Guest Forum

Current Conditions of Small Water Supply System in Japan and Technical Needs

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Since the population has been decreasing in Japan, it is important to focus on the area with small population or low population density. In this article, small water supply systems managed mainly by residents in small residence area were described. Various water supply methodologies and the needs of water treatment facility installed were shown. Based on the reality of waterworks, technical needs for supporting small water supply systems were discussed.

Keywords : Water supply system, drinking water, water treatment, depopulation

Introduction

Although Japan's potable water supply is a mature social infrastructure, it currently faces a number of important and urgent issues. The main issues are listed below[1].

(1) Depopulation and decline in water demand

Water demand continues to decline due to a decrease in domestic water consumption per capita and depopulation.

(2) Rapid increase in demand for facility renewal and decline in investment

The time has come to renew the water supply assets that have been developed to date. However, investment has been declining in recent years, and water supply facilities are aging.

(3) Aging of pipelines

Pipelines, which account for 70% of water supply assets, are aging, but the pipeline renewal rate is only 0.64% per year (as of the end of fiscal 2021), which means that it will take 156 years to renew all pipelines.

(4) Delays in earthquake-resistant measures

The earthquake-resistant measures rate is still not sufficient, at 42.3% for main pipelines, 43.4% for water treatment facilities, and 63.5% for service reservoirs (all as of the end of fiscal 2022).

(5) Problems with business management and water tariff setting

Although waterworks are supposed to be self-supporting, many of those are operating at a loss. Tariffs should be set based on asset management, considering future renewal demand, but in many cases this is not being done.

(6) Reduction in staff and difficulties in technology transfer

The number of employees at waterworks is decreasing and the age of those is increasing. As a result, technology transfer is becoming difficult, and business management itself is becoming difficult.

Against this backdrop, the Waterworks Law was revised in 2019[2]. The most important point of this revision is that the purpose of the law has been changed from "systematic development of water supply" to "strengthening the infrastructure of water supply." In other words, with the serious issues mentioned above, it is not only difficult for small and medium-sized waterworks to overcome these issues, but there are also cases where it is becoming difficult to continue operations in the future. This amendment is considered as a major revision because it changed the purpose of the law itself.

This article focuses on small water supply systems as a symbol of the problems with which water supply in Japan is faced, introducing the trends of the systems regarding both water supply methodologies and the needs for water treatment facilities. Based on the trend introduction, the needs are discussed to support the small water supply systems.

Existence of small water supply systems

Water supply systems serving 5,001 or more people are called potable water supply systems, and those serving 101 to 5,000 people are called small water systems. These are the main types of water supply treated as "water supply" under the law. (There are several other types, such as dedicated water supply systems.) The penetration rate of these types of water supply reached 98.1% in 2020. However, it would be premature to conclude that universal access to water supply is being achieved. There are still local governments where the water supply coverage rate is in the 50% to 60% range, and there is no prospect of a rapid increase in the coverage rate in these areas. Furthermore, even though the coverage rate is in the 98% range, this means that the remaining 2% or so of the population, or more than 2 million people, do not have access to water supply.

In Japan, there are many small water supply systems that are not subject to the Waterworks Law because the water supply population is 100 or less. These include drinking wells, drinking water supply facilities, and small community water supply systems. Not being subject to the Waterworks Law means that these systems are not required to comply with water quality standards or conduct water quality examinations. Since they are not considered as "water supply", this paper refers to them as "small water supply systems."

Most of these are very small facilities managed by local residents, but they face issues such as ensuring the safety of drinking water, increasing maintenance costs due to aging, and resilience to disasters such as earthquakes.

With the ongoing depopulation in various parts of Japan, there is a growing need to focus on small-scale water supply systems, including the small water supply systems mentioned here. From this perspective, authors including myself published "Small Water Supply Systems: Toward a Sustainable Supply of Safe Drinking Water"[3] in 2024. That is the first book to discuss the small water supply systems in Japan comprehensively. While looking at the current situation directly, the book outlines the direction that the water supply in Japan should take as a whole and suggests recommendations from various perspectives.

The current situation and trends in small water supply systems

Among the small water supply systems, there are cases where management by residents is difficult or has reached its limits, and conversely, there are good examples of the systems that have been established in a sustainable manner. There are also cases where new technologies that meet social needs have been successfully created. This section discusses current trends and future directions, focusing on two aspects: water supply methodology and water treatment facilities.

Selection of water supply methodology

There are areas where it is difficult to maintain a centralized water supply system with water treatment facilities and distribution networks, which are referred to as "areas where pipeline maintenance is difficult." In addition, in many cases, it is inefficient or impractical to connect unserved areas to existing centralized potable water supply systems that is the conventional method. In the future, it will be necessary to select water supply systems that are appropriate for local conditions, such as decentralized systems and water transmission by transportation.

The decentralized system is one in which raw water intake, water treatment, and water distribution are all carried out within the local area. A unitized portable equipment is one of the options for the water treatment facilities to be introduced in such areas. Photo 1 shows an example of a facility in Hamamatsu City (supplying drinking water to about 50 people). The water treatment facility on the left side of the photo provides the workflow, which are coagulant injection, sedimentation, rapid filtration, and disinfection. The service reservoir is on the right side of the photo.

Photo 1 Water supply facility installed in Hamamatsu City, Shizuoka Prefecture

The decentralized systems are clearly less expensive in terms of initial costs than the system connecting to the potable water supply, but in this case, it is necessary to address concerns such as facility management responsibilities, maintenance entities, required water quality examinations, and secured fire protection water supply.

Furthermore, instead of the centralized water treatment, the decentralized water treatment close to the point of use is becoming one of realistic options. Examples of the options include Point-of-Entry (POE) systems, which use small-scale water treatment facilities installed at the entrance of buildings to treat water and to supply the water to households, and Point-of-Use (POU) systems, which is even smaller scale and treat water at each faucet.

In Higashi-Chichibu Village, Saitama Prefecture, in addition to the option of introducing the small-scale water treatment facilities similar to those in Hamamatsu City as mentioned above, a plan has been proposed to discontinue the existing water treatment plant and to install small-scale water treatment facilities in each household. A conceptual diagram is shown in Figure 1. It would be difficult to respond to subsequent depopulation if the water treatment plant would be renovated completely, but this system has the advantage to respond to depopulation because water is treated in each household. Higashichichibu Village plans to introduce this system on a trial basis and to verify its effectiveness through water quality examinations and other measures.

In addition, on Kuroshima, a remote island off the coast of Sasebo City in Nagasaki Prefecture, the introduction of the Point-of-Entry (POE) system has been proposed and is being implemented.

This kind of water supply system can be introduced in a short period of time because the system requires neither a network of long pipelines nor large-scale installation work while the system is relatively cheap. However, in this case as well, it is necessary to organize measures to address the concerns mentioned above.

By the way, the law defines "water supply" as a facility that supplies water through pipes but does not assume that water is transported and distributed. However, the needs for transporting water exist in various places because the difficult cases are increasing for the areas (where pipeline maintenance is difficult) to maintain the centralized water supply systems that have been built up to today. For example, in Shitara Town, Aichi Prefecture, the plan to transport water was proposed in the past but was rejected after Aichi Prefecture pointed out that it would not be water supply anymore.

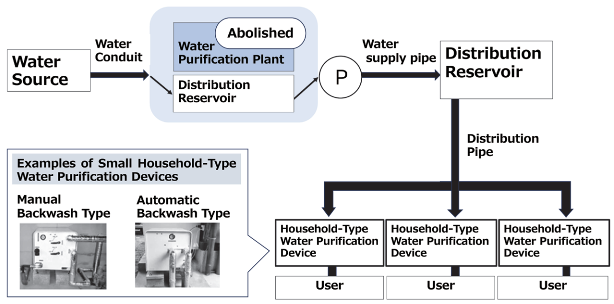

Figure 1 A scheme of installing point of entry type water treatment facility.

Photo 2 An example of water transmission by transportation in Miyazaki City.

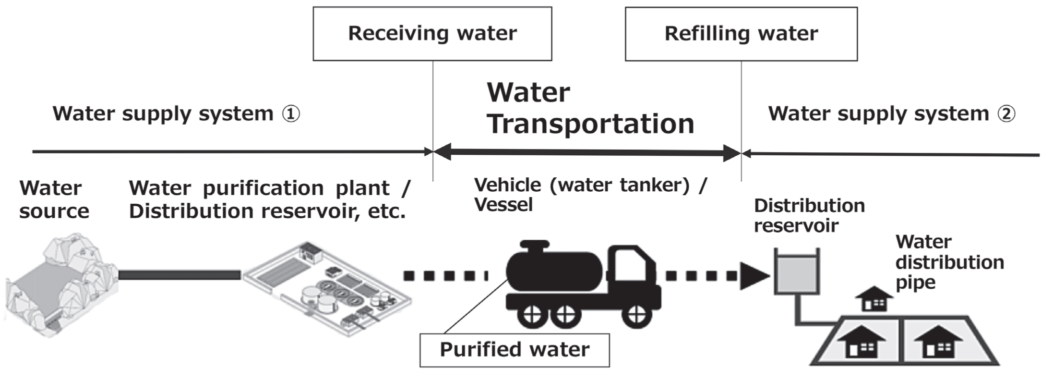

Figure 2 Illustration of water transmission by transportation.

Under these circumstances, the Ministry of Health, Labour and Welfare issued "Points to note regarding water transmission by transportation"[4] in 2023, stating that water transmission by transportation is feasible as a part of waterworks. A conceptual diagram is shown in Figure 2. Since this is the transmission part of the water supply systems, the term "water transmission by transportation" is used instead of "water supply by transportation." Since the water is transmitted in the part of the water transmission, the part is still not considered as the water supply. However, since the service reservoir and beyond can be considered as the part of the waterworks, it is feasible as a part of waterworks. This can be considered as an example of a flexible response without major institutional changes such as legal revisions. As a result, many waterworks can now consider to introduce the water transmission by transportation although they gave up to introduce it. An example of water transmission by transportation in Miyazaki City is shown in Photo 2 showing that the water is supplied from the supply tank vehicle to the service reservoir.

The evaluation example of the advantages of the water supply methodology mentioned above[5] is shown in Figure 3. The area in Nara Prefecture equipped with the small water system has been evaluated. The two-dimensional plane with the horizontal axis representing the water supply population and the vertical axis representing the total length of the pipelines for supply and transmission shows the areas, where the normal water supply can cover, where introducing the water transmission by transportation is better, and where it is better to supply only non-potable water but to supply potable water with another methodology. The important point is to have clarified that the introduction of the water transmission by transportation is effective if the transportation to each household is available based on the condition of the area. It is recommended to discuss such studies actively and to select the realistic or smart option to meet the condition of the local area.

Needs for water treatment facilities

Fukuchiyama City, Kyoto Prefecture, has an ironic example in which no concerns have been raised about the future in areas without the water treatment facilities while concerns have been raised about the continuous maintenance of the water treatment facilities in areas with the water treatment facilities.

In Shizuoka City, measures to achieve sustainable water supply system for the future have been introduced based on the main concerns raised by residents including ensuring stable water supply, installing maintenance-free water intake and treatment facilities, and implementing reliable disinfection.

In addition, although a lot of the small-scale water treatment facilities have been introduced, their water treatment capability is approximately 50 m^3/day but even smaller-scale water treatment facilities have been required. Therefore, the needs for the water treatment facilities suitable for each small community should be extremely small-scale, easy to maintain, and low-cost facilities.It is expected that facilities and new technologies to meet the needs are developed.

On the other hand, the approaches have been proposed

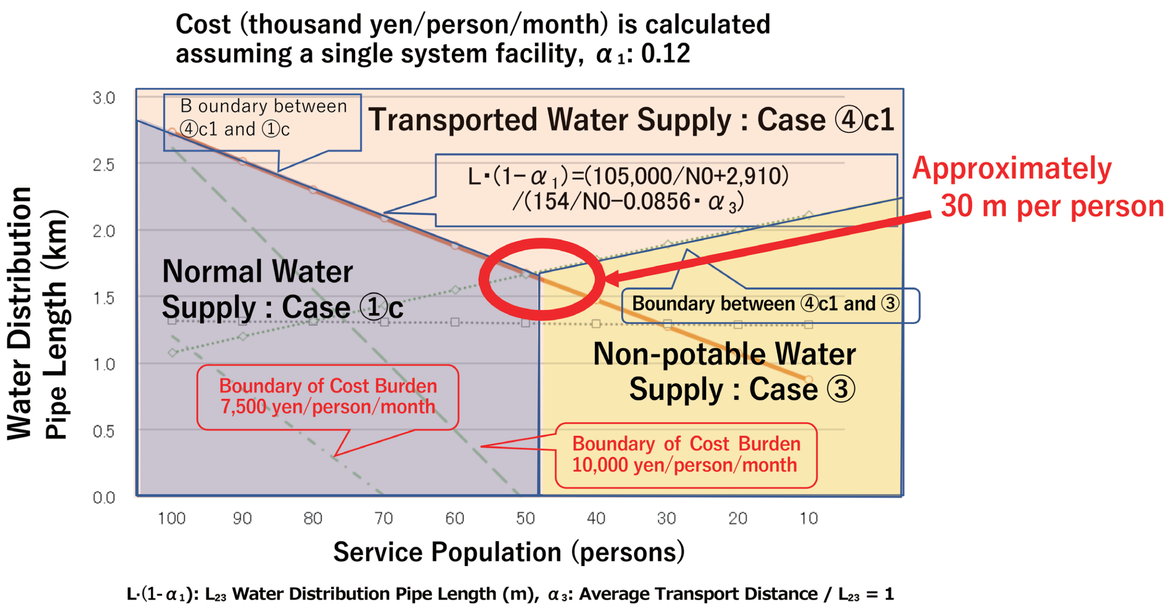

Figure 3 An example of evaluating water supply methodologies.

regarding the social infrastructure development in the depopulating society, which is not limited to potable water supply facilities[6], [7]. In the past, various types of infrastructure have been developed focusing traditionally on durability and permanence (long-term usability). It can be said that efforts have been made to build water supply facilities and equipment that are robust and long-lasting. In contrast, in a shrinking society, it will be necessary to adopt the concept to shorten their lifespan (or to combine extending lifespan and shortening lifespan) by modularizing the infrastructure. The term “shortening lifespan” can also be replaced with “planned service life.” With this approach, we can respond to the future demand change of the area or, in some cases, can decide to withdraw the development. In the future, we believe that it will be necessary to adopt the concept of designing and introducing facilities and equipment that will last for about 10 years. Leasing contracts, which some companies have already started to offer, will also be an option.

In fact, there is an example in Kochi Prefecture where new technologies that meet the above social needs have been successfully developed.

In the mountainous areas of Kochi Prefecture, there are many water supply facilities where residents themselves secure and manage their own domestic water. Kochi Prefecture launched the “Kochi Prefecture Domestic Water Model Development Project” for those facilities and conducted the commissioned work in fiscal 2014.

Through this project, a simple slow sand filter facility (two-tank slow sand filter facility) has newly been developed for small-scale area. The structure of the facility and its surface are shown in Figure 4. The facility consists of two tanks with the gravel layer and the sand layer separated, which is the key feature of the facility. The water in the gravel layer flows upwards and is coarsely filtered. The filtered water flows into the sand layer downwards and is filtered. Simplifying each filtration layer in this way makes cleaning easier, which is the main maintenance work. In addition, no power supply is required.

Another feature of this device is its extremely small size, with a water treatment capacity of 3 to 6 m^3/day (corresponding to a filtration speed of 4 to 8 m/day). This is suitable for a water supply population of several to dozens of people. Furthermore, the facility itself is inexpensive, at 1.3 million yen per unit.

A notable feature of this case is that Kochi Prefecture identified the needs of mountainous areas, demonstrated the required facilities and equipment, and specified the technologies that needed to be developed. This enabled companies to clearly define their development targets and gain a clear outlook for business expansion throughout the prefecture. In fact, the contractor (company) stated that they would not have developed the facility and equipment from scratch without the prefecture’s initiative.

In this way, the project promoted by Kochi Prefecture can be recognized as success in creating new technologies that match social needs. The role played by the prefecture was extremely important. The developed two-tank slow sand filtration facility has become the new technology that matches the needs for each small community[7] such as extremely small-scale, easy to maintain, and low-cost. We hope that it will be widely adopted throughout Japan.

Technological needs supporting small water supply systems

The above section introduced two aspects and their trends regarding water supply methodologies and water treatment facilities. At the same time, there are significant social needs to develop technologies supporting these water supply systems. This section provides an overview of various technologies currently under development and discusses technologies that are effective in alleviating the issues faced by the small water supply systems.

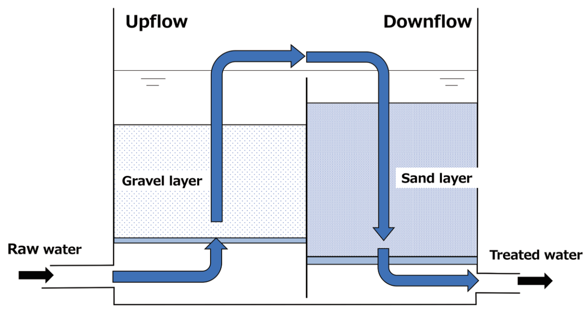

Figure 4 Slow sand filtration facility newly developed for small residence area.

Significance and trends in the introduction of data management and monitoring technologies

Small water supply systems rely on the self-help efforts of residents for transferring the know-how for operation and maintenance as well as managing data, which, in many cases, are done in analog form, i.e., through word of mouth and handwritten notes. This system has been increasingly difficult through the ongoing depopulation and the aging population.

This problem may be dramatically alleviated by information and communication technologies, which require little investment and are easy to operate. With the information and communication technology, data measured without human intervention can be recorded (logged), transmitted, and monitored remotely. If the communication environment is ready, it is possible to transmit not only numerical data but also real-time image data of the area, allowing visual confirmation of the area. However, such remote monitoring technology is generally expensive, and was mostly introduced to the public water treatment plants of the waterworks in the past while few technologies were introduced to the small water supply systems.

To date, the Ministry of Land, Infrastructure, Transport and Tourism has been implementing the “Model Project for Promoting the Use of IoT in Water Supply Services” (subsidy for earthquake-resistant infrastructure)[8] to improve business efficiency and provide high value-added water supply services through the use of advanced technologies such as CPS (Cyber-Physical System) and IoT (Internet of Things). In addition, the Ministry of Land, Infrastructure, Transport and Tourism; the Ministry of Economy, Trade and Industry; and NEDO (New Energy and Industrial Technology Development Organization) have collaborated to build a standard platform for utilization systems of the water supply information, with which a few services have been launched[9].

From the perspective of technologies suitable for the small water supply systems, low-cost and easy operation are essential. Therefore, it is necessary to reduce costs through standard design and mass production, and it is important to develop technologies as “mass-producible services” with a view to expanding their use beyond water supply.

Current situation of development and introduction with future expectations

This section provides an overview of the technologies developed to date and their potential for introduction into the small water supply systems. Some of the new technologies introduced here are summarized on an information website on the small water supply[10].

• Development of water quality management and monitoring technologies

Although the water quality examination has not been conducted on many of the small water supply systems, the cost of the water quality examination is a significant burden if the water quality examination is conducted on the systems. There are 51 items specified in the drinking water quality standards in Japan. It costs an average of about 210,000 yen when the examination is conducted by an inspection agency registered by the Ministry of the Environment. The Waterworks Law requires the regular examinations consisting of three quarterly examinations and eight monthly examinations in addition to the annual examination including all the items. If all the examinations are conducted, approximately 570,000 yen per year is required as the cost of these examinations. The water quality examination cost is a significant burden for small areas with a small water supply population. In fact, some of the small water systems have been downgraded to drinking water supply facilities due to the cost reduction of the expensive water quality examinations as a main reason. As a result, the drinking water supply facilities can be exempt from conducting the water quality examinations since the Waterworks Law does not apply to the facilities. In fact, as an example, in Nishigo Village, Fukushima Prefecture, the annual cost of 740,000 yen was significantly reduced to 59,000 yen through the downgrading. Considering these current situations, the author proposes to introduce a concept of “customized water quality standards”, which involves selecting the examination items definitely necessary for the area and setting the frequency of the examinations[3].

If a system is available to monitor the operation including the water quality of the water supply facilities “at low cost”, the system would provide a great advantage for maintenance and management.
Since communication technologies and terminals have become increasingly sophisticated and widespread in recent years, their utilization should be considered. Various services utilizing the communication infrastructure have already been introduced by private companies related to the water supply.

For example, in Yurihonjo City, Akita Prefecture, data on water quality, water levels, and water distribution volumes are managed collectively using telemeters as well as cloud-based remote monitoring and controlling systems for 16 facilities including water treatment facilities, service reservoirs, and water transmission facilities.

• Development of treatment and operation methods at low maintenance cost

The small water supply systems usually encounter no problems but often encounter big problems to remove turbidity and debris after rain. The easy-maintenance and low-cost water treatment systems are good to be introduced to these facilities. In addition, 56 types of portable water treatment facilities including water treatment devices have been classified according to their treatment capacity, device configuration, target substances to be removed, vehicles capable of loading devices, and operating methods[11].

Photo 1 shows that the small water treatment facilities dedicated for stream water was introduced in Hamamatsu City. As an example of such facility using IoT, a business entity has introduced the cloud-based remote monitoring systems[8], [12]. Although the technology is still under development, the low-cost LPWA (Low Power Wide Area) communication was introduced to the water supply system in a mountain community to reduce the cost for the residents to monitor the water level of the service reservoir[13].

• Examples of development of portable disinfection methods without replenishment

One of the maintenance burdens of small water supply systems is the replenishment of chlorine disinfectants. A portable disinfection method without replenishment of chemicals and frequent maintenance is required, and such technologies have already been developed and proposed in various products.

• Pipeline technology including water leak detection and easy temporary repairs

Since the small water supply systems have vulnerable pipelines, it is required to introduce the pipeline systems which can be repaired with low cost in the event of a disaster or pipeline damage. New technologies using IoT have been developed, and we can see its example in Wajima City in Ishikawa Prefecture[8].

• Inspection and chemical replenishment using robot

The introduction of technologies such as autonomous driving and drones is expected to reduce the burden of maintenance and to solve problems caused by decreasing number of technical staff. Currently, the robot technology in the water supply field has been introduced only to the limited application to observe pipes and tanks where humans cannot access. In the future, robots are expected to be used in a wider range of applications such as the maintenance of water supply facilities in general and the automatic operation of chemical replenishment.

Conclusion

In Japan, disparities in water supply are likely to widen in the future. This applies not only to large, medium, and small water supply systems, but also to small water systems such as small water systems and drinking water supply facilities. Water tariffs, which have traditionally varied by a factor of about 8, are expected to widen to a factor of 20 in the future[14]. Given this situation, we strongly consider that it will be necessary to develop diverse water supply systems and diverse water supply societies in the future.

In response to the many difficult challenges facing Japan's water supply system described at the beginning of this article, numerous creative ingenuities, ideas, and proposals are currently being put forward to strengthen the foundation of water supply businesses and, even more importantly, to enhance their sustainability. These valuable ideas and proposals need to be implemented in society, but first, the technologies to support them should be developed.

We hope that this article will serve as a reference to create diverse technologies in various fields. At the same time, it is essential for the water supply industry to establish systems and mechanisms that do not hinder the formation of diverse water supply systems and societies, and to ensure that these systems and mechanisms are operated flexibly.

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