the subsequent review

Directly after the occurrence of the radioactive substance accident, in order to ensure the safety of tap water as quickly as possible in the face of an unprecedented situation, we worked to examine methods to promptly remove the radioactive substances. As a result, in the short span of around a week, we discovered the method for removal and implemented it in the water treatment.

Radioactive iodine, which had leaked from the nuclear power plant, was existing as iodide ion within the rivers. Iodide ion only slightly adsorbs to powdered activated carbon. However, by iodide ion being moderately oxidized by slight prechlorination treatment and becoming hypoiodous acid, it reacts with organic matter within the water becoming an organic iodine, making for easier adsorption with the powdered activated carbon. Thus, we discovered that radioactive iodine can be reduced through both treatment of slight prechlorination and powdered activated carbon (**Figure 5**).

Moreover, radioactive cesium was not detected in purified water. As it contained a positive charge it adsorbed to suspended substances within the rivers, and we discovered the importance of controlling suspended substances through being able to remove it along with the cesium.

After the accident, obtained knowledge and the research carried out on it afterwards was incorporated into the Tokyo High Quality Management Program.

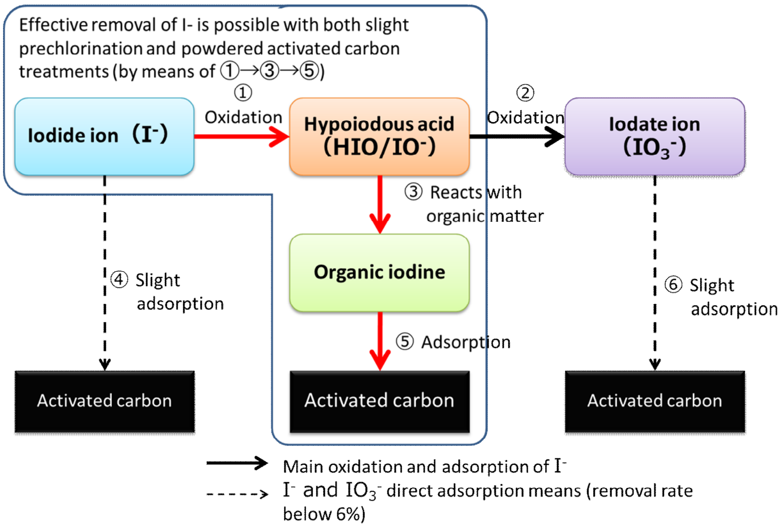


Figure 5 System of radioactive iodine removal

4.2 Handling of the HMT accident and the subsequent review

As soon as the HMT accident occurred, we quickly developed new analysis method, performed water treatment research with powdered activated carbon by desktop experiments, collected information, and applied it to water quality accident response. Also after the resolution of the accident, in order to study measures for similar substances such as HMT, react with chlorine and change into highly harmful substances such as FA and chloroform, we investigated treatments with powdered activated carbon and advanced water treatments. An example is shown in **Figure 6**.

Based on the HMT accident and the subsequent research results, we added the hazards of HMT and similar substances to the Tokyo High Quality Management Program, enhancing its content.

4.3 The expansion of the hazards targeted by Tokyo High Quality Management Program

As massive water quality accidents that have occurred in recent years have been caused by those substances which were not presumed by the Water Safety Plan, we have expanded the target substances in order to allow for more extensive handling of these accidents.

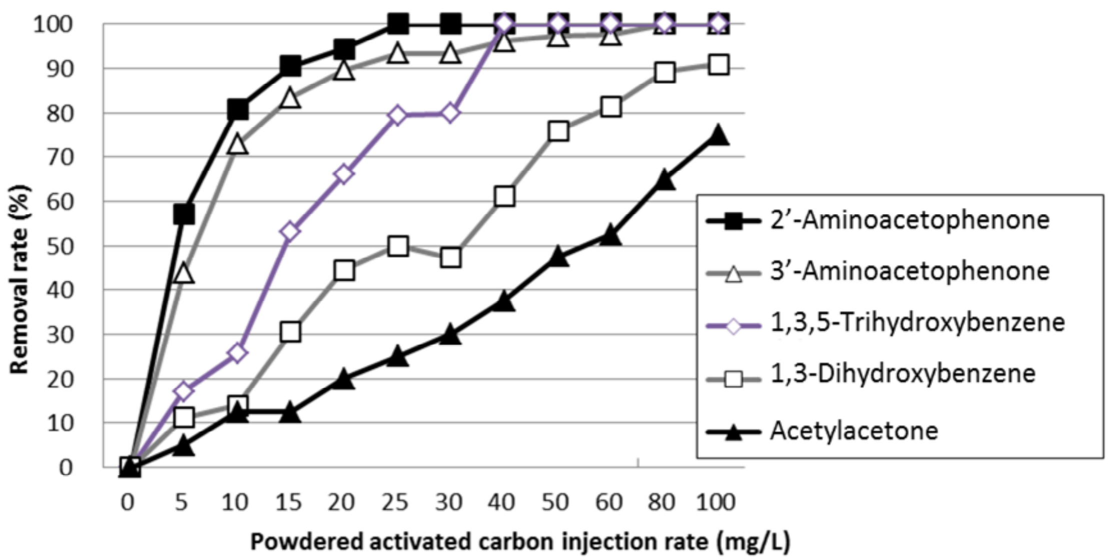


Figure 6 Treatment with powdered activated carbon of substances that change into chloroform when reacting with chlorine

Firstly, based on the PRTR(Pollutant Release and Transfer Register) law system, offices report designated movement and the quantity of emission to government offices. Among them, Tokyo Waterworks Bureau has originally chosen substances such as highly toxic and relatively hardly removable chemicals in water purification system, which are often utilized in river basins. Along with establishing an examination method for these substances, we have comprehended the treatment via water treatment processes, and incorporated the gained knowledge into the Tokyo High Quality Management Program.

Furthermore, for substances in past accident case studies (both domestic and overseas), we have gathered a wide array of information and based on the results we have integrated hazards into the Water Safety Plan such as terrorist acts of contamination and abnormalities due to volcanic eruptions, and also the response methods in relation to them.

5 Conclusion

Tokyo Waterworks Bureau has steadily operated and reviewed the Tokyo High Quality Management Program since it was formulated ten years before in 2008. We have been able to expand the adaptable range of hazards through the program, by covering substances within those specified by the PRTR law system which have high risk of causing water quality accidents, and also past water quality accident causes and terrorist attack occurring both domestically and overseas.

In order to quickly and accurately act in the case of water quality accidents, it is crucial for all personnel to deepen understanding of the program, and to improve their level of consciousness and response capacity in accidents. In the future, through an extensively revised program, we will effectuate accident training and studying of the program in order to better respond to hazards.

Along with endeavoring for the appropriate operation of the program, we will continue to build a water quality management system of the highest standards for ensuring safety and stability in the water supply throughout the future of tap water.

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