IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

Human Journals
Short Communication
January 2022 Vol.:23, Issue:2

Classification of Tap Water and Use of Intermediate Water

IJPPR
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An official Publication of Human Journals
ISSN 2349-7203
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Submitted: 24 December 2021
Accepted: 31 December 2021
Published: 30 January 2022

Keywords: tap water, intermediate water, safety, environmental protection

ABSTRACT

In this study, we clarified the classification of tap water and the use of intermediate water in Japan. The water supply in Japan is categorized as clean (waterworks), intermediate (reclaimed, recycled, and gray water), and sewerage (sewer, sewage system, canalization, and wastewater). Clean potable water is denoted tap water or waterworks and flows through a supply pipeline. Sewerage conducts sewage through a separate pipe, while the intermediate water system transports lightly treated rainwater and sewage for reuse as miscellaneous water. In recent years, the demand for intermediate water has increased in Japan, and its usage is expanding. In addition to the use of recycled water in homes, there is a mechanism for utilizing a large amount of intermediate water, such as rainwater, for new urban development. However, the cost varies depending on the maintenance requirement of the intermediate supply and the amount of water used; therefore, the advantages of this system are not always present in the short term. In the long term, considering environmental protection only, it is preferable to refrain from using clean water and substitute intermediate water; however, the range of use based on safety and other factors must first be evaluated.

INTRODUCTION

Approximately 60% of the human adult body is water, and it is suggested that 2–3 L of water is required per person per day for maintenance[1), 2)]. This water is not limited to beverages and can be supplied from solid food. Along with human health needs, domestic water is also required for other purposes, such as cooking, washing, industry, and maintenance of public facilities, which increases consumption by at least 20–30 times the above figures[2)]. The average water supply in Japan is approximately250 L per person per day, with larger cities using proportionally greater quantities[1)]. Before the formation of cities, naturally circulating water, such as rivers and the well water was used for drinking with no artificial treatment. When the population increased and began to concentrate in the city, the amount of circulating water from the natural self-cleaning actions was insufficient, and newly developed waterworks and sewerage methods to purify the water were devised[1)]. Water that appears clean can contain harmful substances; therefore, not all spring water is suitable for drinking. Water services are paths and equipment through which water flows, and in the past, these were constructed to simulate a narrow river (a waterway), while currently, resin pipes (water pipes) are used that are often buried underground to prevent foreign matter from entering. Tap water is defined as water that passes through a water pipe, and it is generally classified as clean, intermediate, and sewage, although the most common use of the term “tap water” relates to clean drinkable water[3)].

This paper describes the different tap waters and the treatment methods for intermediate water. In many cities in Japan, tap water is used only for clean water and sewage, and the use of intermediate water has been limited. Similarly, clean water and sewage services are regularly developed as part of the urban infrastructure, and intermediate water has rarely been considered. This has been changing in recent years, whereby the use of this intermediate system has increased, mainly in public facilities, with some expansion to private homes[4)]. Here, we introduce the results of our investigation and our suggestions as to why clean water has continually been used as opposed to intermediate water for purposes other than consumption.

Classification of tap water

Water services are generally separated into the clean water supply, intermediate water supply, sewerage, rural water system, and industrial waterworks. Waterworks refers to the public supply of potable water that represents the water service through which clean water flows[3]. Clean water is that which we typically access when we turn on the faucet. There are three water sources: surface water, such as from rivers, lakes, and dams, underground water that trickles into the soil, and groundwater that flows deeper underground. All three types are filtered and chlorinated at purification plants to produce clean water, which is then delivered to homes through pipes (waterworks). Often, these purification plants are operated and managed by local municipalities, and the purification method is unified throughout Japan. The operations are part of the urban infrastructure, and the price of water is generally low. In many cities in Japan, clean water is produced from a base with few impurities (the level of intermediate water described later); therefore, the costs are relatively low. For reference, the cost to fill a bathtub (approximately 200 L), is less than 1USD.

The intermediate water supply delivers what is considered intermediate water, which is defined as domestic and industrial wastewater that is treated and recycled. Alternatively, it may refer to rainwater. Intermediate water is also called miscellaneous or reused water[3),5)]. This type of water is used for purposes other than those ingested by or in direct contact with the human body, such as that used for flushing toilets or maintaining park fountains. Clean water is discharged to the sewer after it has been used, and since intermediate water is produced by simply disinfecting the water and then recirculating it, the waste of clean water is reduced, which relates to more cost-effective tap water (clean water). Intermediate water is often sufficient for many purposes, which leads to cost reduction as less purification is required for clean water production. However, the spread of intermediate water is currently low compared to that of clean water and sewage.

Sewerage is a collection of facilities and equipment that collect sewage and rainwater in urban regions through underground waterways and discharges them into public areas (rivers, lakes, seas, *etc.*). Most of these facilities perform water treatment, such as purification. Sewage is generally used tap water that is sent to a terminal treatment plant (sewage treatment plant) using sewerage (water services)[3]. In sewage treatment plants, sewage is purified to a safe level for discharge into public areas such as rivers and lakes. However, it is not cleaned to a sufficient level to be used as drinking water. It is expected to be purified to

such an extent that it does not harm the aquatic organisms that exist in the environment where it is discharged. After it is released into these environments, it can be reacquired, purified, and delivered to homes as clean water. Currently, sewers and sewage treatment plants are properly maintained in some areas, but there are also cities where sewage is drained directly into rivers and ponds without any special treatment. Waterworks are currently operating in 98% of Japan, but sewerages are only available in 80% of the country, producing a lag of approximately 50%, especially in municipalities with small populations (Fig. 1)[2].

The rural water system supplies water to populations of between101 and 5,000 people. It is mainly used for agriculture and mountain and fishing villages, and although it is similar to waterworks, it is on a smaller scale. Industrial waterworks supply miscellaneous water used for a purpose other than those that come into direct contact with the human body, such as for factories and other business establishments. An example is its use in cooling manufacturing or other equipment. It is similar to intermediate water but is generally considered to be limited to industrial use.

Recent trends

The intermediate water (intermediate water supply) has changed substantially in recent years. Public toilets in vehicles such as trains and airplanes have harnessed reused water (a mixture of detergent and water that has been used once for handwashing) for some time because it is difficult to access clean water while in transit. In hotels and other buildings with high public use, such as schools and halls, intermediate water has occasionally been used for hand-washing, showers, and gardening, which is appealing to people who are aware of environmental issues. Apart from those examples, intermediate water has rarely been employed in private homes, since clean water was readily available at a reasonable price. Since it was expensive to develop an intermediate water facility for personal homes, there were few opportunities for the water to be treated. Intermediate water was the better choice in terms of environmental protection, but it was expected to be difficult to implement because of its high cost.

In the past, water (especially drinking water, denoted here as clean water) was considered inexpensive and inexhaustible. Recently, global warming has reduced annual rainfall, and critical water shortages are expected for some cities[5]. The use of intermediate water has the advantage of immediate cost reduction for consumers as well as long-term environmental

protection, which is compelling for national and local governments; therefore its usage should be expanded[3]. In areas where large-scale urban development is progressing, the installation of an intermediate water supply is obligatory[5]. It is also highly useful in remote islands where freshwater is difficult to obtain, even though seawater is readily available. Large facilities such as factories or school swimming pools are generally assumed to be suitable for intermediate water use, but they can also be useful in private homes. A rainwater tank would be installed at the home, and the stored rainwater could then be used for car washing, while water stored in the bathtub would be appropriate for the laundry. Therefore, awareness of the various ways in which water is used on a daily basis allows for increased allocation of intermediate water over clean water in these instances. This method was originally considered for specific individuals, but with the increase of social networking services (SNS), the information has been made available to a greater number of users, many of whom have switched to this method of water usage. No additional capital is required to implement this process, and it is straightforward to use. In addition, newly built houses are designed to use intermediate water[4], whereby after clean water has been used, it can then be reused as intermediate water, and further actions can be taken to preserve the clean water. For public use, the cost must be considered, as it is difficult to promote any expense based only on environmental protection (Fig. 2). Along with the water collected and used in private homes, there is also the prospect of selling intermediate water to specific groups, which often have water quality standards. In these cases, purification and inspection would be required to safeguard the water (Table 1).

Author's comments

In Japan, the use of tap water (clean water) has been decreasing in recent years, mainly because of the offensive odor due to chlorination, and a large amount of mineral water is now used for drinking and cooking. Clean water is subjected to more frequent and thorough inspections than mineral water to ensure safety, although this fact may not be realized by the general public[8]. The annual consumption of mineral water in PET bottles per Japanese person was 1.6 L in 1990 and increased to 25.7 L in 2014[9]. To be conscious of environmental conservation, as described in the previous section, consumers must consider the importance of water conservation. However, tap water is promoted as inexpensive and inevitably preferred, since the choice between refraining from using clean water and replacing it with intermediate water has not yet been made. If the public acts with an

awareness of environmental protection in the long term as opposed to focusing on the short-term individual benefits, the unnecessary use of clean water can be reduced or avoided.

Utilizing intermediate water is reasonable in terms of reducing the use of clean water; however, depending on the place and purpose of use, there is a risk of the transportation of infectious diseases caused by bacteria such as *Escherichia coli* to humans; therefore, caution is required. For example, intermediate water may be used for shower or washbasin water, which can unintentionally enter the body. Washbasins of hotels often state that the water is not suitable for drinking, but it can still enter the body through such processes as teeth brushing. Therefore, intermediate water should not be used in such places. As shown in Fig. 2, the cost of intermediate water changes depending on the amount used, and unless it is used in large quantities, it will not be cost-effective compared to clean water, and the introduction of purification equipment would not be forthcoming in the short term. It may be necessary to consider the use of intermediate water according to specific equipment and usages.

There are some aspects that can be improved with regard to sewage. Currently, treating sewage has a cost, which is passed on to households according to their usage. If sewage can be prevented from flowing into the sewerage, the cost can be reduced, since the sewerage use would be minimized. For example, sewage could be allocated to fields or processed into intermediate water. Along with feces, *Escherichia coli* are present in sewage, and there is a risk that it contains parasite eggs; therefore, it must be carefully treated[10]. Sewerages can become clogged and deteriorated, even if only infrequently used, and it is considered safer to use them in moderation or eliminate them.

CONCLUSION

In Japan, it was traditionally understood that water and air for human survival could be obtained free of charge or at a low cost. This is partly because the amount used in the past was not large, and there was no interest in environmental protection at that time. Currently, to secure safe drinking water, regular inspections are indispensable, which cost money but provide peace of mind to the user. Certain large cities require sewage to be processed into clean water; therefore, it is no longer possible to readily obtain water as it was in the past. It is possible to select and use expensive and safe water. There are also technologies such as testing and producing fresh water from seawater, but the cost increases with these methods are unavoidable. Inexpensive alternatives can also be used, but their safety may be dubious.

For example, well water is considered to be relatively clean, but it may contain carcinogens such as trifluoromethane derived from the dry-cleaning waste liquid.

This paper describes the trends in tap water in Japan. Attempts to use intermediate water may be somewhat cost-effective, in terms of using clean water for consumption or other purposes that might cause the water to enter the body, and the less clean intermediate water for other purposes. By reducing the use of clean water by replacing it with its intermediate counterpart, clean water will be preserved, and the total cost will be reduced. These efforts by a town or city on a large scale are environmentally friendly, but the cost can increase depending on the amount of intermediate water used. Reusing water in the home without requiring construction should be recommended since the cost will decrease from that of using only clean water. Considering water conservation and environmental protection on a large scale, it would be most effective to reduce the total amount of water used. Some methods to accomplish this could include ensuring a faucet is completely turned off and not dripping water or using a toilet bowl that can save water structurally. Thus, using methods such as these can reduce the use of clean water without resorting to transitioning to intermediate water. This method would be effective for promoting both environmental protection and personal cost reduction.

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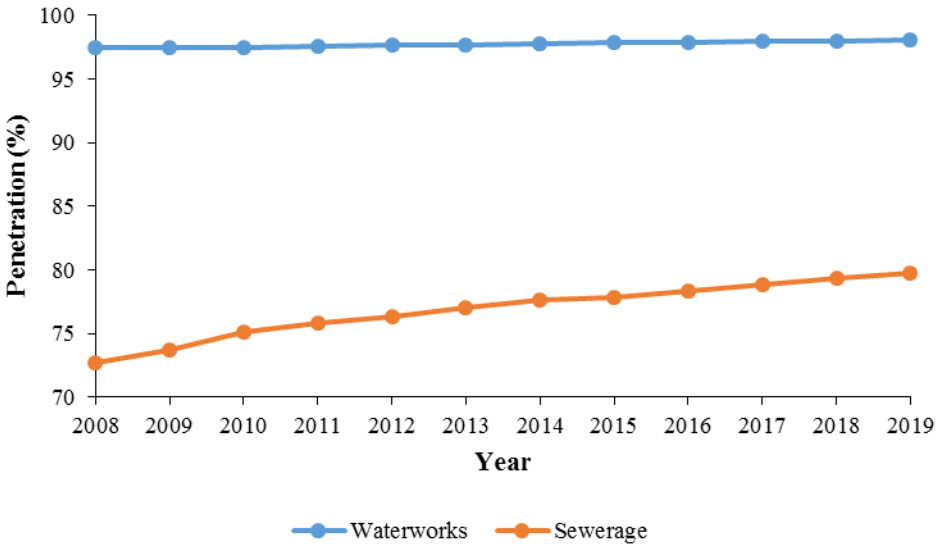

Fig. No. 1 Penetration rate of waterworks and sewerage in Japan

Sewerage penetration rates vary depending on the size of the city. As of 2008, the sewerage penetration rates of populations of total, 1 million or more, 0.5 to 1 million, 0.3 to 0.5 million, 0.1 to 0.3 million, 50to 100 thousand, and less than 50 thousandwere72.7%, 98.6%, 82.9%, 79.6%, 71.0%, 58.9%, and 43.8%, respectively, and as of 2019, they were 79.7%, 99.3%, 88.5%, 85.7%, 79.3%, 66.3%, and 52.5%, respectively.

Based on the data from references 6) and 7).

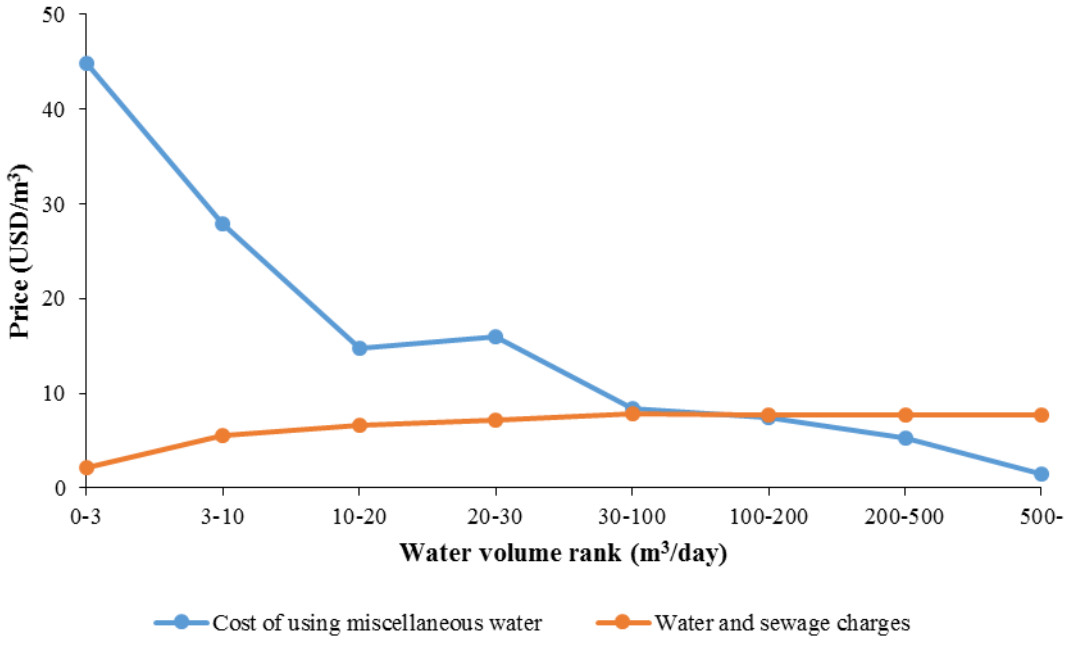

Fig. No. 2 Intermediate water (miscellaneous water) usage costs and water and sewage charges

Based on the results of a 2007 survey of the status of facilities that regularly use intermediate water. Intermediate water usage cost is calculated based on the construction cost (the useful life of 15 years) and maintenance costs.

Water and sewage charges are based on 2003 data from Tokyo. According to a survey by the Water Resources Department of the Ministry of Land, Infrastructure, Transport, and Tourism.

Based on the data from reference 5).

Table No. 1 Water quality standards for the use of intermediate water (miscellaneous water)

Subject	Standards, *etc*.	Supplementary explanation
Water quality standards for retaining residual chlorine applicable to all applications	The concentration of free residual chlorine at the faucet should be≧0.1 mg/L, and ≧0.4 mg/L for combined residual chlorine. If the supplied water is significantly contaminated with pathogenic organisms, or if it contains a large number of organisms or substances that are suspected of being contaminated, the free residual chlorine concentration should be ≧0.2 mg/L, and the combined residual chlorine concentration should be ≧1.5 mg/L.	This standard has the same content as clean water[1)]. Chlorine is added for the purpose of sterilization.
Water quality standards for flush toilets	-The pH value is 5.8-8.6 -The odor is not abnormal -The appearance is almost colorless and transparent. -Coliform bacteria should not be detected	The pH, odor, and appearance adhere to the standards for clean water[2)]. Coliform bacteria as adhere to the standard for sewage[2)].
Water quality standards for watering, landscaping, or cleaning	In addition to the water quality standards for flush toilets, the following must also be met: - Turbidity must be ≦2 degrees.	The turbidity adheres to the standard for clean water[2)].

Free residual chlorine is added for sterilization without being bound to other substances, such as proteins. Combined residual chlorine binds to proteins and sugars, and has weakened bactericidal activity.

Normally, the process of making intermediate water is not as intense as that for clean water, and there are fewer standards (51 items in the case of clean water).

Based on the contents of references 1), 2) and 5).