Theme 4. Operation and Maintenance of Facilities

Contents

1. Introduction

When water supply facilities were being built across the country during the period of rapid expansion, establishing new systems was the priority. The operation and maintenance aspects did not get the necessary attention and budget. Over the years, the water supply industry had to deal with many operational issues, emergency situations and serious disease outbreaks. The lessons learned, especially in the recognition of the importance of maintenance, gradually transformed the utilities to ones that provide a stable supply of safe drinking water to the Japanese population.

Figure 1. Steps toward Good Practices in Maintenance

As conceptualized in Figure 2, corrective maintenance (which implies "run it till it breaks," or maintenance carried out after failure detection) may seem to have an economic advantage in the short term, it has disadvantages compared to preventive maintenance according to the experiences of Japanese water utilities:

- It is less efficient and more expensive in the long term.
- Accidents will undermine users' trust in the water utilities.

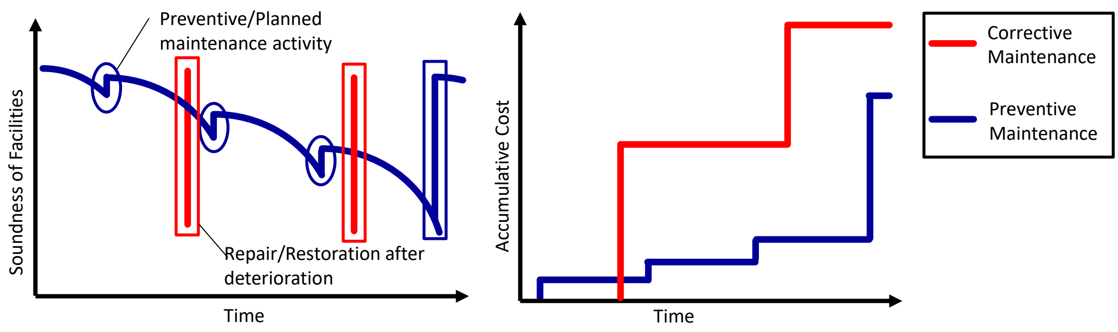


Figure 2. Conceptual Graph of "Corrective Maintenance" and "Preventive Maintenance"

Preventive maintenance either Time-Based Maintenance (TBM) or Condition-Based Maintenance (CBM) is preferable. Its implementation relies on good record keeping and best practices in information sharing.

This module intends to answer to following frequently asked questions from participants of the water supply training courses from developing countries.

Q1. As a result, new facilities often receive higher priority than maintenance, in terms of budget and staffing. How did Japanese utilities achieve good practices in maintenance in spite of these challenges?

Q2. The sharing of information among water utilities is not easy because they are managed at the local level. Another difficulty is that the number of engineers or senior technical personnel, who would benefit from liaising with their counterparts, is limited at any one facility. How do Japanese utilities manage to share the knowledge on maintenance and benefit from each other's experience?

Q3. Developing best practices for maintenance is critical to an efficient operation and for continuous improvement. How can best practices be retained in spite of staff turnover? What is Japan's approach to sharing best practices within a utility and across the water supply sector?

The following sections attempt to provide answers to these questions:

2. Importance of Maintenance (Q1)
3. Laws and Institutional Framework (Q2) and (Q3)
4. Best Practices in Japan (Q3)

2. Importance of Maintenance

When water supply expansion was the priority, operation and maintenance (O&M) was not sufficiently implemented. Attention was paid to O&M only when serious disease outbreaks or accidents occurred. Efforts were made to enhance water safety and avoid supply interruptions with increasing regulations on water quality standards, and to operate facilities efficiently in response to sustained pressure to reduce the numbers of staff.

Today, water supply systems in Japan are very well operated and maintained. It is safe to drink water from the tap anywhere, even in the countryside. There are national guidelines on operation and maintenance and standard operational procedures (SOPs) at the facility level to keep facilities in good condition. These achievements are the result of years of steadfast efforts.

Before the end of World War II in 1945, water supply systems were prevalent only in urban areas. After the 1950s, small rural water supply systems for up to 5,000 people were installed rapidly across the country. Water supply coverage increased significantly from 25.2% in 1950 to 80.8% in 1970. Today's good practices in maintenance have been achieved through on-going efforts to reduce incidences of waterborne diseases including the following:

- Repeated notices from central and prefectural governments on improvement of operation and maintenance.
- Efforts made by utilities to improve their operation and maintenance.

Outbreaks of waterborne diseases (such as dysentery, typhoid fever) were attributed to inadequate disinfection, equipment failures, cross connections, and negative pressure in water supply pipelines. Accidents caused by aging distribution networks were highly publicized. Cross connections presented the opportunity to the utilities to focus on the quality of construction and maintenance after the construction.

Table 1. Disease Outbreaks and Related Maintenance Issues

Item	Triggering events	Issues and causes
Water Treatment Facility	Poor disinfection (waterborne diseases spread by water supply)	No standard manuals nor operational procedures for O&M
	Malfunction of facility and failure of water treatment	
Pipelines	Contamination due to negative pressure (waterborne diseases spread by water supply)	No precise information nor drawings on aged pipelines
	Secondary disaster due to burst pipes	
	Public complaint of rusty/turbid water	
	Dysentery caused by cross connection	Quality control for installation of water service connections

(1) Disease Outbreaks

Outbreaks of waterborne diseases attributed to inadequate maintenance, frequently occurred during the expansion of water supply facilities in Japan. The improvement of maintenance practices supported by national guidelines (*Water Supply Facilities Maintenance Manual*), and the notices from Ministry of Health and Welfare (MHW) to strengthen supervisions and inspections helped prevent disease outbreaks associated with the water supply system.

Water supply coverage was rapidly expanded in Japan to reduce incidence of waterborne diseases. However, according to the surveys by the Ministry of Health and Welfare[1] during 1950-1961, 42% of disease outbreaks were caused by inadequate disinfection and 27% by contamination from back-siphonage of polluted water during interruptions. The Ministry of Health and Welfare recognized that inadequate maintenance was the underlying cause of disease outbreaks and published the *Water Supply Facilities Maintenance Manual* in 1953 to address this problem to prefectural government bodies.

In 1961 the Ministry of Health and Welfare announced the emphasis on proper O&M of water supply facilities, including improvement of disinfection facilities. Regular inspection of facilities was also put in place. Guidance on how to meet the legislative requirements for O&M was provided to the utilities by prefectural agencies and Health Centers. These efforts helped to reduce the incidence of waterborne outbreaks by 1970s.

[1] The Ministry of Health and Welfare was merged with the Ministry of Labour to form the Ministry of Health, Labour and Welfare in 2001.

Column: Guidelines for Water Supply Facilities

The *Water Supply Facilities Maintenance Manual* was first published by the Ministry of Health and Welfare in 1953, aimed at preventing disease outbreaks by ensuring proper operation and maintenance of facilities. After the Water Supply Act was established in 1956, the first revision was published in 1959.

The manual has been revised approximately every 10 years depending on socio-environmental conditions (such as water contamination, increase and decrease of water demands) and technical innovations (such as advanced water purification). The fifth and the latest revision (2006), considers future challenges in achieving sustainability in the water supply business, such as decline in population and water demand, and the need for infrastructure renewal.

Table 2. Revision History of *Water Supply Facilities Maintenance Manual*

Year	Version	Contents of Revision
1953	original	Measures to prevent spread of water borne diseases
1959	1st Revision	Description of maintenance for processes such as purification, transmission and distribution.
1970	2nd Revision	Description of - Water quality management in each facility - Latest instrumentations - Measures to prevent rusty water from water supply pipes
1982	3rd Revision	- Added description of new technologies, such as advanced treatment, etc. - Description of regional management - Description of management of employee health and safety, earthquake and drought
1998	4th Revision	- Risk management and information processing techniques - Latest information such as seawater desalination, cryptosporidium
2006	5th Revision	- Changes in business environment such as tightening water quality standards, managing risk of accidents or disasters, environmental conservation, popularization of information processing, third party consignment. - Maintenance in small- and medium-scale utilities - Added best practices based on the results of questionnaire survey to the water supply utilities

Currently, water supply utilities of Japan are facing many serious issues such as (1) decrease of revenue due to population decline, (2) loss of the technical capabilities due to retirement of a generation of skilled technical staff, and (3) natural disasters such as the Great East Japan

Earthquake of 2011. It is necessary to conduct proper operation and maintenance, rehabilitation and renewal of the facilities to supply safe and secure water. The priority tasks are as follows:

- To prepare manuals and standard operation procedures to maintain the skill and know-how in the organization especially when many workers will be retiring in the near future.
- To prepare for disasters restructuring water supply system in order not to cause malfunction of water supply system.
- To strengthen risk management from source to tap based on the Water Safety Plan.
- To establish long-term rehabilitation-renewal plan using asset management as well as to ensure there is adequate financial sources.
- Prolong asset life cycle by carrying out early detection and repair based on planned maintenance.
- Maintenance of new processes such as membrane filtration.

The manual will be revised to address the current needs.

(2) Cross Connections

In 1960s, serious accidents caused by cross connections occurred. Water supply pipes were connected by mistake to industrial or irrigation pipes. The resulting health problems were well publicized and accelerated implementation of measures for prevention.

Cross connection is fault connection that water supply pipes are connected to pipes for other purpose such as for irrigation, industrial supply or drainage. In the 1960s, rapid expansion of water supply facilities resulted in cases of poor construction practices. There were cross connections with industrial and irrigation pipes in various places in Japan. The seriousness of these problems propelled the national government to strengthen the measures to avoid cross connections. Measures were taken on strengthening construction supervision, accurate recording of construction activities and water quality testing after construction, in all the water supply utilities in Japan.

Example: Cross Connection Accidents in Yokohama and the Counteractions

In 1969, an outbreak of dysentery in a kindergarten in Yokohama was reported. Based on speculation that the dysentery was caused by contaminated tap water, water quality tests were conducted. The result did not show any residual chlorine in the tap water. It was found that a water supply pipeline was cross connected with an industrial water supply pipeline. Later, it was determined that the cross connection was not the cause of the outbreak. Nevertheless, the notion that people including kindergarten children had been drinking industrial water for a long time, caught the attention of the citizens and the Yokohama Waterworks Bureau.

The kindergarten's service pipe was originally connected to a 200 mm distribution pipe. Subsequently, the distribution pipe was relocated 13 times over a 9 year period from 1959. During this period an industrial water pipe of 200 mm was laid near the distribution pipe. In 1968 during the installation of a sewer line some pipes had to be relocated urgently. Workers did not consult the drawings properly. The service pipe was mistakenly connected to the industrial water pipe. Fortunately, the water source of the industrial and the drinking water supply were common and they did almost the same water treatment because the industrial water supply systems had just started off their business and supplied water almost the same quality as the drinking water. Furthermore, the amount of industrial water used was small. Therefore, the cross connection did not cause apparent problems and was not discovered for a long time.

After the incidence, the Ministry of Health and Welfare issued the "Notice of the strengthening of construction supervision of water supply facilities, and comprehensive facility and water quality management" in 1969. It announced the requirement that construction of water supply pipelines must be supervised by qualified personnel. The notice also required complete and accurate recording and reporting of construction activities, proper record keeping of drawings, water quality testing including that of residual chlorine after the construction.

The Yokohama Waterworks Bureau reviewed its operations and construction supervisions to make further improvements. First, the Bureau strengthened planning for emergency repairs and constructions especially when these must be scheduled at night and during holidays. An assistant to the technical supervisor was designated for construction management and supervision. It took 12 years from 1971 and 725 million yen to complete detailed pipeline drawings for sharing correct information. Corrections were made and all information was confirmed to be accurate on the drawings. In 1971, the Bureau assigned a mobile unit for water quality testing, making it possible to respond more quickly to enquiries from citizens and reports on unusual conditions of water sources.

(3) Burst Pipes

Burst pipes, water pressure drop, turbid water often occurred throughout the country in the past. Control measures included planned replacement of aged pipes, use of better pipe materials, improved installation method and sharing information on maintenance. Assistance from national government promoted implementation of these measures.

Pipe breaks lead to pressure drop or contamination due to negative pressure. A major pipe break can cause prolonged supply interruption, serious traffic problems, sink-holes and flooding that have enormous impact on daily lives. The accidents are usually caused by aged pipes, improper installation, or natural disasters. Japanese utilities have taken measures such as planned replacement of aged pipes, improving installation method, enhance earthquake-resistant.

Example: Burst Pipe in Osaka City and the Counteractions

In Osaka City, 70 bursts of 15 main distribution pipes happened for 100 years (1895－1994). The most pipe bursts happened from around 1937. These pipes were usually made of cast iron with coal tar lining and laid from 1933 to 1943. Rust aggregates formed immediately after the installation. The pipes' mechanical strength was rapidly reduced due to graphitization of the cast iron, narrowing of pipe diameter and corrosion from the outside. All these factors contributed to pipe failure.

In the 1951 accident, a fountain of water erupted from a burst 1,500 mm diameter pipe, caused flooding, sagging roads and traffic chaos. 120 houses sustained damages. Water stoppage affected a broad area, while the surrounding area experienced low water pressure. The damage and repairs were costly and time consuming. Subsequently Osaka City implemented a program to strengthen pipes with the use of reinforcing bands, however, it was not a satisfactory solution. Slip-lining systems were intensively introduced to replace old pipes to reduce the number of pipeline accidents.

Column: Japan Water Works Association's Role in Information Sharing

Japan Water Works Association (JWWA) is an umbrella organization for the water supply utilities. JWWA has various committees and convenes meetings to share information among the utilities. In 2008, JWWA published a book on accidents in the water supply sector (*Casebook of Water Supply Accidents for Practical Use: Prevention of Accidents and Transfer of Techniques*), which promotes prevention measures and lessons learned.

JWWA holds annual meetings to discuss the issues of water supply including the practical operation and maintenance issues brought forward by operators. The participants are employees of water utilities, researchers from universities, research institutions and private corporations. The first annual meeting was held in 1950. Since then the meeting topics have expanded from 4 to 11 sectors, covering water supply administration, planning, water sources/intake, purification, transmission and distribution of water, service pipes, machinery, electricity, instruments, water quality, risk management, and disaster preparedness.

The focus on expansion of water supply to nationwide coverage resulted in insufficient attention paid to maintenance of facilities. However, utilities learned from serious accidents, and made efforts to enhance water quality and prevent water stoppage caused by an accident. The national government and prefectural governments also guided and supported the utilities. These approaches from various stakeholders were effective to forge the awareness of importance of the maintenance.

Column: Appropriate management for pipelines and reduction of leakage

Pipelines installed before the World War II were rapidly deteriorating in the 1950s, because of poor quality materials and damage during the war. Increasingly heavy traffic accelerated the deterioration. Leakage rates were 30% in major cities such as Tokyo and Osaka. In 1960 the Ministry of Health and Welfare issued an instruction to prevent leakage.

In 1970 the Ministry of Health and Welfare also issued an instruction on preventive measures for rusty water caused by aged pipes. Subsequent efforts by the utilities in repairs and replacement of the distribution networks brought the ineffective water rate (leakage and miscellaneous loss) down to 16.4% in average in 1980.

Table 3. Events Related Leakage Control in Japan

1945	End of World War II (pipeline damage by war)
September 1946	*Water Leakage Prevention Guidelines* (Ministry of Health and Welfare, Japan Water Works Association)
1950s	Aged pipelines installed before the war and deterioration of pipes of poor material manufactured during the war.
1960	Revision of *the Water Leakage Prevention Guideline* (Water Leakage Prevention Committee, Bureau of Waterworks, Tokyo Metropolitan Government)
1960	Notice of the Ministry of Health and Welfare: on water leakage prevention measures
Around 1970	Media reports on rusty water causing public concern.
1970	Notice of the Ministry of Health and Welfare: on pipeline repair and replacement to prevent leakage and removal of rusting pipes.
1977	*Guidelines for Water Leakage Preventive Measures*

Source: The editorial committee of the One Hundred Year History of Modern Water Supply, "*One Hundred Year History of Modern Water Supply*," Nihon Suido Shimbunsha, 1988.

3. Laws and Institutional Framework

The Water Supply Act regulates maintenance of water supply systems. Facility standards and guidelines for design and maintenance are established and compliance by the all water supply utilities is required. This assures the required level of quality of facilities and maintenance practice across the country.

Article 5 of the Water Supply Act (facility standards) stipulates that "in determining the location and arrangement of water supply facilities, the construction, the operation and the maintenance shall be economic and ease as much as possible. Reliability of the water supply shall also be considered."

Article 19 stipulates that a Technical Administrator of waterworks must be assigned to ascertain conformity to the standards. The *Design Criteria for Water Supply Facilities* was prepared with strict adherence to the facility standards of the Water Supply Act. Application to operate a water supply system is scrutinized against the design criteria before approval. The *Water Supply Facilities Maintenance Manual* is provided as the guidance on operation and maintenance.

Facility standards are important to operation and maintenance. The design and construction division and the maintenance division must fulfil the same objective of supplying water continuously under sustained pressure. The facility standards help to determine the facility design and establish maintenance procedures. Both divisions work together to share the knowledge obtained from maintenance activities and use the information to solve future problems.

Water Supply Act

"Article 5: Standards for waterworks facilities and guidelines for design and maintenance

Waterworks shall be provided with a part or all of facilities such as water intake, water storage, raw water transmission, water purification, water transmission, and water distribution in line with raw water quality and flow rate, topographic conditions, and configuration of the waterworks. Each facility shall conform to the following requirements:

5. The water transmission shall be equipped with pumps, pipelines, and others to convey required amount of purified water.

6. The water distribution shall be equipped with reservoirs, pumps, pipelines, and others to convey required amount of purified water with more than a certain pressure.

2 In determining the location and arrangement of water supply facilities, the construction, the operation and the maintenance shall be economic and ease as much as possible. Reliability of the water supply shall also be considered.

3 Structures and materials of the waterworks shall be sufficiently durable to water pressure, earth pressure, seismic loads, and other loads without contamination and leakage of water.

4. Best Practices in Japan

Effective maintenance of water supply systems are characterized by (1) preventive maintenance, (2) application of construction standards and using high quality materials by standardization, (3) adherence to national guidance, (4) information sharing among the utilities, and (5) standardization of procedures and preparation of manuals which are repositories of cumulated knowledge and skills. Asset management is promoted for a useful tool for planning facility replacement with respect to the financial capability of the utility.

In this chapter, the best practices in the utilities in Japan and the principles and ideas behind the practices are introduced. In the past, the most common approach to maintenance was to repair a failure when it occurs. As the utilities gain more experience with accidents and understanding of leakage prevention, there is a gradual shift to preventive maintenance. Pipeline maintenance is not easy because of the extensiveness of the networks and the fact that they are buried in the ground. The preventive maintenance for pipeline, however, is the most important idea for reducing non-revenue water (NRW); the preventive maintenance largely contributes to low NRW of the utilities in Japan. In this context, this textbook largely focuses on the maintenance of pipelines.

Maintenance practices are guided by: (1) regulations and instructions issued by the central and prefectural governments (top-down); and (2) accumulation and sharing of experiences and know-how (bottom-up). The Japan Water Works Association (JWWA) plays an important role in both top down and bottom up processes.

Revenue of water utilities in Japan is declining because of shrinking population. Asset management has been used by many water supply utilities to ensure that maintenance is conducted effectively. Utilities must (1) project population growth and water demand, and know the condition of the facilities; and (2) ensure proper financing for sustainable operation.

(1) Corrective and Preventive Maintenance

In the past leakage and breakdown of equipment was repaired or replaced when the problem was discovered (corrective maintenance). This is not conducive to sustainable and reliable operation. Therefore, preventive maintenance with planned inspections and facility renewal has been introduced by many utilities to prevent failures.

In the past, water supply pipelines were replaced as a corrective measure when leakage occurred or rusty water was reported. Many utilities recognized the advantages of preventive maintenance and began to conduct planned renewal of facilities. Cast iron, asbestos, and lead pipes were systematically replaced. The toxic nature of pipe materials, such as lead and asbestos, was also an incentive for replacement. The national government provides subsidies for scheduled replacement of aged or asbestos pipes. Utilities also set the priority for the replacement of mechanical and electrical equipment that have short service life or ones that would cause serious damage to the supply system if failure occurs.

Asset management is very effective in managing facility renewal by considering the service life and setting priority according to financial constraints.

(2) Maintenance in Water Treatment Plant

The *Design Criteria for Water Supply Facilities* and the *Water Supply Facilities Maintenance Manual* published by JWWA contributed to the standardization of maintenance practices in water treatment plants in the whole country. Maintenance of mechanical and electrical equipment began to be contracted out to private enterprises, and the practice gradually extended to all other operations.

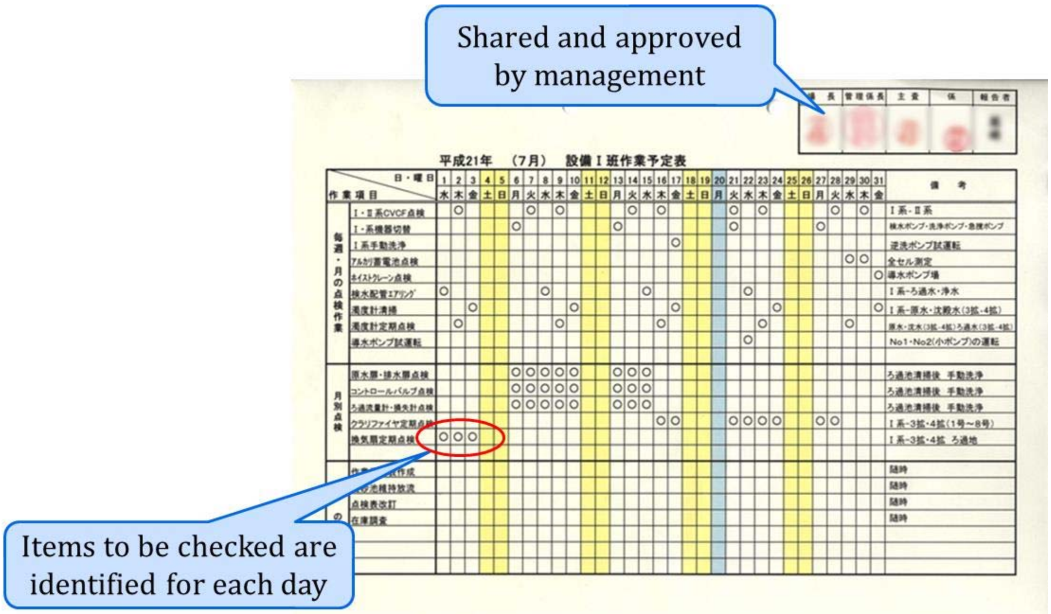
Operation and maintenance of treatment plants require fundamental knowledge of water purification methods and ability to manage all aspects of the operations, including administration, procurement, and maintenance. The design criteria, maintenance manual and on the job training facilitates the transfer of knowledge among treatment plant operators. The guideline and the maintenance manual were compiled based on cumulated knowledge and experience of many utilities in different natural and social situations. These resource materials are used by all of the utilities across the country and institutions of higher education, and professional associations. The national government promotes their use for developing and improving facilities maintenance. Treatment plant operators follow the maintenance manual to prepare their plants' own operation and maintenance manuals, to record operational data, and to perform regular inspections.

Utilities may not have the expertise for the maintenance of special equipment. The vendor may have to deal with the repairs or provide training to utility staff to do so. For an instance, there are many cases that they established relationships based on mutual trust; when there is a problem in equipment, the water supply utilities just called them and they rushed to help them immediately. The sellers also took part in some part of the water supply utilities' work such as operation, maintenance, and regular inspection and maintained the equipment.

There is increasingly outsourcing of maintenance activities because of gradual loss of skilled workers through attrition, a cost saving measure and a measure to increase efficiency by public-private partnerships.

Example: Maintenance of Water Treatment Plant and Consignment

Sapporo City Waterworks Bureau has five water treatment plants in its service area and consigns the operation and maintenance of two plants and inspection of another two to the Sapporo Water Service Association, a general incorporated association. The consignee prepares a work plan and conducts regular inspection as shown by Photo 1.



Source: JICA Training Course Material prepared by Sapporo City Waterworks Bureau (JICA Sapporo, 2015)

Photo 1. Regular Inspection Schedule

Other water utilities usually consign maintenance to private operators. Most of the consignments are outsourcing of individual operations such as meter reading or maintenance of a particular set of equipment. The utility still has the legal responsibility for the out-sourced operation, as stipulated in the Water Supply Act. In recent years, other types of consignment such as; (1) management of technical matters including responsibility stipulated in the Act as "third party consignment"; and (2) design, construction, operation and maintenance as "design build operate (DBO)" are gradually increasing. The utility has the responsibility to monitor the performance of the consignee. The utility publishes the performance evaluation in accordance with the *Draft Manual for Evaluation of Performance of Consigned Maintenance Works for Waterworks Facilities* prepared by JWWA, and audit their facilities properly.

An appropriate amount of chemicals and spare parts must be available for performing daily operations and for urgent situations such as earthquake disaster. Utilities rely on daily inspections to manage their inventory. In the past, utilities had to manage procurement by tracking carefully the movement of items on its inventory. Utilities can now procure required materials and equipment on short notice because of the highly developed logistics of the suppliers.

(3) Pipeline Maintenance

1) Transmission and Distribution Pipe Materials and Maintenance

Materials for pipelines were mostly imported in the early days since the facilities were designed by foreign engineers. Domestic production started when there was public demand to use domestic products. The technology and manufacturing bases were gradually established through trial productions and usage. Domestic products took over the market partly through the establishment of national standards by JWWA.

Materials for pipelines were mostly imported in the early days and were expensive. The general public and policy makers began to demand transition to domestic products. The transition was not successful in the initial stage, because the domestic manufacturing industry was underdeveloped. In the second half of the 1890s, modern water supply system was gradually spreading to major cities in Japan. Development and improvement of water supply materials and equipment intensified. Domestic products gradually became more broadly used. Manufacturing technology also improved by standardized specifications.

At present, ductile iron pipe (DIP), steel pipe, un-plasticized polyvinyl chloride pipe (uPVC), polyethylene pipe (HDPE) are manufactured in Japan. The choice of material depends on ground conditions, purpose and available budget.

Example: Transition of Pipe Materials

Most of the utilities have used various kinds of materials and technologies for pipelines along with the innovations for preventing leakages and corrosion. This Example introduces the history and transition of the materials of pipes and appurtenant technologies.

The water supply system in Kyoto City was established in 1912. Gray cast iron pipes were used like other cities. After a serious pipe burst in 1923 and an earthquake which hit the other part of the country in the same year, deeper underground installation and thicker pipe walls were proposed. Although these were not adopted because of financial concerns, strengthening of pipelines was a serious concern even at that time.

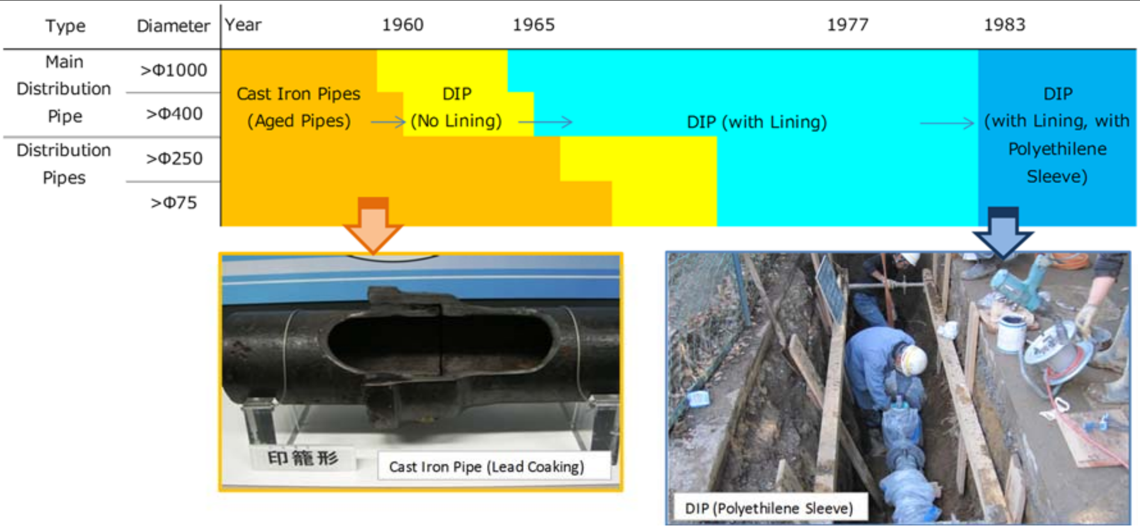
High grade cast iron began to replace gray cast iron as the material of choice, but it was difficult to procure at the time. Utilities turned to asbestos cement pipe as an inexpensive option.

During the 1940s to 1950s, leakage prevention measures for distribution pipes were implemented and significantly increased accounted-for-water by more than 20 percent.

The Kyoto, Osaka and Kobe cities petitioned the General Headquarters of the Allied Forces (GHQ) to lower the required content of residual chlorine (0.4 ppm) which caused steel pipes to rust prematurely by 5 years. Around this time, ductile cast iron pipe from the United States of America (USA) started to be used in Japan. Kyoto City started to use this material from 1959.

During the 1960s, asbestos pipes were used extensively, but the use ended in 1968 due to their rapid deterioration. Thereafter, existing pipe materials were changed to (1) ductile cast iron; (2) ductile cast iron wrapped in polyethylene sleeves for corrosion protection; and (3) earthquake resistant joints.

Bureau of Waterworks, Tokyo Metropolitan Government (BWTMG) started using ductile iron pipes in water distribution networks since 1960. Some new technologies apply an inner lining or polyethylene sleeve to prevent corrosion. The aging cast iron pipes are being replaced at about 300 km to 400 km per year. With a total of 24,000 km distribution pipes, all the water distribution pipes will be replaced in 60 to 80 years.



Source: Training materials for JICA Technical Cooperation Projects

Sources of Photo: (Left) Water Partners Jp Co., Ltd. (Right) Japan Ductile Pipe Association

Figure 3. History of Pipe Materials in BWTMG

2) Materials and Maintenance for Service Connections

Lead, galvanized steel, and copper were commonly used for pipes in the past. Lead pipe was replaced by uPVC pipe etc. because of health concerns caused by the elution of lead. The Water Supply Act stipulates the material and structure for water supply facilities (facility standards).

In 2004, JWWA published the "*Guidelines for Maintenance of Service Connection Facilities*" stipulating the responsibilities to be fulfilled by parties including the national government and users.

Lead and copper were used to manufacture service pipes because of their workability. Lead pipes had to be replaced when the toxicity of lead was understood. Currently, commonly used pipe materials are stainless steel, uPVC, and polyethylene.

Utilities sometimes face difficulty for managing and replacing service pipes because some part of the facilities are the asset of the customers, on contrary to the transmission and distribution pipelines which is owned by utilities. Accidents such as cross connections can be caused by the lack of maintenance and supervision. Manufacturers, certification bodies, utilities, and construction companies, supposedly had lower awareness to maintenance for service connections and could all do more to prevent accidents. Many leakages also occur in service pipes and customers can do more for their maintenance. JWWA prepared the "*Guidelines for*

Maintenance of Service Connection Facilities" in 2004. The guideline clearly describes the problems with maintenance and management of the service connections and the responsibilities of the national government, the water utility, the contractor, and the customer.

The specifications for pipe materials have been developed by JWWA which reflect the input from utilities and the manufacturing industry. JWWA also established an inspection system which helped utilities to procure high quality materials and contributed the development of the water industries. It is important to establish standards for materials and equipment to ensure their quality.

Column: Restrictions on Usage of Lead Pipes in Japan

The regulations on lead pipes were issued in a notification of "public health measures concerning service pipes" in response to a report of a water supply and sanitation committee of Ministry of Health and Welfare in 1989. The highlights of the notification are as follows:

(a) New service pipes must be lead free
(b) Replacement pipes must be lead free
(c) pH must be maintained at a high level in the water supply to suppress lead elution
(d) The public is advised to run water for a while after turning the tap on and use this water for purposes other than drinking or food preparation.

Based on the latest scientific evidence and drinking water quality standards of the World Health Organization (WHO), acceptable limit for lead was changed from 0.1 mg/l to 0.05 mg/l (December 1992), and again to 0.01 mg/l (March 2002).

Notifications and amendments to the water quality standards accelerated the replacement of lead pipes in Japan, but not as much as expected. Utilities tend to give the priority to upgrading the seismic resistance of water pipes. There is also no incentive to deal with the service pipes which are the property of the consumer. There are still many lead pipes remaining in the distribution systems of small- and medium-scale utilities (around 4 million connections in 2010). In 2012, the Ministry of Health, Labor and Welfare issued the "*Guidance for Lead Pipe Replacement*" outlining the technology, policy, and required efforts for each water utility.

Lead pollution in tap water in Flint, Michigan State in USA, which occurred in January 2016, reaffirmed the seriousness of the toxicity of lead.

3) Mapping of Distribution Networks

Digital GIS mapping systems have replaced paper records of distribution networks making it easier for information sharing within the utility and with other related infrastructure agencies to facilitate the communication.

Digital mapping integrated with database systems capture a vast array of information on the distribution network on one single platform. It makes the monitoring of pipeline conditions, locating operational problems and planning repairs and replacements much more efficient.

Traditionally pipeline information was kept as paper drawings and on ledgers, and sometimes saved in microfilms for portability. The information can be lost during disasters, as in the tsunami caused by Great East Japan Earthquake in 2011. It is also more difficult to share the information and data, compared to doing so electronically. Utilities started to transfer their pipeline data to electronic systems. These databases are also useful for hydrological calculations and for asset management.

Whether in paper or electronic format, information held by individual staff should be shared for more efficient management of water distribution, and construction planning to minimize water supply disruption. Sharing of information is the basis for proper pipeline management.

It is also important to update drawings in a timely manner after construction or rehabilitation. Most water utilities in Japan either have a specialized department for this purpose or the task is outsourced.

Example: Tokyo Metropolitan Government; Road Infrastructure Coordination Council

All utilities (water supply, sewer, gas, electricity and telecommunication) must replace their distribution networks from time to time. This should be planned to coincide with their maintenance and repair, to save money on road resurfacing, minimize traffic disruption, and prevent damage to other underground utilities. Committees with representation from implicated service sectors, shares their multi-year infrastructure construction plans and coordinate the work plan.

At the Tokyo Metropolitan Government, the Bureau of Construction organizes meetings of the road infrastructure coordination council several times a year. The council members include the Bureau of Construction of Tokyo, Ministry of Land, Infrastructure, Transport and Tourism, Police Department, Metropolitan Expressway Co., Ltd., Bureau of Waterworks, Bureau of Sewerage, Bureau of Transportation, Nippon Telegraph and Telephone Corporation (NTT), Tokyo Electric Power Company, Tokyo Gas, Tokyo Metro and Japan Railway Company (JR). The council is divided into working groups for coordination, maintenance, and improvement. The coordination working group engages in the coordination of road works and shortening the construction work period.

(4) Construction Quality Management

Construction quality control is essential for improved maintenance and long service life of the facilities. In Japan, it is required by law that construction must be implemented under the supervision of a qualified engineer. Contractors for service connections must be registered and certified as stipulated in the Water Supply Act; this is a quality control measure.

Article 12 of the Water Supply Act stipulates that qualified engineers must supervise the construction of service connections. During the period of high economic growth, many projects were implemented at the same time resulting in poor construction and errors such as cross connections. Contamination of water distribution pipes because of poor quality equipment and construction practices were also reported. As its measures, The Ministry of Health and Welfare set the standards for construction and required that contractors installing service connections be qualified and registered. These approaches are one of the good examples of the measures for improving the construction quality; there are many approaches such as laws, administrative orders and reforms of implementing methods.

Column: Designated Prequalified Contractors and the Registration System for the Contractors for Service Connection

In the beginning, the construction of service connections was mostly carried out by utility workers. Most utilities preferred to maintain close control of new construction and repairs because of the public health responsibility. There was always a concern that unqualified contractors might use inappropriate materials or construction practices. However, there were some exceptions. In the early years of water supply in Yokohama, Tokyo and Osaka, customers were allowed to use their own materials and labor for the construction of service connections as long as they obtained approval from the utility and passed inspection. In response to an increase in the construction of water supply facilities after WWII and multiple natural disasters, many cities began introducing a system of "designated prequalified contractors" for service connections. The system ensured that only qualified contractors approved by the utility could work on service connections. This ensures standards for the design, material selection and construction are met. This requirement also succeeded in reducing leakage. The system also improved the response time to emergency repairs because the standardized construction made it easier to establish the operating procedures for the repair work.

After the system of designated prequalified contractors became widespread, the Japan Plumbing Constructor's Association was established in 1960. Amongst its many activities the association also organizes member companies for disaster recovery in affected areas.

In recent years, most utilities outsource repair and installation because of their shrinking workforce. The revision of the Water Supply Act in 1996 standardized the requirements for designated prequalified contractors. It sets the registration system for the contractors for service connections and introduced unified qualification. Engineers supervising installation of service connections are required to be qualified in accordance with the Water Supply Act.

5. Lessons Learned

The following Japanese experience could be useful for other countries.

- **(Preventive Maintenance)** In the expansion phase of water supply facilities, inadequate facility maintenance sometimes caused disease outbreaks. Utilities improved their maintenance activities to avoid water quality deterioration and supply interruptions. Development of legal frameworks and national guidelines followed immediately after serious accidents, and changed maintenance practices across the country. Preventive maintenance is greatly facilitated by the national facility standards and is very effective in lowering the life cycle cost of the facilities.

- **(Guidelines and Standards)** Good maintenance practices are supported by legislation and strengthened supervision by national and prefectural governments. The Japan Water Works Association (JWWA) prepared the *Design Criteria for Water Supply Facilities* and *Water Supply Facilities Maintenance Manual.* Utilities across the country share their knowledge in these publications, and train their workers based on these standards.

- **(Concepts and Tools)** (1) Preventive maintenance, (2) standards for materials/equipment quality and construction quality, (3) guidelines, and (4) information sharing, contribute to improved operation and maintenance. New tools, such as digital mapping and asset management are very valuable in systematic rehabilitation of water facilities.

- **(Maintenance of Water Treatment Plant)** Utilities share knowledge by preparing operation manuals. The workers can be trained according to a standardized set of procedures. The accumulated knowledge and specialized skills can be shared with other utilities at annual meetings of JWWA. Maintenance practices for safe and stable supply were established as a result of the struggle to transform the personal knowledges which were exclusively owned by skilled staff to collective knowledges which could share with all staff. The collective knowledge realized well planned and organized maintenance activities. Recently, maintenance is outsourced to private companies in most water treatment plants. It is important to properly monitor the performance of the private companies. The maintenance evaluation manual prepared by JWWA is very useful for this purpose. The selection of suppliers for spare parts and chemicals and inventory control are also important.

- **(Quality Control)** In the past, accidents were attributed to poor quality pipe materials and poor construction. Now there are more robust pipe materials and construction quality has improved. Manufacturers are developing better technologies. At the same time the establishment of standards and inspection system by JWWA contributes to setting an acceptable level of quality across the country. Construction quality also improved with the registration system for the contractors for service connections as required by the Water Supply Act. Information on pipelines after construction and repairs should be properly recorded and shared within the water utility. Good pipe materials, control of construction quality and information sharing help utilities to comprehend their own systems and improve their maintenance practices. Both the public and private sectors contributed to improved quality control.