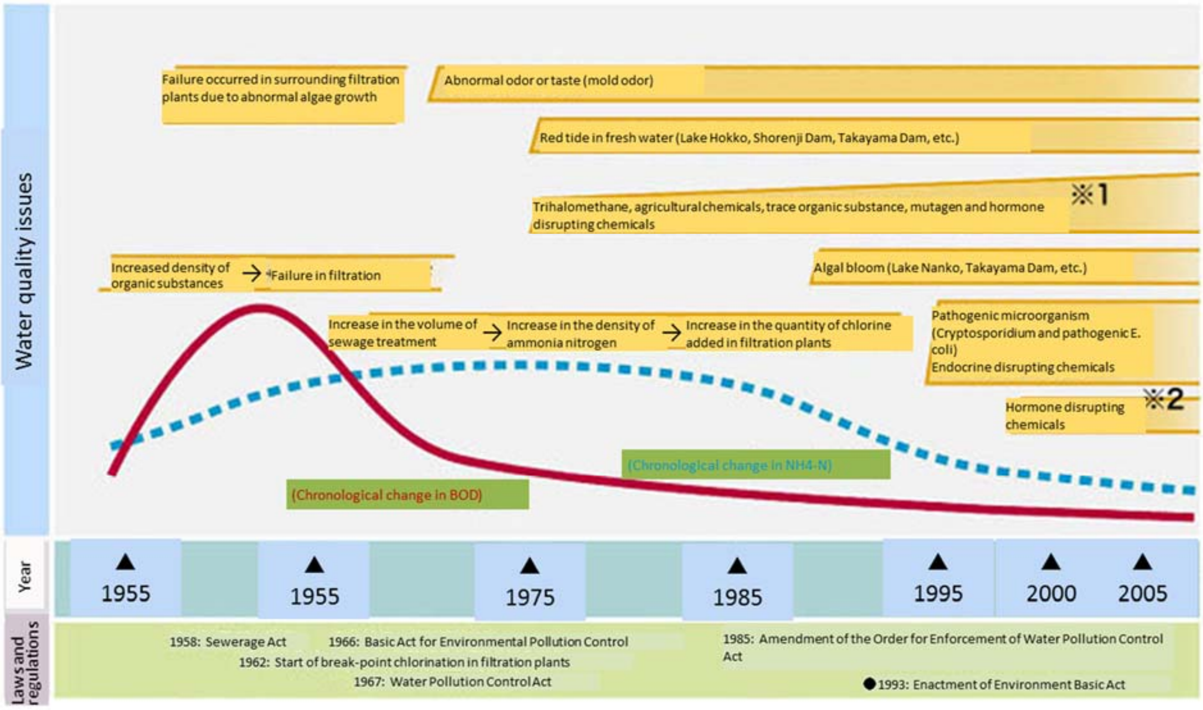
Theme 3. Water Quality Management

Contents

1. Introduction

Japan has one of the safest water supplies in the world. Water quality management has been an important public health focus ever since the first modern waterworks started in Yokohama City in 1887. Utilities successfully dealt with every water quality change at water sources and have accumulated valuable experience in this field. This module explains the basic principles and importance of water quality management in water supply systems in Japan.



*1 Polychlorinated biphenyl (PCB) typically from wastes

*2 Priority chemical substances in SPEED ’98 specified by the Environment Agency.

Source: Yodogawa River office, Ministry of Land, Infrastructure, Transport and Tourism, *Historical transition of water quality problem*, https://www.yodogawa.kkr.mlit.go.jp/know/data/problem/02/a.html

Figure 1. Water Quality Issues of Yodo River, a Source of Drinking Water for Osaka

Japanese utilities have a vast pool of knowledge and experience in water quality management and this module will answer following questions frequently asked from the participants of water supply training courses:

Q1. What measures were implemented to reduce the incidence of waterborne diseases such as cholera, which affected Japanese society in the past?

Q2. Why Japan could implement long-lasting water quality management?

Q3. What are the requirements for compliance with water quality standards for water utilities in Japan?

Q4. How has the good quality equipment required for water quality management been procured in Japan?

Q5. How has Japan dealt with the serious problems caused by deterioration of source water quality?

The following sections attempt to provide answers to these questions:

- 2. Importance of Water Quality Management (1) and (2) (Q1)
- 2. Importance of Water Quality Management (3) (Q2)
- 2. Importance of Water Quality Management (4) and 3. Drinking Water Quality Standards and its Compliance (1), (2) and 4. Drinking Water Quality Testing (1), (2) and (3) (Q3)
- 5. Standards for Water Supply Materials and Equipment for (Q4)
- 6. Preventing Deterioration of Source Water Quality for (Q5)

2. Importance of Water Quality Management

(1) History and Background on Water Quality Management

Safe drinking water is of utmost importance to public health. The Water Supply Act stipulates "water quality standards," "securement of appropriate water supply facilities" and "proper water quality management" to ensure that utilities appropriately manage secure and stable water supply from source through consumer.

The management of water quality begins from the water source through treatment and distribution to the taps of the customers.

Japan has been focusing on epidemiological safety in establishing modern water supply. The World Health Organization (WHO) defines safe drinking water as water that "does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages." The Water Supply Act established in Japan in 1957, stipulates detailed standards for the quality of drinking water and declaring that water quality management is essential for the water supply.

The Ministry of Health, Labour and Welfare (MHLW) developed the New Water Supply Vision in March 2013. Chapter 5 of the document on "Targeted Outcomes" states that "the ideal goal is to provide safe water supply by securing the best quality of raw water, treating the water appropriately, maintaining water quality in the pipelines and service connections and taking measures to secure proper hygiene of water wells so that all citizens can drink safe water anytime, anywhere." This clearly defines the concept of safe water and water quality management.

The Water Supply Act has a number of provisions concerning water quality. Article 4 on water quality standards specifies the requirements for "clean" water and the measures that should be taken to ensure proper operation and management of water supply facilities.

Article 5 sets out the Water Supply Facility Standards. Article 12 deals with supervision of construction work by a qualified engineer. Article 13 specifies the inspection of facilities and water quality testing required before commencement of operation. Article 16 states the structure and materials of service connection facilities shall be in accordance with the standards.

Article 19 specifies that a technical administrator must be appointed at each utility. Article 20 states the requirement for periodical and temporally water quality testing. Article 21 states the mandatory health checkup of workers. Article 22 lists disinfection and other necessary measures required for sanitary purposes. Article 23 defines the provisions on emergency suspension of water supply when health concerns arise.

These legislative requirements intend to safeguard public health by enforcing appropriate water quality management measures in every facet of the water supply system, from raw water intake to delivery at the taps.

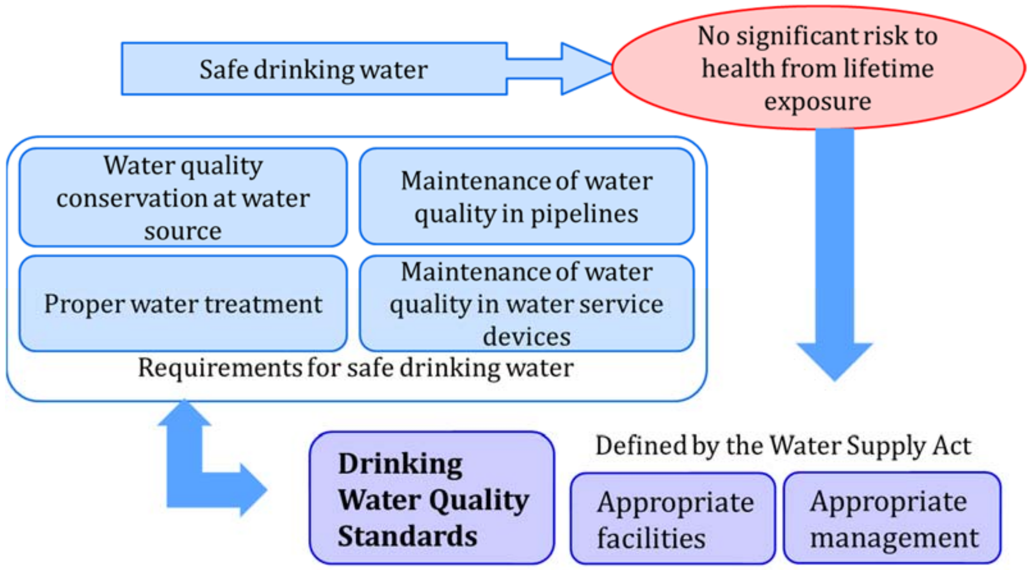


Figure 2. Concept of Water Quality Management

The Waterworks Ordinance (1890) clearly recognized that water supply development improves public health. The Health Department of the Home Ministry[1] was in charge of water supply at that time. In 1893, the responsibility was divided into two parts with the Health Bureau looking after the public health aspects, and the Engineering Bureau taking care of technical matters. In 1938, the Ministry of Health and Welfare[2] was established and its Public Health Bureau took over the public health portfolio. The technical responsibilities were eventually moved to the Ministry of Construction[3] after World War II (WW II). Over this long history and the changes in responsible authorities, the concern with water quality has always been managed from the perspective of public health.

After WW II, General Headquarters of the Supreme Commander for the Allied Powers (GHQ) ordered thorough chlorination of water as part of the treatment process. In addition, public health engineering was introduced in the National Institute of Public Health and staff of

[1] The Home Ministry was changed into the Ministry of Home Affairs in 1947, then it was merged into the Ministry of Internal Affairs and Communications in 2001.
[2] The Ministry of Health and Welfare was merged with the Ministry of Labour to form the Ministry of Health, Labour and Welfare in 2001.
[3] The Ministry of Construction was merged with the Ministry of Transport and two Agencies to form the Ministry of Land, Infrastructure, Transport in 2001.

water utilities and prefectures were trained on water quality management. In 1957, the Cabinet gave the Ministry of Health and Welfare the sole administrative responsibility for water supply. The Water Supply Act was enacted in the same year specifying a number of requirements regarding water quality management.

Column: Article 18 of the Water Supply Act

Article 18 of the Water Supply Act stipulates that customers have the right to request a utility to inspect service connection facilities and test water quality. This right entrenched in the Waterworks Ordinance demonstrates Japan's commitment to water safety and public health.

In other words, the Act enacts the aim of water supply to contribute public health and indicates water quality standards, as it put great emphasis on the epidemiological safety of drinking water. Moreover, with the provision of the right to request water inspection by customer, the Water Supply Act require that utilities, even as public monopolies, must discharge their responsibilities to their customer with vigilance and provide the enforcement mechanisms to ensure that the water supply is safe and reliable at all times.

Safe water is guaranteed by law in Japan as summarized above.

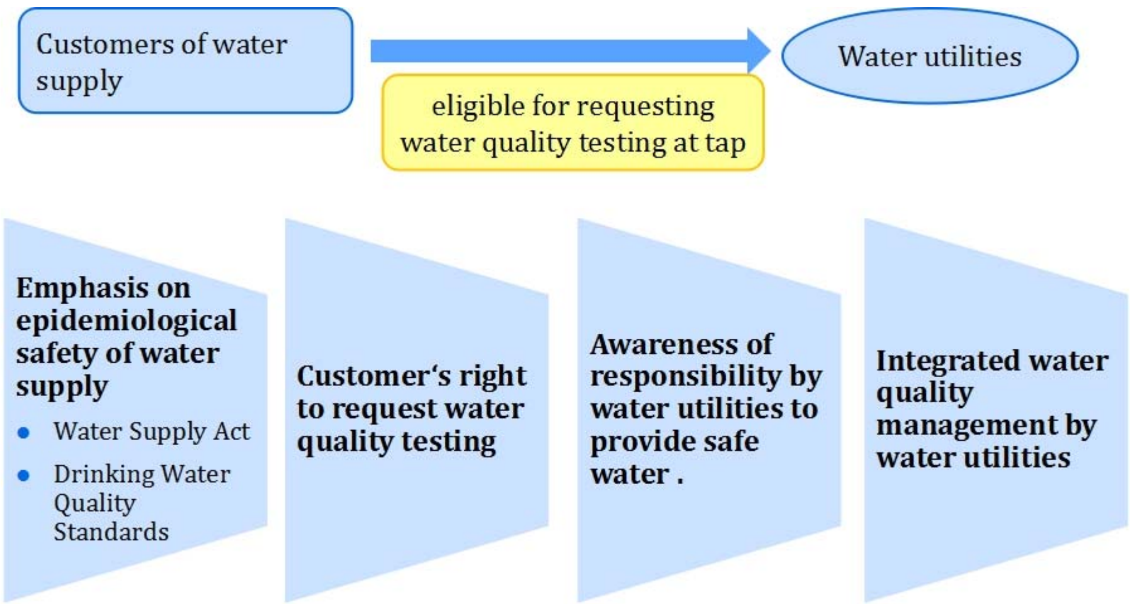


Figure 3. Implications of Article 18 of the Water Supply Act

(2) Water Quality Management System

Water quality is monitored at the water source, treatment plant, distribution reservoir and customers’ taps.

In Japan, water quality is checked at the water source, each water treatment process, distribution reservoir and customers’ taps.

Water quality can be affected by environmental conditions and human activities. The effects can be acute or long lasting. Water quality changes must be tracked and the causes and effects of the changes must be investigated. The parameters, which influence water treatment (such as turbidity and electrical conductivity) are automatically measured. Comprehensive water quality testing at the water source is conducted at least once a year even for groundwater, the source which is considered to be stable.

Water quality management in the treatment plant monitors the efficiency of the treatment to optimize the quantity of chemical injections and produce safe drinking water that will comply with water quality standards. Turbidity, pH, electrical conductivity and temperature are measured by automated instruments. Comprehensive testing is conducted about once a month.

At the distribution reservoir, turbidity, color, residual chlorine and pH are monitored by automated instruments for any water quality deterioration, and changes of air temperature and retention time. There are additional dosing facilities to inject more chlorine if the residual chlorine decreases because of change in temperature.

The purpose of water quality management on taps is monitoring the suitability for water quality standards. Water quality at customers’ taps is tested for residual chlorine, color and turbidity every day and tested once a month or once every three months for other items. Recently, automated measuring instruments have now replaced manual tests in some areas.

Since 2000, the Ministry of Health, Labour and Welfare (MHLW) conducts annual survey on proficiency testing to assess laboratory performance and verify the accuracy and reliability of test results of the registered water quality testing organizations. A total of 441 organizations were assessed in 2015. These are grouped as follows:

・Water quality testing organizations registered by the Minister of Health, Labour and Welfare (212 entities)
・Water utilities’ testing organizations who showed willingness to participate to the survey (175 entities)

・Local governments' laboratories who showed willingness to participate to the survey (54 entities)

The result of the survey with each organization's assessment and ranking in the proficiency testing is published. MHLW investigates the cause of any deficiency and recommends improvement for those with low result in statistical value ranging from 1.4 to 8.3%.

MHLW reviews historical water quality data when they revise water quality standards and waterworks management policies. Process data are also tracked and used as feedback for management of water source, treatment plant and distribution and supply departments within the utility. These data are utilized for water resource conservation, adjusting treatment processes and developing preventive measures for accidents.

(3) Costs of Water Quality Management

Water quality management requires significant financial commitment which must be clearly stated in the utility's financial plan. Small-scale water supply systems can save on water quality management by starting with good quality water sources.

Water quality management requires significant financial commitment, e.g. costs for coagulant and electricity, testing, adjusting the treatment processes, equipment for water quality analysis and human resources development.

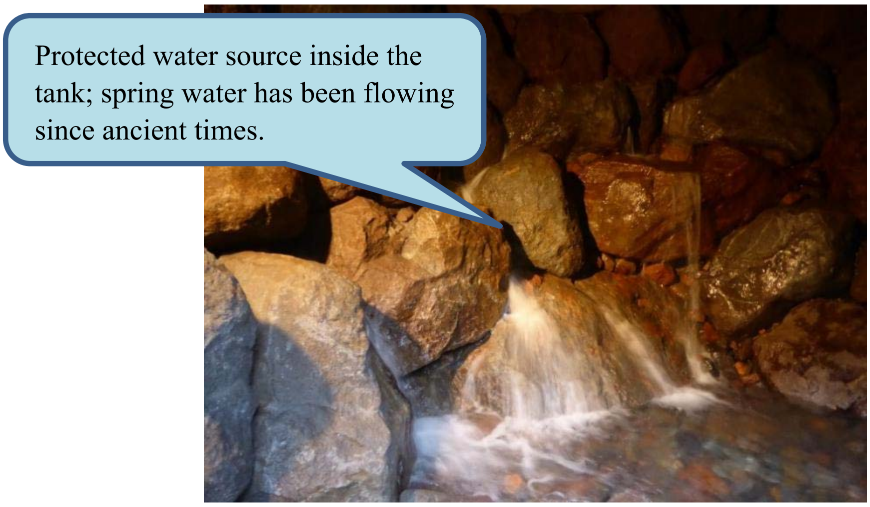
Figure 4. Costs Related to Water Quality Management

Utilities’ financial plans must include carefully considered costs for water quality management. These are then verified and approved by the supervising authority. This means that utilities need to estimate the costs accurately from the planning stage and ensure that the costs are recovered from the water tariffs. With limited revenue base and human resources, small-scale water supply systems start with good quality water sources and easily operated facilities to reduce treatment costs.

Column: Small-Scale Water Supply System Using a Water Source of Good Quality

If the source is surface water, a treatment process is essential. The treatment process and maintenance can be easy if groundwater or spring water of good quality can be used and care is taken not to contaminate the water source.

Using good quality springs as water source is acceptable for residents because they have been using such water sources since ancient times.



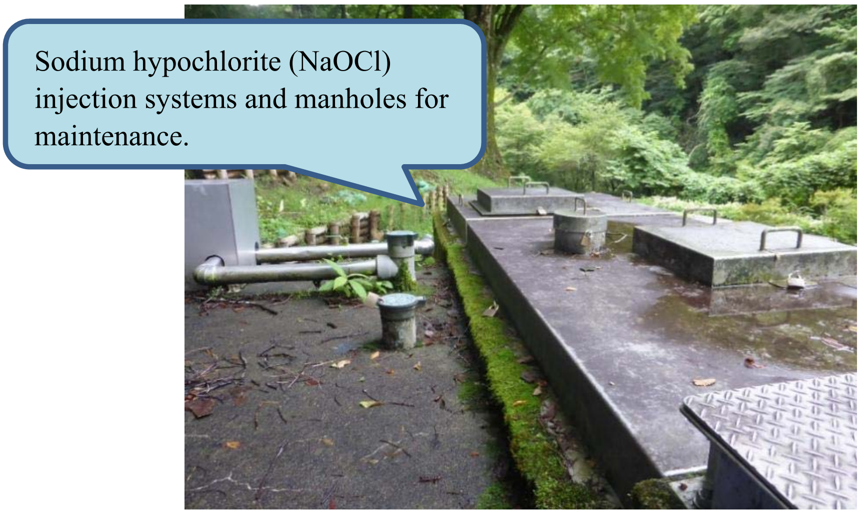


Photo 1. One of the Water sources in Hakone Town (September 18, 2015)

(4) Clarify Responsible Person for Water Quality Management

To appropriately manage water quality, a water utility needs to appoint a Technical Administrator. In addition, national and prefectural governments have administration systems to check water quality management. Small-scale utilities are supported by the administration systems.

Article 19 of the Water Supply Act requires that utilities appoint a Technical Administrator responsible for technical aspects of water supply management. The administrator has to inspect the facilities for compliance with the facility standards, test water quality, implement public health measures and suspend water supply if necessary.

A qualified administrator must have relevant formal training and adequate experience. The training course for qualification of Technical Administrators is offered by the Japan Water Works Association and completion of the course can compensate for lack of relevant experience (Article 19, Paragraph 3 of the Water Supply Act, Article 6 of the Order for the Act and Article 14 of the Ordinance for Enforcement of the Act). Water utilities appoint a Technical Administrator among those who are qualified.

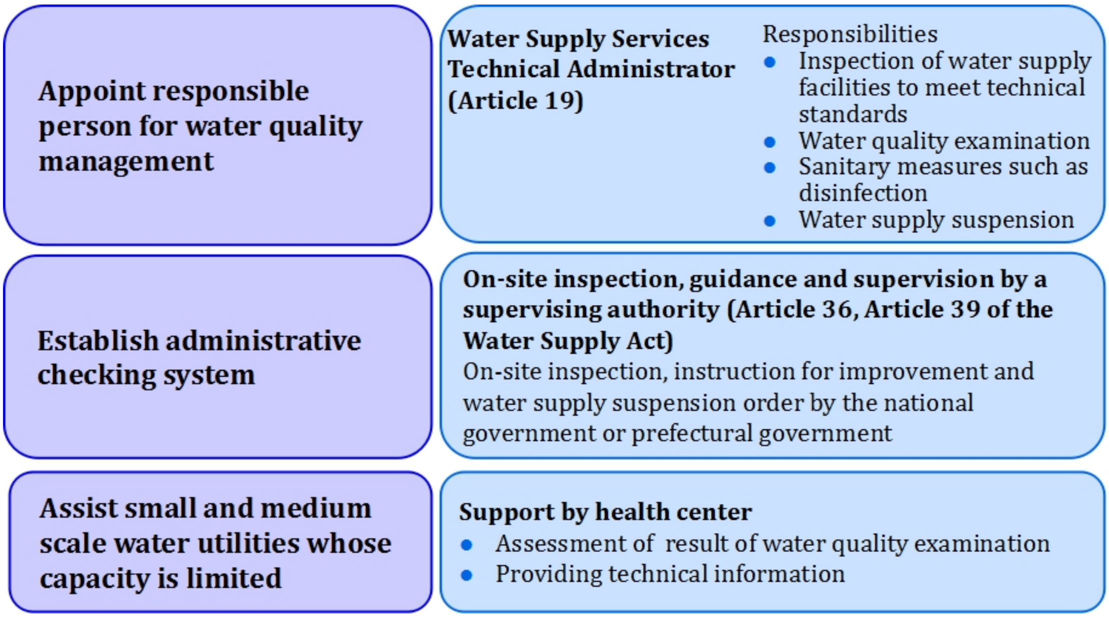


Figure 5. Framework for Water Quality Management

Site inspections by the Ministry of Health, Labour and Welfare (MHLW) and verification of the results of water quality testing by a prefectural health center are key steps in the overall management of water quality. If a water utility is judged to be not operating appropriately including its water quality management, it can be order to make improvements based on Article 36 of the Act. Water supply operations can be suspended based on Article 37.

The prefectural health center evaluates the results of water quality tests and provides technical advice on water quality. It plays an important role especially for small and medium scale utilities that do not have adequate technical expertise.

The key aspects to bear in mind when designing the water quality management system are: 1) clearly identify who is responsible for water quality management; 2) establish a system to verify that water quality is meeting the standards required by law; and 3) provide support for small and medium scale utilities to compensate for their inadequate expertise.

3. Drinking Water Quality Standards and its Compliance

(1) Formulation of Drinking Water Quality Standards

In Japan, water quality standards are established to be compatible with social demands (risk management level), natural environment and availability of testing instruments, while the focus is always on safety of drinking water. There is close to 100% compliance from Japanese utilities.

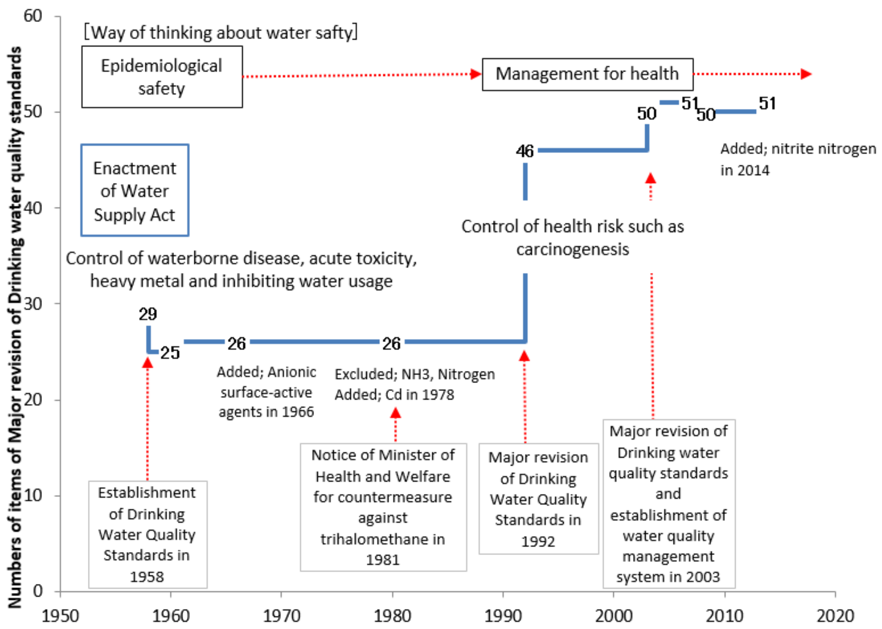
There are no international standards for drinking water quality. Many countries, including Japan, set their national standards based on their own environment and considerations. Countries without legislative or administrative frameworks for such standards usually follow WHO guidelines.

Japan has been establishing water quality standards with focus on safety, and to be suitable for its situation. The compliance of the water quality standards is almost 100%.

Article 4 of the Water Supply Act of Japan, stipulates the drinking water quality standards and Article 5 stipulates the facility standards required to achieve the desired water quality. The water quality standards in the first Water Supply Act stipulated two types of parameters in drinking water; that obviously cause health risks and that may pose nuisances in daily use such as odor, taste and color. Water quality standards are designed to protect the health of the most vulnerable members of society by setting the maximum acceptable concentrations of harmful substances determined on a scientific basis. The acceptable daily intake of contaminants is multiplied by a safety factor to avoid any possible health hazard. The maximum acceptable concentrations of non-health related qualities can vary depending on the local circumstances. For example, the *WHO Guidelines for Drinking Water Quality* specify the pH range of 6.5 to 8.5. Japanese standards set a lower range between 5.8 and 8.6 because the country has a lot of volcanoes and some of its water sources have this level of acidity. Very few countries adopt pH as low as 5.8 which can be highly corrosive.

Japanese standard for manganese has been 0.05 mg/l since 1992. The WHO guideline value has changed over time; it was 0.4 mg/l, then lowered to 0.1 mg/l in the second edition (1993) and "no guideline value" in the third edition. Manganese often reacts with residual chlorine to form manganese oxide which forms a black coating on pipes. Even concentrations of manganese < 0.05 mg/l may cause black precipitate which sloughs off turning the water black. 0.01 mg/l is determined as "Complementary Items to Set the Targets for Water Quality Management," which is items to be paid attention for water quality management other than the water quality standards' value in order to ensure the safety of drinking water for the future.

The Water Supply Act was enacted in 1957 with replacing Waterworks Ordinances. Following that, the Ministerial Ordinance on Water Quality Standards was enacted in 1958. After three minor revisions that added and deleted some parameters, the Drinking Water Quality Standards (existing 26 parameters) underwent a major revision in 1992 (figure 6).



Source: Material prepared by Koichi Ogasawara

Figure 6. Changes to Drinking Water Quality Standards in Japan

To respond to newly recognized contaminants and disinfection by-products, the national government and relevant institutions issued notifications with interim indicators and testing methods, such as the following:

- 1981: Acceptable limits for and the measures to reduce trihalomethanes, which have carcinogenic properties.
- 1984: Provisional water quality standards for and measures to reduce trichloroethylene, tetrachloroethylene and trichloroethane, which are contaminants in groundwater, originated from organic solvents from high-tech plants.
- 1990: Provisional drinking water quality standards concerning agricultural chemicals used on golf courses.

The national government and relevant institutions have issued these notices every time when the items cause health problems had detected. These notifications provide additional protection against contaminants not covered by the standards in Article 4 of the Water Supply Act, thus ensuring the quality of the drinking water at all times.

Before the major revision in 1992, the water quality concerns were mainly focused on the control of waterborne diseases, inhibitory substances, chemicals with acute toxicity, heavy metals and the aesthetic parameters. The significant changes made in 1992 reflect the new concern for long-term health risks from carcinogens. The revision resulted in a set of water quality standards with 29 parameters which address health concerns and 17 parameters related to aesthetic characteristics of drinking water, which turned into 20 parameters as of 2016. Trihalomethanes, volatile organochlorine compounds, selenium and major agricultural chemicals used on golf courses, dealt interim with under former notification, were incorporated into the health standards at that time.

These transitions were due to the shift on public health issues at times. First, successful control of waterborne diseases was achieved, while the medical treatment against acute toxic matters improved. These resulted lengthening of lifetime in Japanese society, and the public concern shifted to focus on more timely problems; increased mortality by cancer. Therefore, it has been needed to strengthen water quality management to control carcinogenic agents.

Meanwhile, WHO issued the second edition of *the Guidelines for Drinking Water Quality* in 1993. The Japanese government while respecting the WHO Guidelines, reconciled these with the country's own natural environments and social characteristics. Japan focused on disinfection byproducts other than trihalomethane such as haloacetic acid, so the standard values for them were set. The Japanese standard values were set based on large number of testing data of water sources and treated water. If the testing data had been low enough compared to those of WHO guideline values, such items were omitted from the list of Japanese standards. After 10 years of careful review, the Japanese water quality standards were revised in 2003.

(2) Notifications about Drinking Water Quality

Prefectural health centers and local authorities are important players in disseminating information on drinking water quality and changes to water quality standards.

Water quality standards concerning 25 - 26 parameters were established since 1958 until 1992. Additions and deletions of these parameters are announced through notifications as circumstances change. Utilities are informed of the changes by prefectural health centers and relevant local authorities. At times of major revisions such as those in 1992 and 2003, guidance and training sessions were organized to help utilities fully understand the changes. The dissemination of information on water quality as well as guidance and supervision of water utilities have been effective.

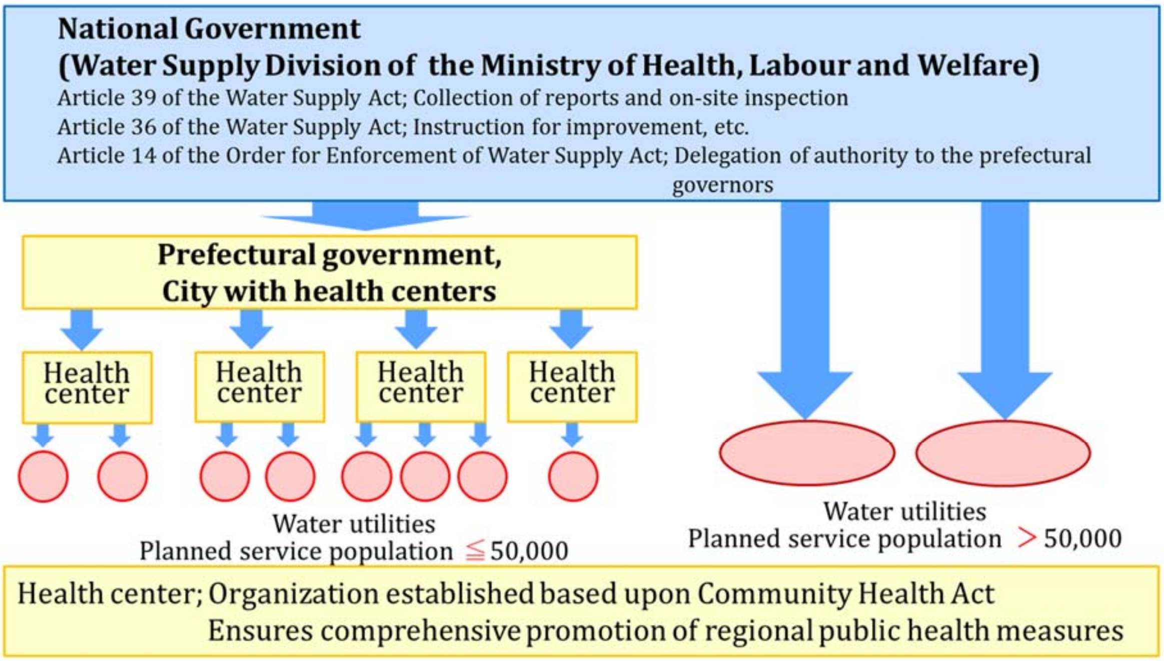


Figure 7. Administrative Framework for Water Supply

4. Drinking Water Quality Testing

(1) Water Quality Parameters and Analytical Methods

The number of water quality standard parameters has increased from time to time to reflect social concerns and availability of analytical methods. Design of water quality standards requires viability of analytical methods.

Japanese water quality standards are revised by the following procedure: (i) Committee on Living Environment and Water Supply, Health Science Council of the Ministry of Health, Labour and Welfare (MHLW) sets some parameters and values based on WHO *Guidelines for Drinking Water Quality* and research papers on health effect surveys; (ii) some large utilities conduct continuous surveys of source water and purified water; (iii) the Committee submits the report, and new parameters are added when 1/10 of the values set by the Committee are observed at the survey; (iv) MHLW amends the water quality standards based on the report of the Committee together with the analytical methods. The measurements should have an accuracy within 1/10 of the standard.

Drinking water quality parameters measured in the early days involved the use of comparatively simple instruments and microbial tests. When new parameters were added they required more advanced instruments such as absorption spectrophotometers (the chemical reaction in a sample is measured by light spectrum) and mass spectrometers. Some parameters were omitted because they were rarely detected (1,1-Dichloroethene in 2004). A comparison of the instruments used today and in 1978 is shown in Table 1.

As shown in Table 1, the number of substances that must be tested increased significantly since 1978. In 1978, the absorption spectrophotometer and atomic absorption spectrophotometer were the main measuring devices. While technology has improved tremendously by 2003, gas chromatography (GC) and liquid chromatography (LC) have become more sophisticated and mass spectrometer (the mass of a molecular or ion are detected and the measurement value is obtained as mass spectrum, MS) are more widely available. GC/MS and LC/MS are now often used in water quality testing. Water quality standards are revised as more harmful substances, such as carcinogens, are observed in the water supply. As new standards are added, it is necessary to have the appropriate technologies available for their testing.

In summary, Japan originally set the drinking water quality standards to prevent waterborne diseases and acute toxicity caused by chemical substances and heavy metals. Absorption spectrophotometers and atomic absorption spectrophotometers were the main instruments in those days. When carcinogens and chronic toxicity became serious concerns, advanced technologies such as mass spectrometers were needed and became widely used.

Table 1. Instruments Used for the Measurement of Parameters in Drinking Water Quality Standard

Current water quality testing methods		water quality testing methods in 1978	
Main instruments	**Parameters: 51 in total**	**Main instruments**	**Parameters: 26 in total**
Sensory analysis	Taste, Odor	Sensory analysis	Taste, Odor
Incubator	Standard plate count, *E. Coli*	Incubator	Standard plate count, E. Coli
		Titration (Burette)	Cl^-, Ca^+, Mg, Organic substances (Potassium permanganate consumption)
Analytical balance	Total residue	Analytical balance	Total residue
pH meter with glass electrode	pH Value	pH meter with glass electrode	pH Value
Absorption spectrophotometer	Non-ionic surfactant, Color, Turbidity	Absorption spectrophotometer	As, Cr^{6+}, CN^-, NO_3^-, NO_2^-, F, Fe, Anionic surfactant, Phenols, Color, Turbidity, Organic phosphorus
Atomic absorption photometer	Hg	Atomic absorption photometer	Cd, Hg, Pb, Zn, Cu, Mn
TOC analyzer	TOC		
Flameless atomic absorption photometer	Cd, Se, Pb, Cr^{6+}, Zn, Al, Fe, Cu, Na, Mn, Ca^+, Mg		
Ion chromatography	NO_3^-, NO_2^-, CN, F, B, Chloric acid, Bromic acid, Na, Cl^-		
Inductively-coupled plasma emission analyzer (ICP)	Cd, Pb, Cr^{6+}, Zn, Al, Fe, Cu, Na, Mn, Ca^+, Mg		
Inductively-coupled plasma mass spectrometer (ICP-MS)	Cd, Se, Pb, Cr^{6+}, Zn, Al, Fe, Cu, Na, Mn, Ca^+, Mg		
Gas chromatography-mass spectrometer (GC-MS)	Carbon tetrachloride, 1,4-dioxane, 1,2-Dichloroethylene, Dichloromethane, Tetrachloroethylene, Trichloroethylene, Benzene, Chloroacetic acid, Chloroform, Dichloroacetic acid, Dibromochloromethane, Total trihalomethane, Trichloroacetic acid, Dibromochloromethane, Bromoform, Formaldehyde, Geosmin, 2-Methylisoborneol, Phenols		
Liquid chromatography	Anionic surfactant		
Liquid chromatography-mass spectrometer (LC-MS)	Chloroacetic acid, Dichloroacetic acid, Trichloroacetic acid, Formaldehyde, Phenols		

Note: Some of the parameters can be measured by different kind of instruments.

The setting of water quality standards has to reconcile with priority concerns in the society and what can be measured with available technologies. Furthermore, it is necessary to evaluate priorities of society for introducing the items which involve high level technology to measure.

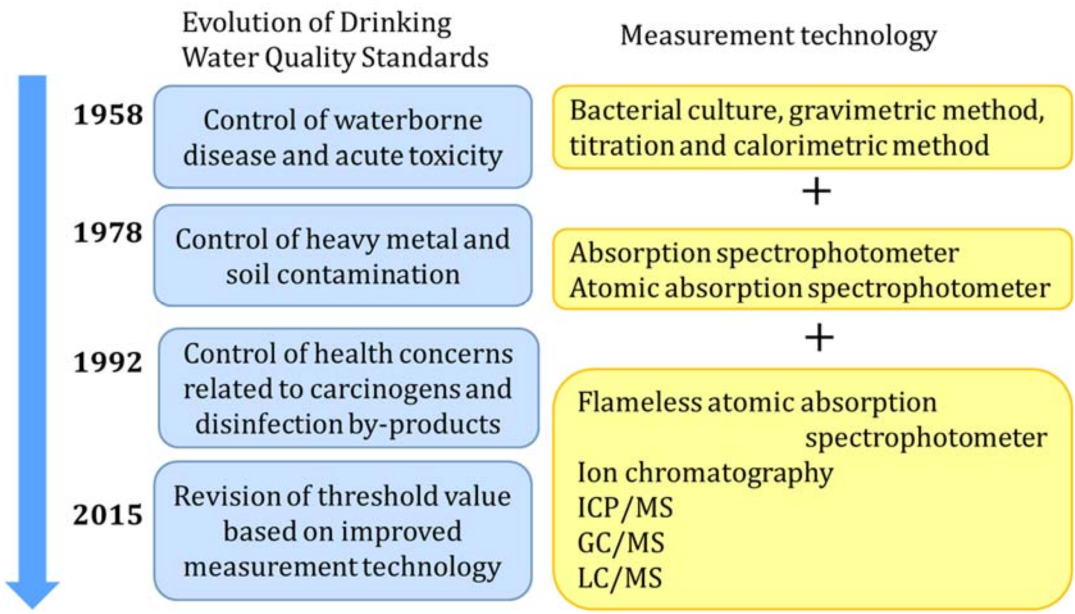


Figure 8. Water Quality Standards and Measurement Techniques

Photo 2. Gas Chromatography-Mass Spectrometer (at the National Institute of Public Health)

(2) Responsibility for Water Quality Testing

Utilities are responsible for routine testing to demonstrate that quality of the supplied water meets the legislated standards. Small and medium scale utilities do not have in-house expertise and rely on health centers to fulfill this responsibility. When utilities and health centers could not pay for expensive instruments for the increasing number of parameters to be tested, nationally-registered private facilities began to conduct the testing.

Small and medium scale utilities often do not have the facilities and technical capability to conduct all the required water quality testing; this was a problem even in 1978 when the list of substances to be tested was relatively modest compared to today. Considering the situation, in 1957, the government proposed to the Diet that: 1. utilities may identify a technical personnel in charge among them and share the responsibility; and 2. health centers could include water quality testing as one of their services. This system worked and health centers and utilities were reporting deterioration in water quality to administrative authorities. However by 1992 the health centers could no longer afford to continue the testing service, as the number of parameters was increasing significantly, and more expensive instruments such as mass spectrometers were required to test for tracing chemical substances such as organochlorine compounds. As the result, number of nationally-registered private facilities began to carry out the more sophisticated tests, as well as sample pick up and other related services. MHLW supervises these private testing facilities and the registration must be renewed every three years. MHLW conducts proficiency tests by sending out blind samples periodically to check the reliability of the test procedures and to ensure that improvements are made if required.

Today, the utilities, which have their own testing facilities and technical personnel, are roughly limited to those who are serving more than 300,000 people. Most utilities including medium size ones are outsourcing this task. The outsourcing however does not diminish the important responsibility that each utility has in the daily measurement of residual chlorine and the development of an annual water quality monitoring plan. Determining water safety and ensuring the quality of the water supply still remain a primary responsibility.

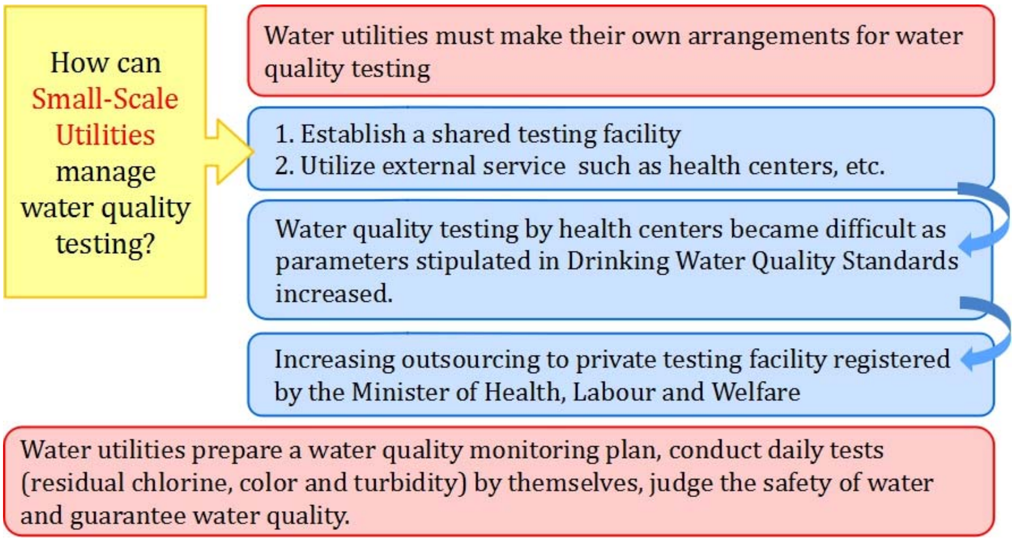


Figure 9. Responsibility of Utilities for Drinking Water Quality Testing

(3) Administrative Framework for Water Quality Testing

Utilities have to prepare annual water quality testing plan as required by Ordinance for Enforcement of the Water Supply Act. The testing plan and test results are reviewed by national and prefectural governments and health centers.

The drinking water quality standards revised in 2003 stipulate that utilities must prepare an Annual Water Quality Examination Plan (AWQEP), containing the following information:

1. The conditions to be considered in preparing AWQEP

(i.e. expected water quality throughout the supply system from raw water to customer’s tap, factors contributing to the presence of contaminants and the priority of the substances to be tested)

2. Daily and regular tests to be performed

(i.e. substances and items to be monitored, sampling locations and number of tests to be conducted; justification for reducing the frequency of tests required in the Ordinance for Enforcement of Water Supply Act)

3. Items omitted from regular testing and justification for the omission.

(i.e. reason for not testing certain items required to be tested according to the Ordinance for Enforcement of Water Supply Act) 4. Occasions of ad-hoc testing (i.e. state the need to conduct non-scheduled testing and the substances to be measured) 5. Outsourcing plan (i.e. specify in detail the tests to be outsourced to local government agencies or organizations registered by the Minister of Health, Labour and Welfare) 6. Other items to be considered in water quality testing (i.e. evaluation of test results, review of the AWQEP, accuracy and reliability of the tests and liaison with the parties concerned)

Authorities which give Approval (License) can conduct on-site inspections, check the AWQEP, the results of the tests or obtain the information in a report in accordance with Article 39 of Water Supply Act and Article 14 of the Order for Enforcement of Water Supply Act, as shown in Figure 7. If any deviation is detected, the authority shall order improvements to be made based on Article 36 of Water Supply Act.

Column: Water Quality Management Personnel

Drinking water quality management involves many workers at treatment plants, technical staff conducting water quality testing, workers in charge of monitoring tap water quality, and administrators who supervise these steps.

The Bureau of Waterworks, Tokyo Metropolitan Government, the largest water utility in Japan, has 3,794 employees (as of March 2015). Water quality management employees account for 24.6% (933) of the entire staff complement: 98 in the Purification Division, 65 in the Water Quality Management Center, 121 in the Water Resources Administration Office and the Reservoir Management Offices, 398 in the 3 Purification Management Offices, 260 in the 6 Purification Plants. This is a much larger work force than that of the utilities in rural areas. It is difficult for other utilities to assign as many employees as Tokyo to the water quality management as they need to allocate more people to water distribution. The water utilities in rural areas make effort to achieve the standards' value which is applied equally nationwide.

These workers are aware of the direct impact that drinking water has on public health. They work hard to supply high quality water and are proud to be part of this service. When they explain the work to students visiting the water treatment plant as a part of school education, they are reminded of their mission and are motivated to do their best.

Other personnel supporting water quality management are maintenance staff of the water facility manufacturers, administrative officers who distribute information concerning water quality and check compliance.

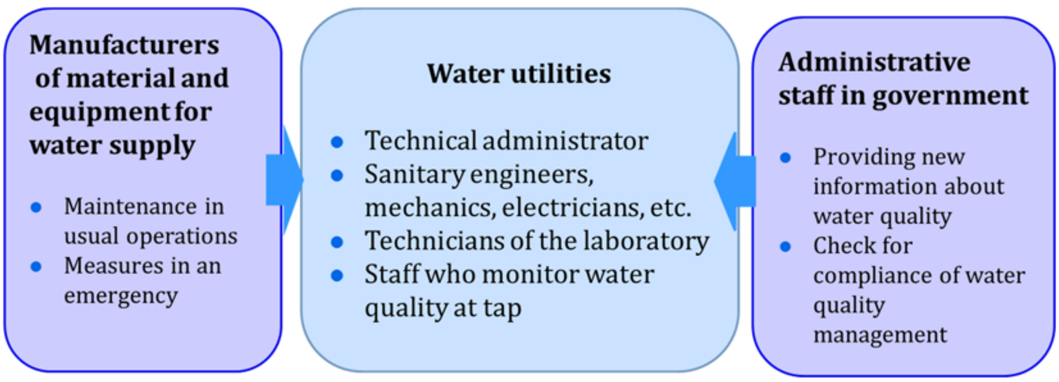


Figure 10. Water Quality Management Personnel

5. Standards for Water Supply Materials and Equipment

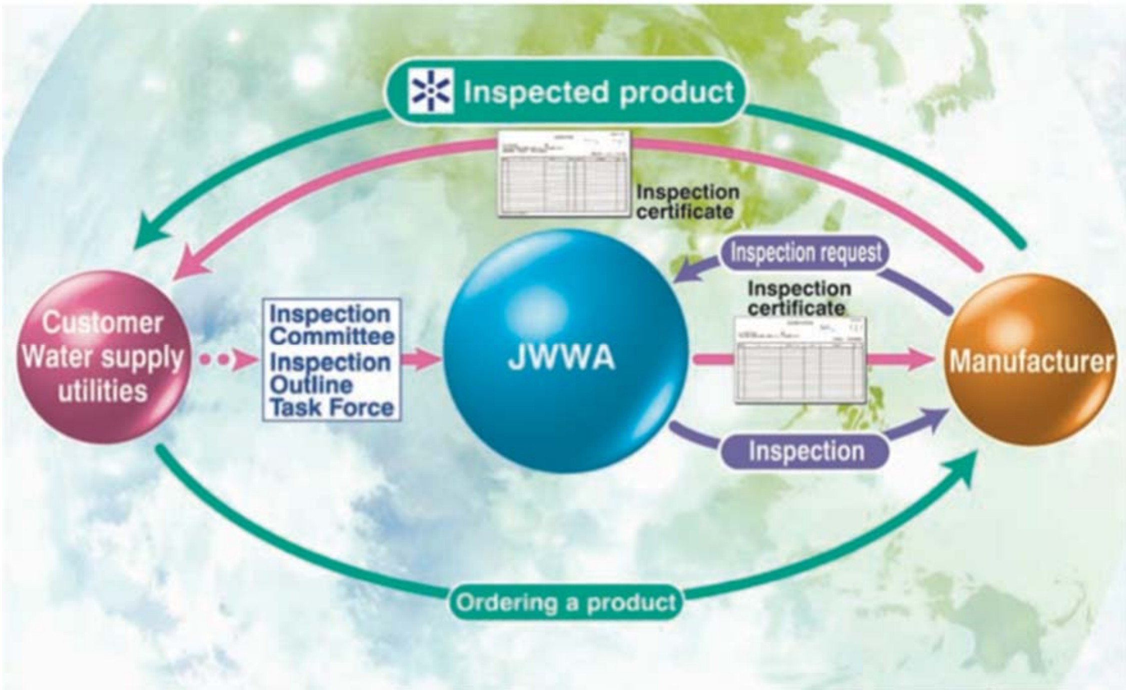
Water quality management should be conducted at the water source, throughout the treatment processes, distribution networks and up to the customers' taps. Materials and equipment used in the water supply systems must meet specified standards and this is very important for water quality management. The Japan Water Works Association inspects, certifies and registers products to ensure that they are in compliance with quality standards.

Drinking water must be clean and safe from the time it leaves the treatment plant to when it reaches the customer's home. The quality of materials and equipment of the distribution system are important for maintaining water quality.

In Japan, there are quality standards for materials and equipment used in the water supply system. Products that comply with the standards are certified. The Federation of Water Authorities, the predecessor of the Japan Water Works Association (JWWA), developed the first set of standards for cast iron pipes in 1914. These were later revised and expanded.

Each utility used to visit manufacturing facilities separately to check for product compliance. JWWA took over the task on behalf of its members in 1935 for cost reduction of utilities and efficiency of inspection. In 1997, the certification system was revised to evaluate performance and function to simplify the complex process of approving service connection facilities' model and ease some of the restrictions.

New standards and inspection methods have to be established as new materials and equipment are being developed and used in the water supply systems. JWWA ensures that strict and fair inspections are conducted in accordance with the Water Supply Act.



Source: Japan Water Works Association, "*Profile Public Interest Incorporated Association Japan Water Works Association*," http://www.jwwa.or.jp/jigyou/kaigai_file/JwwaProfile2015.pdf

Figure 11. Inspection System for Water Supply Materials and Equipment

Standards for materials and quality of water supply devices, such as faucets, and chemicals such as disinfectants, are specified in the Ordinance of Ministry of Health, Labour and Welfare. Product characteristics such as pressure resistance, degree of dissolution and volume of impurities in chlorine and other chemicals are required to meet specified standards. On requests from manufacturers, JWWA's Quality Certification Center evaluates, certifies and registers the products, before they go on sale and put qualified stamps on.

Utilities nationwide use the registered and certified materials and equipment because of the reliability offered by the registration and certification system. As a result, Japanese water supply facilities are able to keep a high quality of service. Usage of the standardized materials and equipment is significantly meaningful for water supply.

6. Preventing Deterioration of Source Water Quality

(1) Deterioration of Source Water Quality

As the economy grew in Japan, the inflow load increased in accordance with the rapid population growth. Water sources had been polluted by agricultural chemicals and industrial wastewater. Therefore, water source conservation, sewage treatment and industrial wastewater treatment were needed.

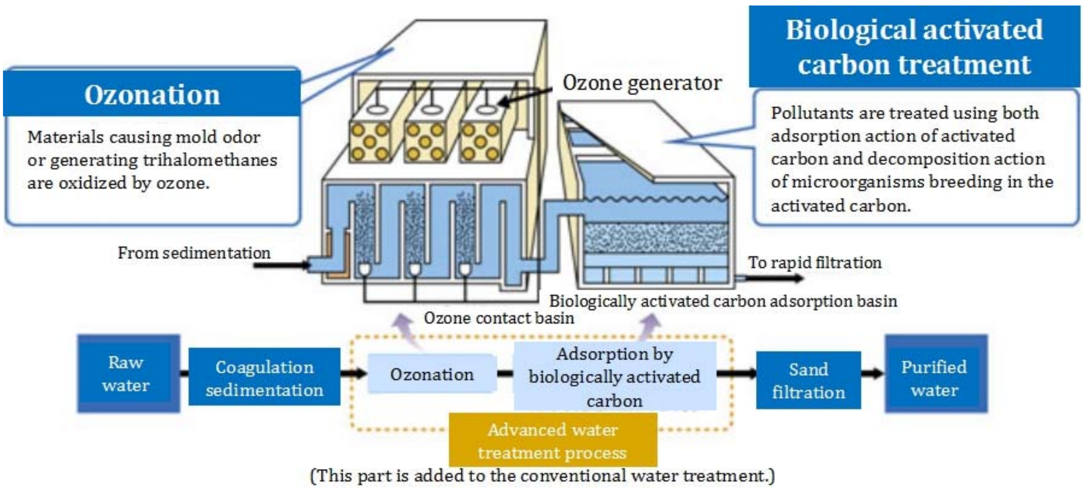
During the period of high economic growth in the 1960s, wastewater from factories caused serious contamination of the sources for drinking water. There were increased incidents of pollution related illnesses. Unpleasant odor and taste due to eutrophication in dams and lakes became a social issue. In 1970, the Water Pollution Control Act together with the Act on Entrepreneurs' Bearing of the Cost of Public Pollution Control Works, were enacted to protect the quality of the water sources against contamination by industrial wastewater.

Source: Website of Kasumigaura River Office, http://www.ktr.mlit.go.jp/kasumi/kasumi00026.html

Photo 3. Float for Collecting Blue-Green Algae (often encountered from 1960s to 1970s)

Regulations on wastewater from factories were strengthened in the 1970s and Japan's anti-pollution measures were deemed "successful for the most part" by the Organization for Economic Co-operation and Development (OECD) in 1978. Since the late 1970s, domestic wastewater became more of an issue than industrial wastewater because economic growth turned sluggish.

Untreated domestic wastewater was discharged into rivers because sewage system development was not catching up with the rapid population growth. The nitrogen and phosphorus it contains caused eutrophication and harmful algal bloom. Odor also became a big problem. The Ministry of Environment and the Ministry of Construction promoted the combined Johkasou, Japanese on-site advanced treatment systems for domestic wastewater including excrement and grey water, and sewage system and the quality of river water improved significantly. However, water quality was not improved in some lakes and ponds, because the pollutants settled as sedimentation and flowed up when the water temperature rose. Some utilities moved their intake facilities upstream or introduced advanced water treatment systems to deal with the situation. Japanese government established subsidies for the advanced water treatments in 1988.



Source: Website of the Bureau of Waterworks, Tokyo Metropolitan Government

https://www.waterworks.metro.tokyo.jp/suigen/kodojosui.html

Figure 12. Example of Advanced Water Treatment

There were no water quality standards for odorous chemicals such as geosmin and 2-methylisoborneol before eutrophication became an issue. While the odor and taste may be unpleasant, the water remains safe to drink. Initially utilities were reluctant to invest in expensive advanced treatments to deal with these problems. Today, utilities are skilled in advanced treatment processes to produce safe, odor free and good tasting drinking water.

There is a limit to cope with excessive pollutant loads discharged to water source and worsened quality of water source only with development of treatment facilities. Measures to prevent pollutants from getting into the water sources in the first place are needed. These include river flow improvement with erosion control works, river bank protection and forestation of catchment area and sewerage system improvements.

It is evident that utilities must take measures to maintain the quality of water sources. Especially for lakes that receive industrial and domestic sewage, pollutants can result in proliferation of blue green algae and aquatic plants and in turn, eutrophication and deterioration of water quality that put increasing burden on the treatment processes. Utilities must engage in environmental protection activities such as forestation of catchment area and lake conservation, and convince customers and residents in catchment area of the importance of these activities.

Example: Treatment System to the Chiba Prefectural Waterworks

Chiba Prefecture, a suburb of Tokyo saw a big increase in population. At that time, untreated domestic wastewater was discharged into Imba-numa (a large lake), the water source of the Chiba Prefectural Waterworks.

Eutrophication in the lake caused huge algae blooms. Water had a bad taste and odor. In 1970, activated carbon was used at the intake to adsorb the odorous compounds in the transmission pipelines and then allowed to settle out at the treatment plant.

However, this method did not solve the root problems. Chiba Prefectural Waterworks organized an experts committee in 1973 to investigate and demonstrate the use of advanced treatment. Then the Chiba Prefectural Waterworks introduced ozone with powdered activated carbon injection in 1976, and ozone with granular activated carbon in 1980.

Example: Moving Intake Facilities to Upstream

The Abukuma River (length: 239 km; basin: 5,390 km^2) is the second longest river in the Tohoku region in Fukushima Prefecture (Northeast of the main island). Northern urban area of the prefecture had nuisances with water quality deterioration and droughts of Abukuma River.

Fukushima City and surrounding towns joined the national government's Surikamigawa Dam Project, upstream of the Surikami River (part of the Abukuma River system). These municipalities established the Bulk Water Authority using water from the Surikamigawa Dam.

Fukushima Water Supply Authority was established in 1985 to supply 149,920 m^3/day (latest plan: 231,570 m^3/day) for 3 cities including Fukushima City and 3 towns. The Surikamigawa Dam was completed in 2005 and the Fukushima Water Supply Authority started to implement full-scale supply in 2007.

Fukushima Waterworks Bureau had to use activated carbon to treat the water from Abukuma River. After switching to the bulk water from Fukushima Water Supply Authority, it no longer required the activated carbon treatment and also reduced the level of chlorination. The chlorine odor on taps decreased. The Waterworks succeeded to distribute quality drinking water to users by using water further upriver.

Source: Surikamigawa Dam and Reservoir Management Office http://www.thr.mlit.go.jp/surikami/

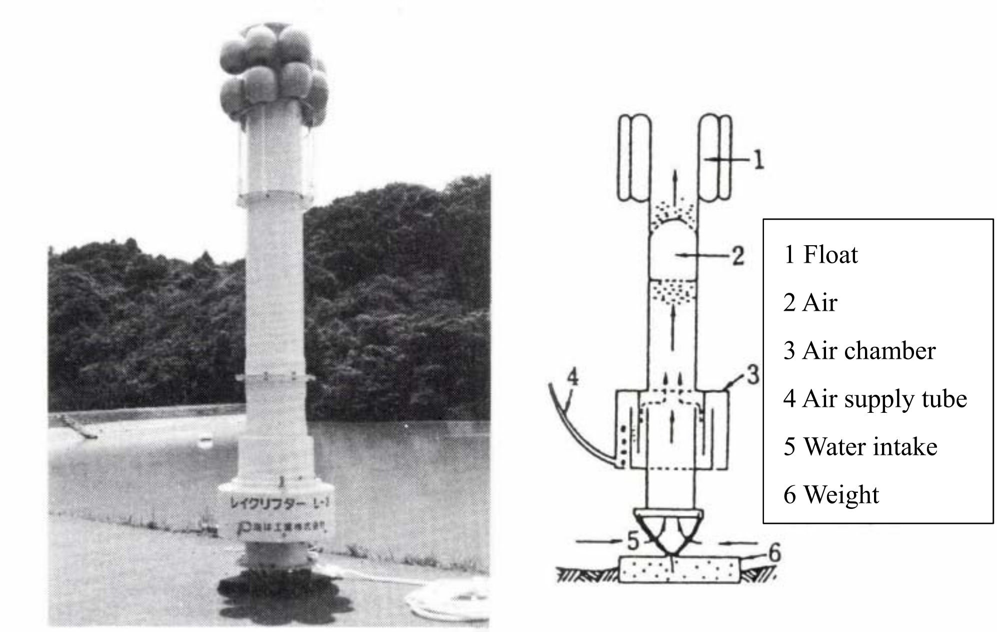
Photo 4. Surikamigawa Dam

Eutrophication problems can be solved by removing blue-green algae, by purifying inflowing rivers (utilizing vegetation or soil to purify river water), or circulating lake water artificially (using air lifting towers or aeration systems). Purification carried out by phytoremediation is a biological treatment method using plant-based systems and microbiological processes to eliminate contaminants in nature by utilizing a natural ecosystem (absorbing and collecting nitrogen and phosphorus by the extremely fast growing water hyacinth).

When water supply systems expanded rapidly, most of the efforts were devoted to the construction of facilities and development of sewage systems tended to be of a lower priority. Source water quality issues were not well understood and problems were dealt with on an ad hoc basis. It is preferable to prevent deterioration of water quality, understand the impact of effluent treatment on water supply and develop the required infrastructure. Developing countries located in the tropics and subtropics typically have more serious eutrophication problems in their reservoirs and lakes. The warm climate and heavy rainfall mean more nutrients are washed from the soil into the water and resulting in higher biological activities.

Column: Artificial Circulation of Lake Water

Artificial circulation, mixing of deeper and upper layers of the reservoir, can prevent eutrophication. This method prevents oxygen depletion at the deep layers caused by dead phytoplankton/algae decay. This involves an upper layer aeration and circulation, deeper layer aeration and aero-hydraulic guns.



Source: Sadao KOJIMA, *Artificial circulation of lake water as a counter-measure to eutrofication; It's principle and results*, Japanese Journal of Water Treatment Biology Vol. 24 (1988) No. 1, p.9-23.
https://www.jstage.jst.go.jp/article/jswtb1964/24/1/24_1_9/_pdf

Figure 13. Schematic of the Aero-Hydraulic Gun

(2) Conservation of Water Catchment Forests

Some utilities practice forest conservation upstream of the water sources as a strategy to preserve the water quality for the entire watershed.

Many utilities conduct water resource conservation upstream of their water sources. Under the Forest Act, forests located upstream of water sources are designated as "reserve forests" and tree cutting or development projects are prohibited since a long time ago. In some cases, utilities take more proactive measures by owning the forests and taking care of the trees with volunteers. In 1910 the Tokyo Metropolitan Government started the management of a water catchment forest that recharges the water source in Okutama. Yokohama City also purchased a forest on a mountain outside the prefecture in 1916. Many utilities in Fukuoka, Okayama, Kofu, Morioka city and Kagawa Prefecture followed suit.

Table 2. Examples of Catchment Forest Conservation by Some Utilities

Water utility	Location	Area
Tokyo Metropolis	Upstream of Tama River (Okutama machi and part of Yamanashi Prefecture), started in 1910 as the first attempt	23,000 ha
Yokohama City (Kanagawa Prefecture)	Upstream of Doshi River (Yamanashi Prefecture), located outside Kanagawa prefecture	2,873 ha
Kagawa Prefecture	Upstream of Yoshino River (Kochi Prefecture) Subsidy for tree thinning	–

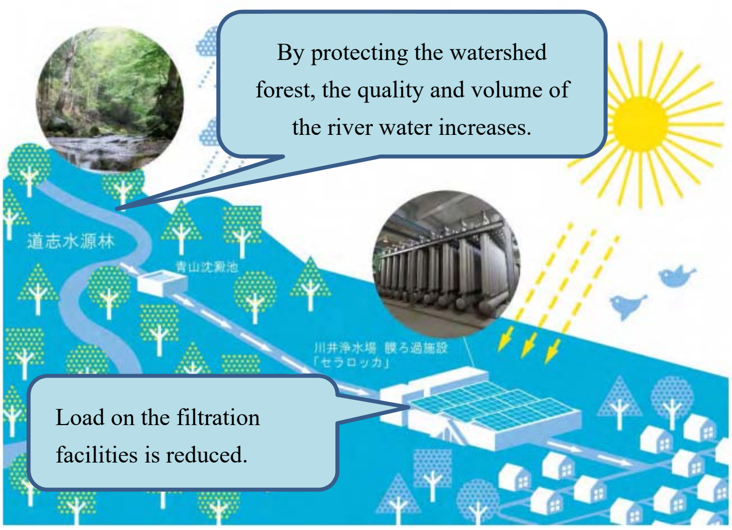
Example: Watershed Forest in Doshi

The Yokohama City water supply system was established in 1887, and the water intake was moved to Doshi River, a tributary of the Sagami River, in 1897. Yokohama City procured publicly-owned forest from Yamanashi Prefecture in 1916 and implemented conservation projects to protect the water source. The forest is designated as the Yokohama City Doshi Watershed Forest (Doshi Forest). Doshi Forest is located in Doshi Village, south east of Yamanashi Prefecture, upstream of the Doshi River.

The forest accounts for 36% of the area of the village. Yokohama City established the Doshi Forest Fund. Donations and sales of bottled water from this water source support the conservation activities by citizen volunteers.

Source: Yokohama Waterworks Bureau, *Doshi Watershed Forest*,
http://www.city.yokohama.lg.jp/suidou/kyoku/torikumi/suigen-hozen/suigenkanyourin-sub-wind.html

Figure 14. Doshi Watershed Forest



Source: Water Works Bureau, City of Yokohama, *The Eleventh Plan for Doshi Watershed Forest*,
http://www.city.yokohama.lg.jp/suidou/kyoku/torikumi/suigen-hozen/pdf/doushisuigenrinpuran.pdf

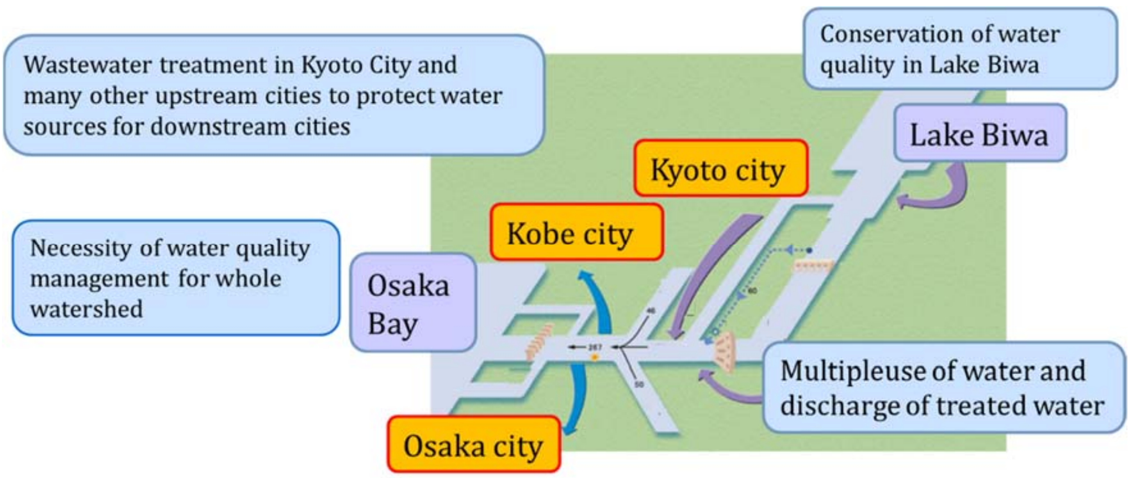
Figure 15. Schematic of a Forest Recharging a Water Source

(3) Legislative Framework for Protection of Water Source Quality

Promoting water quality management over an entire watershed is difficult in Japan. The different laws implicated are under the jurisdiction of various authorities. Improvement of the situation and source water quality are expected as a result of better coordination among utilities and prefectures and establishment of the Basic Act on Water Cycle.

The Water Supply Act stipulates the management of water supply systems by municipalities. This comes from the fact that small scale water management had been done based on historically formed communities. Communities traditionally used spring water and groundwater as water sources in many parts of Japan. Gradually these developed into small water supply systems.

However, after water usage expanded, this management model is no efficient or effective when water quality management evolved to focusing efforts on the entire watershed. To secure as much as quality river water continuously for waterworks, integrated water management with consideration of entire watershed should have been undertaken.



Source：Yodogawa River Office, http://www.yodogawa.kkr.mlit.go.jp/know/data/use/

Figure 16. Water Quality Management from the Perspective of River Usage and the Entire Water System of Yodo River

Efforts are made to coordinate various legislative frameworks (Water Pollution Control Act-related regulations, various legal systems and institutional frameworks) and technical efforts (installation of sewage system and Johkasou).

Currently, the River Act and sewage systems are under the control of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The Ministry of the Environment takes care of water environment of lakes and rivers, the Ministry of Economy, Trade and Industry (METI), industrial water intake and the Ministry of Agriculture, Forestry and Fisheries (MAFF), agricultural water. Water supply and sanitation administration should be implemented with the coordination of authorities dealing with the environment and construction.

In 1994, the Law concerning the Promotion of Projects to Preserve Water Quality in Drinking Water was introduced by MHLW; and the Law concerning Special Measures for the Preservation of Water Quality in Headwaters Areas for the Purpose of Preventing Specific Trouble in the Drinking Water Supply was introduced by the Ministry of the Environment.

The purpose of the Law concerning the Promotion of Projects to Preserve Water Quality in Drinking Water is to “ensure the supply of safe drinking water of good quality and contribute to the improvement of public health and living environment by taking measures to promote the implementation of programs that contribute to the protection of the quality of source water for public water supply.” Under this Act, if a utility makes a request to the prefecture that controls the water source catchment area, the prefecture can request the upstream prefecture as well as the river administrator to establish a plan to enhance programs for water quality conservation in response to their needs. It means that a mechanism, where a request can be made via a prefecture from downstream to upstream and from utilities to river administrators, is established by Law. This framework is based on watershed management. The effectiveness of this framework is still unclear because requests have been made only for areas directly upstream and rivers in the same prefecture since the Act was enacted.

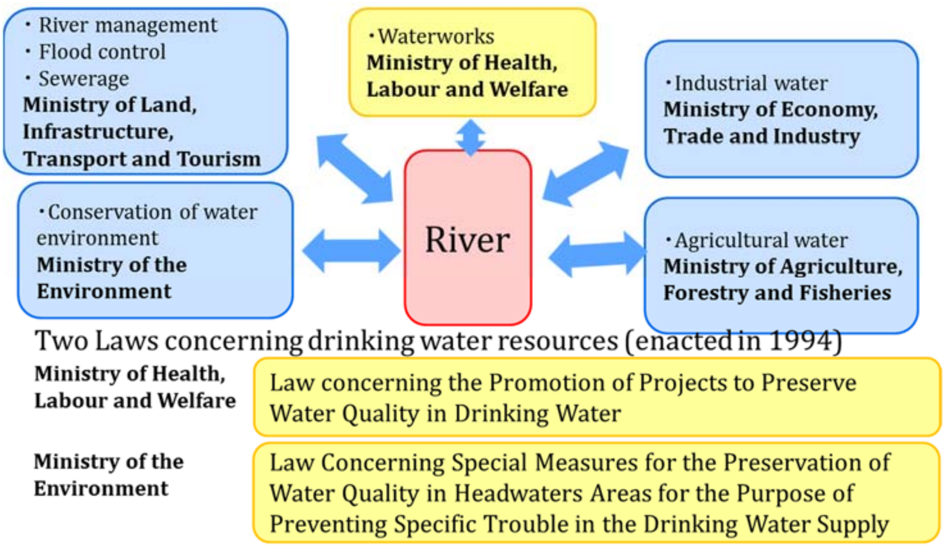


Figure 17. Status of River Management

The Basic Act on Water Cycle was established in 2014, which is expected to facilitate the consideration of the entire watershed in water quality management. It takes a considerable time to coordinate administrative systems of various ministries and to arrive at some consensus.

Column: Establishment of the Basic Act on Water Cycle and the Way Forward

Until the Basic Act on Water Cycle was promulgated, there was no national comprehensive policy to address principles and directions regarding water issues, to conserve and protect water resource. The responsibilities reside with different authorities: river and sewage systems are controlled by MLIT, industrial water by METI, agricultural water by MAFF and drinking water by MHLW. There were not enough frameworks, such as integrated control of all aspects of the water cycle, systems and plans for community-driven water resource conservation in each watershed, and legislation on groundwater use.

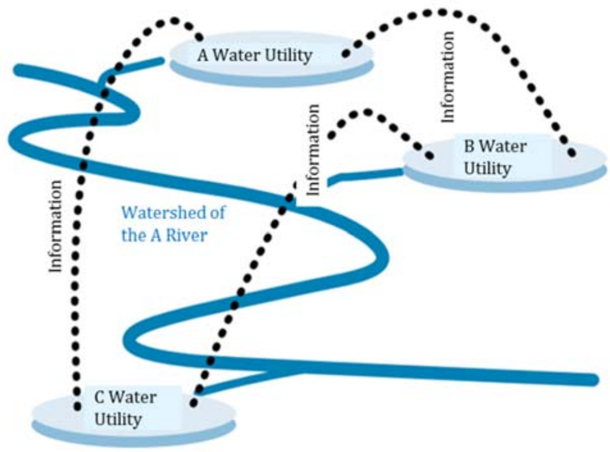
In the midst of growing social interest in water issues including the possibility of global water shortage, the National Commission on Water System Reform was established in June 2008. The Commission was made up of academic experts, citizens, and Diet members from all parties. It pointed out the dysfunction of an administrative framework with ministries operating in isolation, the need to break down the silos and called for the integrated promotion of water administration and the establishment of a basic law.

The bill for the Basic Act on Water Cycle was introduced and enacted in 2014.

A special characteristic of the Law is the setting up of the cabinet office that cuts across multiple ministries for integrated and comprehensive discussion and implementation of top-level policies dealing with every stage of the water cycle. The cabinet office is headed by the Prime Minister and composed of the chief cabinet secretary and ministers. This integrated team will tackle water issues which involve many sectors and jurisdictions.

The Water Cycle Basic Plan was established in 2015, and will be reviewed every five years.

Groundwater abstraction continues to be a concern in many parts of Japan and there are restrictions with very stringent targets set in the Industrial Water Act and the Building Water Act, designed to prevent land subsidence. The Water Cycle Basic Plan should make it clear what concrete measures the national government would take and it is hoped that effective plans could be developed.



Source: Fukushima Prefecture, "*Vision for the Daily-life Water in Fukushima*," (2006), p.61

Figure 18. Concept of Watershed Monitoring

(4) Practical Measures against Water Source Pollution

In Japan, cooperation among utilities in different prefectures is credited for solving an accident when chemicals were discharged from a factory located upstream of several water treatment plants and generated harmful disinfection byproducts.

In May 2012, a factory discharged hexamethylenetetramine into upstream of the Tone river, which flows Kanto Region. Formaldehyde was produced as a by-product and detected when several treatment plants downriver chlorinated the water. The formaldehyde level almost reached the maximum concentration allowed by the water quality standards.

This case attracted lots of public attention. Several utilities had to stop their water supply at one point. The prefectures affected immediately announced the situation and the Ministry of Health, Labour and Welfare (MHLW) investigated and published a report on the incident and the public notice "Concerning enhancement of countermeasures against water source pollution" was issued in March 2013 to prevent future accidents.

The incident shows the necessity of cooperation and information sharing among utilities in the same watershed. Associations made up of utilities in the same watershed had been formed: the Tonegawa/Arakawa Watershed Water Utility Association, the Kisogawa Watershed Water Utility Association and the Toyokawa/Yahagigawa Watershed Water Utility Association against Water Pollution. These associations share information on their website as well as work together on improvements. Watersheds which do not have formal associations rely on informal systems. Environmental departments of utilities would report incidents to water supply department of the prefecture which in turn shares the information with utilities downriver.

MHLW requires each utility to develop a water safety plan. The plan must describe the measures to be taken in response to change in water quality. It is essential to detect the change at the earliest possible stage. Therefore, sharing water quality information with utilities in the same watershed is important.

Example: Impact of Contamination Accident Upstream on Utilities Downstream

"Formaldehyde incident at Tone River"

On May 15, 2012, formaldehyde at 0.045 mg/l was detected in the treated water during routine testing conducted by the Enterprise Bureau of Saitama Prefecture. The concentration approached the allowable limit of 0.08 mg/l for drinking water. Tests were carried out more frequently and the incident was investigated. Nearby utilities informed by Saitama prefecture started to strengthen their monitoring. Exposure above the maximum allowable limit of 0.08 mg/l causes irritation to the airways.

Activated carbon was used in many plants to absorb the formaldehyde and its precursors and the chlorine treatment process was adjusted, both had limited impact. The plants which do not have ozone and biological activated carbon treatment processes, shifted the water source to ground water, utilized stored water for emergencies, or got water from utilities in other watersheds.

On May 19, some water treatment plants stopped supplying water when the concentration of formaldehyde approached the allowable limit for an extended period. Water supply was resumed in all plants on May 20.

The study by the National Institute of Health Sciences revealed that the formaldehyde was generated by the hexamethylenetetramine in the source water, based on the water quality analysis and correlation of formation potential of formaldehyde in raw water.

The investigation followed by the incident revealed that from May 10 to 19 neutralized plating waste solution containing hexamethylenetetramine was discharged by a waste disposal company to the drainage system which runs into the Tone River system.

Table 3. Damage Caused by Formaldehyde Incident of May 19, 2012

Victim utilities	Venues	Business type	Countermeasure	Damage
A	Ibaraki Prefecture	waterworks	Injection of Activated Carbon and change of volume of chlorine	No suspension of water supply
B	Gunma Prefecture	Water Utilities for Bulk Water Supply	Suspension and limitation of transmission, etc.	No suspension of water supply
C	Saitama Prefecture	Water Utilities for Bulk Water Supply	Suspension of intake and transmission	No suspension of water supply
D	Chiba Prefecture	Water Utilities for Bulk Water Supply	Suspension of transmission	No suspension of water supply
E	Chiba Prefecture	waterworks	Suspension of intake and distribution	suspension of water supply in whole service area
F	Chiba Prefecture	waterworks	Suspension of intake from Water Utilities for Bulk Water Supply	suspension of water supply in whole service area
G	Chiba Prefecture	waterworks	Suspension of intake from Water Utilities for Bulk Water Supply	suspension of water supply in whole service area
H	Chiba Prefecture	waterworks	Suspension of intake from Water Utilities for Bulk Water Supply	suspension of water supply in part of service area
I	Chiba Prefecture	waterworks	Suspension of intake from Water Utilities for Bulk Water Supply	suspension of water supply in part of service area
J	Tokyo Metropolis	waterworks	Suspension of intake and distribution only in suffered plant	No suspension of water supply by changing of distribution pipelines

7. Lessons Learned

The following Japanese experience could be useful for other countries.

- **(From Source to Taps)** Water quality management is considered as a whole of management procedures to meet the water quality standards of tap water throughout from the water source. The national government and water utilities have been actively involved in periodical review of water quality standards, improvement of water quality testing methods, monitoring by administrative organizations, quality control of materials and equipment, and human resource development.

- **(Public Health)** Japan has been focusing on epidemiological safety of modern water supply because it experienced outbreak of waterborne diseases. Water quality management is critical to utilities' ability to supply safe drinking water; which is very important to public health.

- **(Monitoring)** Water quality is monitored at the water source, treatment plant, distribution reservoir up to the customers' taps. Automated systems have been introduced in place of manual tests for daily testing of residual chlorine, color and turbidity. It is important to utilize the data accumulated for water resource conservation, water treatment and emergency response to accidental contamination of source water quality.

- **(Cost of Water Quality Management)** Utilities have made sustained efforts in water quality management by securing the necessary budget in their business plan. This is based on the recognition that water quality management requires certain costs for chemicals, electricity and many other expenses.

- **(Starting with a Good Quality Water Source)** Small-scale utilities with limited technical capability and funding have utilized a good quality water source and have installed facilities to simplify and economize the treatment process.

- **(Designing Water Quality Management System)** In designing water quality management system, it should comply with the legal requirements prescribed by the relevant acts and regulations. These include: (1) designating a responsible officer for water quality management; (2) having national or local government oversight and (3) supporting small and medium scale utilities with limited capacity.

- **(Setting Water Quality Standards)** The aim of setting drinking water quality standards is the protection of public health from toxic substances and bacteria, and the parameters of our health concern. Water quality standards for contaminants suspected to cause long term health risks (such as cancer), are revised as a result of new knowledge, public concerns, and availability of measurement instruments. It was important to establish the standards considering qualities of water resources and drinking water, the technical levels of water quality testing and measurement instruments in the country.

- **(Standards for Materials and Equipment)** It is important that utilities use certified materials and equipment. Article 5 of the Water Supply Act stipulates performance standards for pipes, equipment and facilities. Standards for structure and materials are specified in the Ordinance of Ministry of Health, Labour and Welfare. The inspection and certification services of Japan Water Works Association for materials and equipment play an important role in maintaining the high quality of such products. It is essential that water supply systems utilize standardized materials and equipment.

- **(Protecting Water Sources)** Utilities use advanced treatment processes to deal with odor caused by quality deterioration of water sources. Advanced treatments were introduced but they are expensive. Therefore, government authorities take water resource conservation measures such as construction of sewage facilities, regulation of industrial wastewater, enhancement of information sharing among surface water users, awareness-raising activities, and conservation of water catchment forests. At present, as the water demand saturated and stabled, it became important to conduct water resource conservation with stakeholders around watershed while seeking for cleaner water source, for example, by moving intake facilities to upstream.

- **(Cooperation in Watershed)** Utilities in the same watershed cooperate, share information and take prompt action together in case of incidents of pollution. The formal mechanisms for cooperation and coordination greatly facilitate information sharing and water quality management. In this regard, the development of a comprehensive water safety plan is promoted by the national government in Japan.