WATER QUALITY NEEDS AND STANDARDS FOR DIFFERENT SECTORS AND USES

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Summary

Water is used for various kinds of purposes, e.g. daily life, agriculture, industry, and fishery. It supports the full range of human activities and nature and the global ecosystem as well. Impurities which exist in water include not only essential substances necessary for supporting the life of living creatures, but also hazardous substances, which are not just unnecessary for living creatures but cause health problems. Water also contains parasites, infectious microorganisms, and chemical substances, such as agricultural chemicals, which may cause health problems to humans or other living creatures. It is necessary, therefore, to develop water quality standards for a wide range of purposes.

Water is a basic nutrient of the human body and is critical to human life. It supports the digestion of food, transportation and use of nutrients and the elimination of toxins and wastes from the body. Water is also essential for food preparation.

Agricultural use dominates overall uses of fresh water. Agricultural water is supplied either by precipitation or by irrigation, or both. Salinization caused by inappropriate irrigation practice inhibits water uptake to agricultural crops, degrades soil texture, and finally deteriorates the productivity of land. Therefore, deliberate consideration including irrigation water quality and irrigation practice must be paid to prevent salinization.

Fish cultivation including artificial hatching needs large amounts of water. Water reuse is therefore a vital measure in this industry, for both economical benefit and conservation of limited water resources. An appropriate level of water quality must be secured in order not to cause any adverse effect on cultivated fish, or any health risk to people who consume the cultivated fish as a protein source.

Many industries need water for production, utilizing specific properties of water such as its solubility, transportation potential, or heat exchanging capacity. Principal uses of water in industries are boiler make-up, processing, product treatment and cleaning, cooling.

1. Introduction

Water is used for various kinds of purposes: in daily life, agriculture, industry, and fishery. Water is supplied from the ocean to the atmosphere through evaporation and comes back to the ground surface as rainfall. It supports various kinds of human activities and nature and the global ecosystem as well. While water flows over the ground surface and becomes available as a resource in rivers, lakes/marshes, underground water, and coastal water, it absorbs inorganic substances from the soil, and organic substances and microorganisms generated by living organisms and human activities.

Impurities which exist in water include not only essential substances necessary for supporting the life of living creatures, such as nitrogen, phosphorus and iron, but also hazardous substances, such as arsenic and mercury, which are not just unnecessary for living creatures, but cause health problems. Water also contains parasites, infectious microorganisms, and chemical substances such as agricultural chemicals, which may cause health problems to humans or other living creatures. It can also contain other substances which do not cause any hazard to humans or living creatures, but disturbs proper use of water, such as silt and sand which make water turbid. It is therefore necessary to develop water quality standards for a wide range of purposes.

2. Health care and emergency measures

2.1. Health care

Water is a basic nutrient of the human body and is critical to human life. It supports the digestion of food, transportation and use of nutrients and the elimination of toxins and wastes from the body. Water is also essential in food preparation.

2.1.1 Water quantity requirements

The human body requires a certain amount of water in order to be able to sustain life before mild and then severe dehydration occurs. The US National Institute of Health provides a definition of mild dehydration as the loss of water by 3 to 5% of body weight, moderate dehydration by 6 to 10% and severe dehydration by 9 to 15%. Mild dehydration can be recovered by increase of water intake and this may be enhanced through the use of oral re-hydration salt (ORS).

Dehydration may be caused by severe diarrhea, excess alcohol intake, increased temperature or decreased relative humidity combined with inadequate water intake. Long-term dehydration may result in adverse health effects such as urinary calculus formation, urinary tract cancer and poor oral health. Urinary calculus formation is significantly increased when the urine volume excreted drops below one liter per day. Urinary volume exceeding 2 to 2.5 liter per day can prevent recurrence of calculus in chronic patients.

WHO, UNEP and IPCS use guidelines for volume of water intake as shown in Table 1. Adult males need 2.9 liters on average, adult females 2.2 liters, and children 1.0 liter per day, but daily intake increases with temperature, up to 4.5 liters. Specific population groups have particular hydration requirements, including young children, women in pregnancy or lactation, the elderly, terminally ill, and athletes. The loss of water from the bodies of small children is proportionally greater than for adults. In the WHO guidelines for drinking water quality, the values for chemical contaminants are based on the assumption of 60 kg adults consuming two liters of water per day. WHO produce specific guidelines for specific population groups, e.g. one liter per day for a 10 kg child or 0.75 liter per day for a 5 kg infant.

	Volume (liters day^{-1})		
	Average conditions	**Manual labor in high temperature**	**Total needs during pregnancy and lactation**
Female adults	2.2	4.5	4.8 (pregnancy) 5.5 (lactation)
Male adults	2.9	4.5	
Children	1.0	4.5	

Table 1. Volume of water required for hydration

In order to minimize the health risk from dehydration, an average of three liters per day is required for adults; however, in tropical hot climate or in conditions of excessive physical activity, it is necessary to take more than 4.5 liters. Approximately, one thirds of the total intake of water is taken through food and the rest is from drinking water. The quantity of water intake from food varies with the culture, diet and the manner of cooking.

In addition to drinking and cooking water, more water is needed for maintaining basic health, which means water for hand and food washing, bathing and laundry. Diseases related to poor personal hygiene such as diarrhea, eye and skin diseases, are caused by lack of water. Such water-related diseases are classified into four categories:

- Waterborne diseases caused through the ingestion of contaminated water.
- Water-washed diseases caused by insufficient volume of water for personal hygiene.
- Water-based diseases caused by infectious microorganisms such as schistosomiasis.
- Water-related diseases caused by insect vectors such as mosquitoes whose larvae live in water, and which transmit several infectious diseases such as malaria, dengue fever, etc.

It was reported that a median reduction of 35% in diarrhea from improved hand washing is achievable through a hygienic education program. Although water is the essential for promoting personal hygiene, the quantity of water for a hygienic condition is seriously related to accessibility of water, which means the type of water supply or the distance from water sources. Table 2 shows water consumption in several types of water supply. Reducing the time used in fetching water gives people more time for child feeding, food preparation and better hygiene. Figure 1 shows that once the time to fetch water exceeds a few minutes, the quantity of water collected decreases significantly. Figure 1 also shows that if a distance of one kilometer or more than 30 minutes total collection time is exceeded, the quantity of water will be further decreased. Therefore, the quantity as well as quality of available water is also closely related to health.

Type of supply	**Average consumption (L $person^{-1}$ day^{-1})**	**Service level**
Traditional sources, springs or hand pump	15.8	Communal
Standpost	15.5	Communal
Yard tap	50	In compound
House connection	155	Within house (multiple)

Table 2. Average water consumption figures

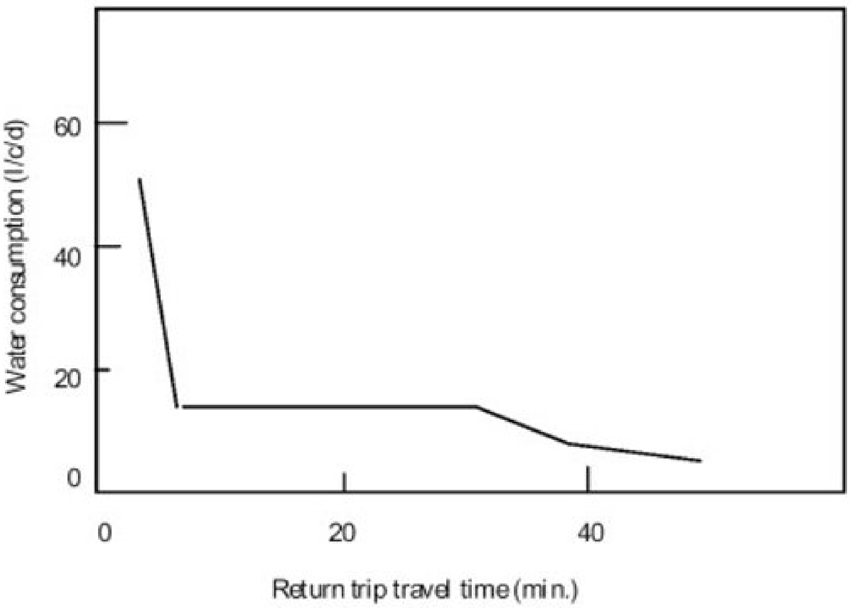

Figure 1. Relationship between travel time and water consumption

The quantity of water used by households primarily depends on the access, as determined by the distance and time to the water source. Table 3 shows the estimated quantity of water at each service level and the risk of health conditions. The level of access can also be interpreted in term of household water security. The no-access group, for example, has no household water security as the quantities collected are low, the efforts taken to fetch water is excessive and quality cannot be assured. Therefore, it is recommendable to provide at least 50 liters of safe water per capita per day.

Service level	**Distance/ time**	**Quantity of water**	**Hygienic condition**
No access	More than 1000 m or 30 minutes total collection	Very low (less than 5 liter	Hygiene not assured and consumption needs may be at risk. Quality difficult to assure.
Basic access	Between 100 and 1000 m or 5 to 30 minutes total collection time	Low. Average is unlikely to exceed 20 L c^{-1} d^{-1}	Not all requirements may be met. Quality difficult to assure
Intermediate access	On plot. Single tap in house or yard.	Medium, likely to be around 50 L c^{-1} d^{-1}	Most basic hygiene and consumption needs met.

			Bathing and laundry possible on-site. Quality more readily assured
Optimal access	Water is piped into the home through multiple taps	Above 100 L c^{-1} d^{-1}	All uses can be met, quality readily assured

Table 3. Service levels of water and hygienic condition.

2.1.2 Water quality requirements

Water quality standards show the levels which do not cause any hazard to human bodies or restrictions to the use of water. In order to establish water quality standards, scientific examinations on the safety and availability of water for each usage is required. Even though a standard has been established, if no one can afford any technologies to measure the concentration of impurities or manage and process water resource to reach the standard, or cannot afford the cost necessary for these technologies, then the standard will never have any effect. Therefore, each standard varies depending on the nature, society, culture and economic situation in each region.

Once the standard has been established, it is necessary to ensure that the standard is effectively enforced. In order to assure compliance with the law, temporary and/or continuous monitoring is needed. According to the results of the monitoring, some revision may be needed when hazards are identified within the limit level of concentration, also it will be necessary to take certain measures such as revision of the regulations.

Regulatory standards should include monitoring, which verifies the compliance of the standard. On the other hand, the guideline serves just as a reference when the goal or the standard for the desired water quality is provided. A typical example of this is WHO guidelines for drinking water quality (the Guidelines).

2.1.2.1 WHO guidelines for drinking water quality

WHO considers that the access to safe drinking water is a basic human right and an essential component for health protection. It has published the Guidelines to express the importance of drinking water quality to human health. The first and the second editions were published in 1984-5 and in 1993-7, respectively. In 2000, the development of the third edition of the Guidelines was agreed and all six WHO Regional Offices as well as the Headquarters participated in the process. The first draft of the third edition was released for public review in early 2003. The Guidelines primarily aims at assisting the development of national standards by health regulators, policy makers, and their advisers, and the Guidelines are kept updateds, to reflect state-of-art scientific findings.

The third edition of the Guidelines supersede previous edition, and it further develops concept approaches and information. This edition acknowledges that the microbial hazards continue to be the primary concern to most countries. It proposes the multiple barrier principle, and stresses the importance of source protection. This edition adds other chemical substances which have not appeared in previous editions, and covers new scientific findings on these substances. The third edition also includes discussion of the roles and responsibilities of key stakeholders in order to ensure drinking water safety. Several specific circumstances are also mentioned, including arsenic and fluoride in groundwater. This chemical hazard was highlighted by recognition of the scale of arsenic exposure through drinking water.

2.1.2.2 Water for medical purposes

Among the water for medical treatment, the drinking water does not have to be anything special, except immuno-compromised patients such as HIV-positives and other patients after surgery. Patients in whom the immunity level is low are easily infected by bacteria such as *Legionella*, which causes opportunistic infectious disease even though they do not cause any problem for normal healthy people. Water should therefore be boiled then cooled for such patients.

Other than drinking water, the water injected directly into human bodies, such as the water for injection must be secured for pathogen-free distilled water. The water obtained by high-pressure reverse osmotic membrane process may also be used since it can produce the same quality as that of distilled water. Even if both dissolved salt and the microorganisms themselves are excluded, however, there is a possibility that the microorganisms have produced a toxin. If endotoxin is 0.25 endotoxin-unit mL^{-1} or less, it can be assumed that pyrogen does not exist. In addition, the water used for washing during surgery or for washing surgical apparatus should have the same quality as that of injection water.

2.2. Water supply for emergency situations

It is inevitable that serious disasters damage various lifelines to support suffering people. In the case of a strong earthquake, physical forces damage the water supply facilities which secure continuous supply of potable water. Then, public water supply system can no longer provide sufficient quantity of water for daily activities such as domestic, social, and business purposes. Furthermore, the damage may severely affect services in hospitals and ambulances. Accidental spill of hazardous chemicals from factories or road tankers in water catchments area can also affect water supply systems in terms of water quality management. If the amount of chemicals exceeds the manageable limit in the water supply system, the supply to the communities must be suspended.

Water quality standards and the Guidelines are established from the viewpoint of preventing long-term chronic toxicity. Therefore, they do not intend to provide instructive guidance on short-term acceptable limits of impurities in water in the case of emergencies. Infectious microorganisms should not be in drinking water, but some pollutants at a certain level must be accepted if they do not cause health problems through short-term exposure, since it will be used only for a short period of time. For short-term exposure to chemical substances, the Health Advisory of United States EPA provides useful information to assess the provisional quality levels of water.

The Great Hanshin-Awaji Earthquake occurred at 5:46 a.m. on January 17, 1995 in the southern part of Hyogo Prefecture, Japan. The epicenter was located in Akashi Strait. A magnitude of 7.2 on Richter scale was recorded and the earthquake registered an intensity of 7 on the Japanese scale in Kobe. The earthquake caused terrible damage to the citizens in the southern part of Hyogo Prefecture. The number of fatalities caused by the earthquake was more than 6300 and the number of collapsed houses, both complete and partial, was more than 237 000. The earthquake devastated lifelines, as well as residential and commercial buildings, railroads, and highways. The water supply was interrupted in ten cities and seven towns. Immediately after the earthquake, the whole Prefecture wrestled with this disaster under the command of the local Governor.

2.2.1 Enhanced disinfection

In emergency situations, securing water quantity is more important than water quality, so water supply facilities resumed the service without confidence in the quality of supplied water. In order to secure short-term safety from biological contamination, enhanced disinfection was practiced. The target of enhanced disinfection was set at 1.5 mg L^{-1} of residual chlorine at the outlet of the water purification plant. As no infectious disease outbreak was reported, the target was assumed appropriate, but further enhancement might have been necessary to secure biological safety against pathogenic microorganisms if the earthquake had occurred in summer.

However, the huge demand for sodium hypochlorite (disinfectant) may not be met because of extremely bad traffic congestion caused by the earthquake. Emergency logistics including the rearrangement of the system, i.e. the method of delivery, water storage tanks, etc. should be well considered. In addition, emergency manuals must be prepared, describing the stock, handling, and use. Waterworks utilities and related departments should themselves provide disinfectant, and whenever needed, they should dose it into water wagons and/or water storage tanks.

2.2.2 'Boil water' notice

Just after the Earthquake, the emergency operation center discussed issuing a 'boil water' notice as public information through mass media. The discussion was focused on the USA's case of the Great Northridge Earthquake in 1994. However, the discussion reached the conclusion that it was very difficult to publish the 'boil water' notice under circumstances in which heat sources (electricity or gas) were completely stopped throughout the city, and fire had broken out everywhere and was further spreading owing to the shortage of water for fire fighting. If the earthquake disaster had occurred in summer, it could have been assumed that a 'boil water' notice would have been issued whenever or wherever necessary.

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Biographical Sketches

Yasumoto Magara is Professor of Engineering at Hokkaido University, where he has been on faculty since 1997. He was admitted to Hokkaido University in 1960 and received the degree of Bachelor of Engineering in Sanitary Engineering in 1964 and Master of Engineering in 1966. After working for the same university for 4 years, he moved to the National Institute of Public Health in 1970. He served as the Director of the Institute since 1984 for Department of Sanitary Engineering, then Department of Water Supply Engineering. In the meantime, he also obtained a Ph.D. in Engineering from Hokkaido University in 1979 and was conferred Honorary Doctoral Degree in Engineering from Chiangmai University in 1994. Since 1964, his research subjects have been in environmental engineering and have included advanced water purification for drinking water, control of hazardous chemicals in drinking water, planning and treatment of domestic waste including human excreta, management of ambient water quality, and mechanisms of biological wastewater treatment system performance. He has also been a member of governmental deliberation councils of several ministries and agencies including Ministry of Health and Welfare, Ministry of Education, Environmental Agency, and National Land Agency. He meanwhile performs international activities with JICA (Japan International Cooperation Agency) and World Health Organization. As for academic fields, he plays a pivotal role in many associations and societies, and has been Chairman of the Japan Society on Water Environment.

Professor Magara has written and edited books on analysis and assessment of drinking water. He has been the author or co-author of more than 100 research articles.

Harukuni Tachibana is Associate Professor of Engineering at Hokkaido University, where he has been on faculty since 1996. He was admitted to Hokkaido University in 1963 and received the degree of Bachelor of Engineering in Sanitary Engineering in 1967 and Master of Engineering in 1969. Since 1970, he worked for the same department as instructor until 1996. In the meantime, he also obtained a Doctor of

Engineering from Hokkaido University in 1994 and served as associate professor of the newly established Division of Environmental Resource Engineering at Hokkaido University. His principal research field covers aquatic environmental engineering, aquatic chemistry for water pollution control, and environmental biology. He regards the keywords of his research field as: water analysis, preservation of water environment, eutrophication, and preservation of wetland.

Doctor Tachibana has written several books on water analysis and aquatic environments, including lakes and rivers.

He is the member of the Japanese Society of Civil Engineering, Japan Society on Water Environment, and Japanese Society of Limnology.