ENVIRONMENTAL AND HEALTH ASPECTS OF WATER SUPPLY AND SANITATION

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Summary

Aquatic environment is one manifestation of the water circulation of the Earth. People rely on limited quantity of water; therefore, water becomes scarce as world population increases so rapidly. Still 1.1 billion people do not have improved water supply which assures safe and healthy life. United Nations and other international organizations set global target to improve poor water supply and sanitation.

Waterworks developments have many difficulties due to financial, material, and human resource shortages. Financial status of waterworks in developing countries is so fragile due to large portion of un-accounted for water. In addition, water charge in often set extremely low so that the waterworks corporation falls into financial difficulty.

Water qualities are set to be safe enough for people's use and environmental conservation. WHO developed the drinking water quality guidelines, which supports individual country to establish its own national water quality standards. Microbial aspects have prior importance with their severity and extent of contamination. Coliform organisms have long been recognized as a suitable microbial indicator for drinking water safety. For chemical contamination, the guideline values are calculated based on Tolerable daily intake (TDI), which considers their carcinogenicity.

For agriculture, irrigation water may cause salinization if it contains large quantity of salts. Salinization deteriorates the productivity of agricultural land and eventually it becomes heath land. Water contamination directly affects aquaculture. The death of aquatic organisms is mainly caused by poisoning, asphyxiation, or epidermal lesion by corrosive chemicals. The water quality should be maintained below the acceptable level.

Wastewater has been used for various ways from agriculture, aquaculture, urban domestic uses, etc. Health aspects are major concern to reuse wastewater, and quality standards are established. Bacterial count and helminthes egg are principal indicators to ensure wastewater safety.

1. Introduction

Aquatic environment is one manifestation of the water circulation of the Earth. Especially when the freshwater resources, which are deeply connected to human life, are considered, the amount of water circulation is stable, consisting only about 150×10^{12} m^3 that circulate in about one week to ten days. That is, these freshwater resources of only about 150×10^{12} m^3 are used currently by six billion people, by eight billion people in the near future and by ten billion people by the middle of the 21st century. Assuming the average yearly precipitation is 1800 to 2000 mm, evaporation and infiltration rate are 30%, respectively, and average consumption of water per person per day is 250 liters, the area of water catchment required for one citizen is estimated to be approximately 300 to 500 m^2. The used water becomes the treated water of BOD 20 mg L^{-1} when it is discharged as domestic wastewater and treated by biological wastewater treatment process in sewage treatment plant. However, in order to reduce the BOD to about 4 mg L^{-1} for the maintenance of biological ecosystem in the aquatic environment, there must be about five times more water for dilution. In other words, in order to dilute the treated waste water from the sewage treatment plant to maintain the ecosystems of the aquatic environment, about four times the area required for daily water consumption, which is 1200 to 2000 m^2, or total of 1500 to 2500 m^2 is required as the area of water source per person.

Although a freshwater resource is not so much fluctuated globally, it is regionally localized. The available freshwater resource in Asia is the smallest, which is as small as 4000 m^3 per capita per year followed by 4200 m^3 per capita per year in Europe. Since these limited water resources have to be shared among the increasing population, especially in Asia, which has high population growth, the availability of water will become even worse. Furthermore, ensuring the water catchment area itself becomes difficult since agricultural lands and residential areas continuously expand to support such ever-increasing population; therefore, the direction of water and environmental health management must be concerned by all.

Freshwater resources come into existence when water evaporates from the surface and then precipitates to reach to ground surface again, some of them gathers to form rivers, lakes, etc. and other becomes groundwater. Although rainwater itself does not originally contain pollutants, it captures pollutants during precipitation and/or flowing processes on ground surface due to the properties of water. Therefore, the surface water is often not appropriate for direct drinking. Groundwater may be used for drinking since these pollutants are reduced by the self-purification effect of the soil, unless some hazardous substances exist in the soil and elude into the water. Except for such clean groundwater, most of the freshwater resources existent as water resources cannot be used without treatment, or much worse, they may even cause various health damages including infectious diseases.

2. Sustainable development of environmental health

It is needless to say that various benefits are anticipated when safe drinking water and sanitation facilities can be used. The largest benefit is the assurance of healthy life, which involves the backbone of human dignity. While being relieved from the threats of infectious diseases is the largest benefit, some kind of place for live exists since people and communities naturally live where there is water available. However, it is also an unavoidable fact that there are people who have more children expecting labor as the most difficult choice in seeking richer life or who move into the cities where cash income can be expected without securing the place for living to form the slums to which the infrastructure establishment cannot be reached. Consequently, the hygienic condition for the entire city decreases because the safe water is not provided in the slum areas even when infrastructure such as waterworks facilities in the core area of the city are established, leading to the danger of infectious diseases originating in this area.

Water is essential for people to live, and they must go to where water is to use the water or carry the water to where it is used. Moreover, if the water cannot be used as it is some kind of processing is necessary. Skin and eye diseases can be prevented by using water to wash the body. Infectious disease can be prevented by washing hands before meals. Water can be used to wash the anus after using the toilet and flush the excreta in addition to washing the clothes, etc. to lead sanitary life. In addition, water can be used to extinguish fires in the area.

Toilet should be facilitated to prevent the entry of hygienic insects and animals that carry the pathogens in the excreta, and it act as a barrier to release of parasitic worms or their eggs in the excreta into the surrounding environment. However, the role of toilets is lost unless the excreta are eventually removed from the pits or feces tanks. Sanitary facilities become complete when not only the toilets are established but also the sanitary treatment of the excreta from toilet is conducted.

Whether it is tube well, public faucet, household supply, dry-vault toilet, on-site domestic wastewater treatment tank or sewerage, water and sanitary facilities cannot be sustained unless adequate operation and maintenance are conducted at the same time as the facility development. It is needless to say that costs are required for facility establishment or maintenance and control. The costs vary depending on the convenience gained by the facilities. Comparing the benefits gained through services as in water supply where safe water is supplied from every tap at any time and sewer where domestic wastewater including excreta is removed immediately from living environment with the benefits gained through use of safe drinking water by hand pumping from tube wells and secure of a place for excretion as in pit latrine, there is a large difference in costs for sustaining each benefit. However, it is an international principle that the costs for safe water and hygiene facilities are paid by those who get the benefits.

Since the disposable income per person in the developing countries, especially in the poorest countries is small, the possible limit of payment is naturally small as well. Even in the developing countries, the disposable income for the residents of large cities such as the capital is greatly higher than for the residents of rural areas. Thus it is a mistake

to judge that there is no difference in the dispensable limit to the developing countries in general. The conclusion is that the fact that the dispensable limit for the costs of water and sanitation varies even within one country must be recognized. The problem depends on whether there is a system that is feasible to facilitate and maintenance/control that can provide for healthy living environment within the dispensable limit of the community. Even if the facility is developed by international aid or national subsidy, the facility will eventually have frequent breakdowns or become unable to continue providing safe water or sanitation services if the revenue does not suffice the costs required in funding for facility renewal in the future and daily maintenance, leading to facility deterioration without use. Then the region will return to the poor society which cannot maintain the human dignity. In order to prevent such cases, the intensive feasibility study must be done as to the sustainability of the facility from the stages of project development.

Both drinking water supply and sanitation treatment are related to the public health and health for people in the region. Furthermore, it costs to maintain and operation the facilities/services, and there must be revenue that meets the cost through charges, etc. Therefore, a standard that provides for the guideline for such services is required. In the case of waterworks, water quality is one applicable standard. WHO recommends the guideline for drinking water quality to all WHO member countries and areas for establishment of each national standard with consideration of social, economical, cultural, etc. conditions of them? Moreover, facility standard for supplying drinking water that satisfies the water quality standard and standards for maintenance and operation must set as well. However, it is necessary that the characteristics of each country are understood, and human resources with scientific and technical knowledge and funding required for research, etc. be ensured. Due to such reasons, aids required to establish adequate facilities in the so-called software field must be reinforced in addition to aids in funding and technology required for facility development.

3. Health problems and their resolution

3.1. Historical brief

World Health Organization (WHO) estimates that 2.4 billion people worldwide still do not have any acceptable means of sanitation while 1.1 billion people do not have an improved water supply. For those who are threatened by the health risks, United Nations (UN) and other organizations have launched several programs and action plans which protect and promote the health for the world population. One of major turning points came in 1976; UN Conference on Human Settlements (Habitat) in Vancouver. The Conference impressed on the many governmental delegations that the improvement of water supply and sanitation services in poor countries was the emergence tasks for all people. Habitat then recommended setting up realistic targets and programs to provide water and sanitation for unserved urban and rural people.

Two years later, the International Conference on Primary Health Care was held in Alma-Ata, USSR which called for urgent and effective action to develop and implement primary health care throughout the world. The Declaration of Alma-Ata adopted during the Conference aimed to attain an acceptable level of health for all the people of the

world by the year 2000 and included adequate supply of safe water and basic sanitation as essential element as well as nutrition, immunization, etc.

The 1980s, the International Drinking Water Supply and Sanitation Decade (IDWSSD), saw big strides made in finding affordable technologies and participatory approaches to help serving those without access to improved water and sanitation services. But IDWSSD also demonstrated conclusively that "business as usual" would never bring improvements quickly enough to cope with the backlog and provide access to growing populations.

In 1990, the Water Supply and Sanitation Collaboration Council (WSSCC) was established in order to maintain the momentum of the IDWSSD. The mission of the WSSCC is to accelerate the achievement of sustainable water, sanitation and waste management services for all people, with special attention to the unserved poor. WSSCC bridges between professional association and international NGOs with many aspects; i.e. technical, regional, tactical, networking, etc.

The VISION 21 "Water for People" initiative was launched in March 2000, which aims:

- To reduce by half the number of people without access to hygienic sanitation facilities and adequate quantities of affordable and safe water by 2015.
- To achieve universal access to hygiene, sanitation and water services by 2025.

In order to achieve the 2015 target, the annual investment in water supply should be increased by 31 percent (39 percent for the urban water sector and 19 percent for the rural water sector). In sanitation, the numbers are even more drastic as the current coverage level is low. In urban areas, 1.085 billion additional people should be provided with sanitation service, requiring a 28 percent increase in effective annual expenditure. In rural areas, the global target is to provide an additional 1.089 billion people with sanitation service, implying a quadrupling of the annual progress achieved over the 1990s. To achieve the total sanitation target by 2015 would require that the annual expenditure of the 1990s almost double. These targets were endorsed by UN Millennium Summit in September 2000 and included in Millennium Development Goals (MDGs).

The integrated development of waterworks and sanitation facilities is important not only in urban areas, but also in rural areas. In general, it is more important in rural areas, since they are economically backward. After the development of the water supply and sanitation facilities, the most important issue is the sustainability of water supply and sanitation services in order to encourage the willingness to pay of community.

The World Summit on Sustainable Development held in Johannesburg in 2002 included 2015 targets to halve the unserved people in its Plan for Implementation. Today, world people are obliged to contribute for eradicating poor health and improving living condition.

3.2. Global water supply and sanitation assessment 2000

The Global Water Supply and Sanitation Assessment 2000 presented the findings of the fourth assessment by the WHO and United Nations Children's Fund (UNICEF) Joint Monitoring Programme. Previous reports were produced in 1991, 1993 and 1996. The assessment has found that:

- There are four billion cases of diarrhea in the world every year, with 2.2 million deaths, mostly among children under five. Safe water, adequate sanitation and hygiene can reduce diarrhea disease by between one-quarter and one-third of these cases.
- Rural services still lag far behind urban ones, but delivering affordable services to the rapidly growing numbers of urban poor remains a formidable challenge.
- There are huge inequities in the amounts invested in improving services to the better-off sections of urban society compared with investments in providing basic services for the unserved poor

The Assessment makes clear that many people are being deprived of this right. It has further found that:

- The tariff charged by the water agencies in developing countries is not sufficient to cope with the costs of producing and distributing water. In Africa, Asia, and Latin America and the Caribbean the ratio between the unit average tariff and the unit production cost is 0.8, 0.7 and 0.9, respectively.
- In Africa, 30 percent of the rural water supplies are not functioning at any one time. In Asia, and Latin America and the Caribbean, the numbers are, 17 percent and 4 percent, respectively.
- In the developing regions of the world, treatment of wastewater is applied in only a small number of systems. Only about 35 percent of the wastewater is treated in Asia, while the figure is 14 percent in Latin America. Only a negligible percentage of treatment has been reported in Africa. Even in industrialized countries, sewage is not universally treated.
- In large cities of developing countries, the percentage of unaccounted-for water is very high, around 40 percent. Most of this water is simply lost before reaching the potential user. The consequences are particularly serious to the poor living in marginal areas where the water will be wasted before reaching them.
- Not all the water distributed in large cities is safe. A number of cities reported that most samples violated water quality standards.

In addition, there are many barriers to expanding access to improved sanitation services, including:

(1) Lack of political will,
(2) Low prestige and recognition,
(3) Poor policy at all levels,
(4) Weak institutional framework,
(5) Inadequate and poorly used resources,
(6) Inappropriate approaches,
(7) Failure to recognize defects of current excreta management systems,
(8) Neglect of consumer preferences,
(9) Ineffective promotion and low public awareness, and

(10) Women and children last.

The reasons for apparent low demand need to be understood, to determine whether changes can be brought about through political, financial or technical means, or simply by improving information. People may want sanitation very egarly, yet be powerless to express their desire in financial or political terms. Some may want safe excreta management facilities, but not at the prevailing price. Others may not want the available "improvements" at any price. Cultural beliefs have a strong impact on sanitation, and even on the possibility of talking about sanitation. In many cultures, the handling of excreta is considered a taboo and viewed as disgusting or a dangerous nuisance, not to be discussed. No one wants to be associated with excreta. Those who reduce its offensive characteristics for others may be stigmatized by association. Problems cannot be solved if people do not want to talk about them and be associated with their solution. In many contexts, taboos – including modern technological ones – block the safe recovery of valuable agricultural resources from human wastes. To counter the excreta taboo, education promoting sanitation and hygiene should link the value of excreta (feces and urine) with ecology and health protection.

Three principles are fundamental to the creation of socially, economically and ecologically sustainable sanitation systems;

(I) Equity. All segments of society have access to safe, appropriate sanitation systems adapted to their needs and means,
(II) Health promotion and protection from disease. Sanitation systems should prevent users and other people from contracting excreta-related diseases and should interrupt the cycle of disease transmission,
(III) Protection of the environment. Sanitation systems should neither pollute ecosystems nor deplete scare resources.

3.3. Priority of water supply and sanitation

The condition of water supply system in developing countries, both the coverage to total population and the quality of services (water pressure, quantity and quality of water, service time water is supplied, etc.), are not satisfactory. In addition, the condition of sanitation services including toilet facility is much worse than that of water supply. The development of water supply or sanitation system only can hardly achieve the comprehensive improvement of public health aspects, which include the prevention of inundation, vector control, and the eradication of water-related infection. In addition to the developments of facilities, community empowerment in water supply and sanitation system is also necessary to improve the people's life.

Water supply is regarded as a Basic Human Needs (BHN), and the amount of external aids for the field is steadily increasing. Their justification is, however, doubtful considering the viewpoint of development economics. Proper investment on water supply and sanitation is said to be about one fifth of the total necessary amount. Furthermore, the amount that can be given by a non-charge monetary assistance is limited to only a proportion of total investment, and the project selection should be made very strictly. As WHO holds "Some for all rather than more for some" as a slogan

for the aiding approach for the year 2000, projects with larger beneficiaries for a smaller cost should be selected.

Investment in water supply and sanitation project are financed either by government agencies or by external support agencies. In Africa, Asia, and Latin America and the Caribbean, around 40 percent of water supply and sanitation projects were supported by external assistances. The investment is not evenly distributed between urban and rural areas, and between water supply and sanitation projects. So far, sanitation is not normally considered a priority in development in comparison with the need of safe water. Especially, sanitation improvement in rural area has long been neglected. Different from water supply projects, which are often large-scale investments; very basic sanitation facilities (i.e. latrines, or toilets) are usually made by household and no external support is expected. The imparity of development level between these two may cause water pollution and contamination of water resources.

3.4. Water supply facilities

Regardless of the political forms of the countries, welfare of citizens is an important matter. Development of systems to provide safe drinking water is a crucial measure to take.

Waterworks holds an especially important role as a basis for development of business and industry and for maintenance of city functions including fire extinguishing. That is, there is a wide range of waterworks from small-scale waterworks for providing drinking water to multi-purpose large-scale works. As to the construction investment and maintenance cost, it is also a well-known matter that cost-effectiveness is higher in urban areas where population density is higher than in local villages with low population density. As to the users, people in the urban areas have higher income level than those in local villages, and therefore the ability to pay for the water service costs is higher in urban areas.

3.4.1. Financial sustainability

According to these viewpoints, the following items need to develop an appropriate institutional management. The level of government that manages the waterworks project varies depending on the state of development. In many cases, waterworks management is the responsibility of local government, but the central government assists the development in forms of loan guarantees, low-interest loans, and/or financial assistances for the construction. The maintenance and/or management costs for waterworks in small cities or local villages are sometimes assisted by the central government directly or by external commercial waterworks company. The problem here is, however, that there are many ambiguous matters on the legal background of these aids. Sometimes the loan guarantees or the interest rates are set in favor of the central government, or sometimes there is over-assisting in maintenance and/or management costs to local government.

In longer view, one important goal for waterworks projects is financial independence. The national, local and municipal governments should prepare the legal administration system and give financial supports so that in the end the waterworks corporation can

achieve the goal, i.e. residents and/or users pay for the proper cost, and for rationalization of management. The master plan to develop legal administration system is, therefore, should be made in relation to local autonomy, administration and finance, etc.

Regarding to the waterworks projects with governmental subsidies, they are divided roughly into two categories, one with legal institutionalization on subsidy acceptance and the other with temporary subsidies for the concerned waterworks projects due to certain circumstances. The primary purpose of subsidies is to keep the level of water charges low, as well as difference correction among waterworks projects. In many cases, the amount of subsidy given to a waterworks project is calculated either by a fixed accounting standard or by a certain range. However, the specific circumstances and its accounting standard should be identified and understood as to the temporary subsidies.

3.4.2. Difficulties for waterworks development

In many waterworks projects in developing countries, the waterworks facilities and equipment are not repaired, resulting system failure and water shortage. There are many possible causes as follows:

(1) Financial shortage
Personnel expenses, power supply costs, and interest payments are among unmanageable expenses, and they are the expenses of substantial amount which must be paid without condition in short term. However, it is at the discretion of the authorities to judge how much should be expended as to the facilities and equipment repair since the deterioration and wear are not clearly visible. The repair expenses are thus usually cut down in order to balance the revenue and expenditure when financial problems arise, resulting in the mistiming of facilities/equipment repair, which will result in requirement of a large expenditure to renew the facilities/equipment because they are not repairable.

(2) Material shortage
The repair is sometimes impossible because the necessary parts, machines, or equipment are not available even though there is sufficient fund and authorities' willingness to repair.

(3) Unavailability or shortage of engineers
In some cases, the repair cannot be practiced because there is no or only few engineers who have enough knowledge of waterworks facilities and equipment. Though it is possible to entrust these matters to specialized private sector in industrialized countries, it is often difficult in developing countries.

(4) Loss of written documents
It takes at least several years after acquiring waterworks facilities/equipment before repair is necessary due to aging failures. However, in many cases the basic written documents that had been provided at the time of setup are not stored properly and therefore it is difficult to identify the current condition or to repair the

facility/equipment. The schematic drawings for plumbing are especially important for repairs (in cases of facility configuration change) since identification of pipe arrangement will require a large amount of time and cost.

(5) Fixed water charges
Leaks in customers' properties are usually repaired by the user without any intervention if it affects his/her water charges. It is neglected, on the other hand, if the charges are fixed because it does not affect to be paid, and these results in lower profit rates.

(6) Extremely low water charges
Water charges are sometimes extremely low where per capita income is low. If the charge is too low, the waterworks falls to financial imbalance and the repair activities are delayed.

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Biographical Sketch

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 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 was also obtained the 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 the 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 the international activities with JICA (Japan International Cooperation Agency) and World Health Organization. As for academic fields, he plays pivotal role in many associations and societies, and has been Chairman of 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.