DEVELOPMENT OF WATER RESOURCES

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Summary

Water is provided by precipitation and surface flow, and becomes an available water resource. In becoming a water resource, water dissolves or suspends various kinds of impurities. It is necessary to show the level of impurities which do not cause any hazard to human health and beneficial uses.

People exploit safe and clean water for agricultural, domestic and industrial purposes. Surface water, groundwater, rainwater, and seawater are the possible water sources. No water source is perfectly safe, so water treatment as well as source management are important in securing water resources.

The increasing world population leads to an increase in the requirement of fresh water for many purposes. Population growth also brings in its wake a high burden of municipal sewage, livestock excreta and industrial wastewater, threatening sources of drinking water. Water resources must therefore be managed to provide for every human activity in sustainable way.

High arsenic contaminations has been reported in West Bengal in India and southern and western Bangladesh. The total population in Bangladesh exposed above 0.01 mg L^{-1} (the WHO guideline value) is around 51 million.

Problems that may arise from the use of salty irrigation waters can be classified into two types. One type is referred to as a salinity hazard that can lead to a saline soil condition. The other type affects the soil itself and is referred as a sodium hazard. In some cases there is a combined hazard, which results from both conditions and can lead to a saline-sodic soil condition.

For designing water treatment facilities, there are many factors to be considered. If a good water source is available, the process of water treatment can be simple. Conversely, if the raw water is organically or inorganically polluted, the water treatment facility must have a complex process train. The type of water source and the magnitude of its pollution are the first factors to be considered when selecting the method of water treatment.

There are a wide range of alternative methods for the disposal of sewage and wastewater. Historically, various sewage treatment methods have been invented and practiced successively. Size of the service area, technical level of plant operators, cost recovery capacity, available land space, and required effluent water quality determine appropriate system configurations.

Conjunctive use of water is a form of integrated management involving wise use of three water resources—surface water, groundwater and reclaimed wastewater. Health protection from the use of reclaimed wastewater is one of the most critical objectives in any wastewater reclamation and reuse project. The management of health risk associated with using reclaimed wastewater is achieved by reducing concentrations of contaminants and/or limiting chances of contact with the reclaimed wastewater.

1. Introduction

Water is provided by precipitation and flow over the ground surface, thus becoming an available water resource. In this process, it dissolves or suspends various kinds of impurities. Water is used for a variety of purposes and it also sustains ecosystems. There is an acceptable level of impurities for every form of water use. It is necessary to show the level of impurities which do not cause any hazard to human health and the various beneficial uses.

The water resource which the global water cycle provides is limited, and the level of water resources per person are ever decreasing due to human population growth. It is essential to manage water through proper watershed management and thus control its quality and quantity to ensure efficient use of the limited resource. In development of water resources it is very important to maintain an appropriate water environment that does not produce a health hazard by contamination.

People exploit safe and clean water for agricultural, domestic and industrial purposes. Surface water, groundwater, rainwater, and seawater are the possible water sources. Surface water is the most convenient source for human use since it can be available on the spot. But it is easily contaminated by polluted water or human activities. Groundwater is considered as a reliable source in terms of quality and seasonal change. But brackish groundwater for irrigation purpose causes salinization of farmland. Rainwater harvesting has been practiced for centuries and is still an important water source for many rural communities. Rainwater is basically clean but safe collection and storage are needed since precipitation is usually seasonal and water needs to be stored for the dry season. Seawater can be, to some extent, a possible water source for industrial purposes, e.g. cooling water for thermal power plants.

No water source is perfectly safe, so water treatment, as well as source management, is important for securing water resources. Drinking water treatment takes many forms, from small to large scale, from simple to sophisticated process train for removing a variety of contaminants. Wastewater treatment also has great importance, like drinking water treatment. Wastewater treatment converts used water into a possible water resource. Due to the constraints in many water-stressed regions, reuse of wastewater is already widely practiced. The purpose of reuse covers irrigation, groundwater recharge, toilet flushing, gardening, and sometimes drinking. Of course, extreme care must be taken for potable use, but other usages must also comply with relevant guidelines.

The increasing world population leads to an increase in the requirement of fresh water for many purposes. Population growth also brings in its wake a high load of municipal sewage, livestock excreta and industrial wastewater, threatening sources of drinking water, both surface and groundwater. Most fecal-oral pathogens are known to cause gastrointestinal illnesses. Water resources must therefore be secure enough for every human activity, in sustainable way.

2. Water source management and considerations

2.1. Mitigation of the impact of water-born diseases

2.1.1 Watersheds as nature's boundaries for surface water supplies

The greatest impact of water pollution on human health comes through drinking water acting as an important vehicle for the transmission of a large variety of infectious diseases. In many industrialized countries, the widespread occurrence of the protozoan parasites *Cryptosporidium parvum* and *Giardia* in surface waters demonstrates that any drinking water treatment plant which draws its water from a surface source is at risk. At the same time, water utilities which draw their source from ground water under the direct influence of surface water is not necessarily free from this threat.

Categorization of waterborne pathogens can be made by the combination of concepts such as the probability of an event and the severity of that event, for prioritization of the risk in the process of risk analysis. Recent concerns with *Cryptosporidium* and *Giardia* have centered on the method of water treatment, due to their unusual resistance to conventional disinfectants used worldwide. Many human activities have potential to disseminate *Cryptosporidium* and *Giardia* oocysts into watersheds. These include livestock grazing, manure handling, human settlement, and outdoor recreation. *Cryptosporidium* is known to be zoonotic, and infected calves deliver approximately 10^{10} oocysts daily for up to two weeks. It is likely that human patients also excrete a similar number. Fresh feces from grazing animals, yard and dairy washings and bedding leachates seem the most likely agricultural source of pathogenic agents including oocysts.

It is not realistic; however, to ban all the economic and social activities in the catchment area. There are several key controls to keep pathogens from entering source waters—an appropriate level of grazing and the length of time without incurring damage to natural values, prevention and control of zoonotic diseases (animal health), correct handling and disposal of farm wastes (composting of manures, and human settlement. Cattle kept in uplands might have little effect on water quality, as long as the range of the river is kept in good condition with riparian pastures (the ground cover provided by vegetation on land). Fencing around reservoirs and streams should be provided to restrict access by both farm animals and wild mammals, though little is known about the prevalence of shedding among wildlife species.

It is clear that control of water contamination from agricultural wastes depends mostly on compliance with regulatory codes of agricultural practices for waste management. Regulations themselves are something like living things, and need to be customized to address regional or local conditions. Existing regulations need to be more effectively enforced for the protection of water resources from microbial contamination. On the other hand, people have to be made aware that their voluntary compliance with these regulations is essential, for them and their descendants to enjoy the benefit of safe drinking water.

2.1.2 Human settlements, outdoor recreation and others

There is always a low level of cryptosporidiosis in the community (among humans and animals). While it is unlikely that drinking water is a major cause of this background level, it is also true that most fecal-oral microbial agents have the potential to be transmitted through contaminated water. Human settlements in watersheds should be properly planned and controlled to prevent adverse effects on water sources. Improper disposal of human waste can add to the variety of pathogens in drinking water sources. It is thus crucial to have appropriate sewage treatment plants or on-site sewage disposal systems that are able to deal with the risk arising from the release of infectious microbes into nearby waters.

As watersheds contain streams, lakes and forests, they are potential sites for various recreational activities like off-road and on-road motoring, cycling, backpacking, swimming, sailing, windsurfing, rafting, etc. Little is known on the effects of recreation on source water quality. Thus, it is recommended that research be conducted on the impacts of different types of outdoor activities on drinking water sources. Knowledge obtained from results of such studies should be promptly incorporated into watershed management strategies. In reality, the level of protection provided to drinking water sources from human-related activities should appropriately balance the cost and benefits of having safe drinking water

2.1.3 Sharing health risk

The survival of pathogenic organisms in drinking water is the result of multiple problems within the water source, the collection system, the treatment chains, and/or the distribution and storage facilities. It is thus in principle necessary to implement a multi-barrier approach based on a total system concept. This total approach will ensure that not only is the treatment designed to produce water of good quality, but that quality is also maintained throughout the transport of water to the end user. The purpose of this approach is to eradicate all pathogenic organisms at each stage from the source of contamination until the water comes out of the consumer's tap.

Considering the enormous variety of possible contaminants both at source and within the distribution system itself, developing a real-time monitoring system for each pathogen is not practical. One interesting approach would be, then, to adapt the use of Hazard Analysis Critical Control Point (HACCP) principles for drinking water risk management. It is designed primarily as a preventive system of control to assure product safety where effort is applied to reduce/remove risks as close to their source as possible. Key features of HACCP are the identification of hazards and the specific measures to control hazards, emphasizing elements that can be monitored, and verified, in real time. It requires documentation to demonstrate that the critical control activities are properly working.

Water treatment processes that reduce the level of contamination in the source to produce safe drinking water require reliable information about the microbial quality of the source water. Fluctuation due to peak events (heavy rainfall, dredging a riverbed, etc.) and the level and source of variation, should be taken into consideration. It also requires knowledge about the effectiveness of different treatment processes in inactivating or removing pathogens. These, together with knowledge about the sources and risk of post-treatment contamination, make it possible to determine the most relevant risk management options in the water distribution system.

As risk management is a total system approach, involvement of a multi-disciplinary team is essential. Catchment control, for example, may involve events with transboundary hygienic and environmental impacts, and thus requires an inter-regional or international approach. This means that effective risk management requires acknowledgement and co-operation of various agencies.

In particular, it is important to note that immuno-compromised individuals such as AIDS patients and those taking immuno-suppressive medications are unable to clear cryptosporidial infection and suffer severe diarrhea, while immunologically healthy individuals experience a transient diarrhea. In addition, cryptosporidial infection occurs readily among those with impaired immunity, resulting in a life-threatening gastroenteritis with high mortality.
Together with development of safe drinking water resources, the crux of mitigation of risks associated with microbial infections is managing how such information is communicated, since this will play an important role in public perception and in the exchange of sound scientific information. Rapid local liaison with water companies and local public health authorities should be developed to assess the impact of cryptosporidial contamination on water supplies.

Data sharing between authorities and the public (including the healthy population as well as those who have impaired immunity) should also be encouraged. Those who wish to take independent action to prevent/reduce the risk for waterborne cryptosporidiosis may choose to take precautions similar to those recommended during outbreaks, though the magnitude of the risk for ingesting *Cryptosporidium* oocysts from drinking water in a non-outbreak situation is uncertain. Education and counseling by the local health authorities at a local community basis is essential for people's better understanding about the ways of transmission of cryptosporidiosis.

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Biographical Sketches

Tasuku Kamei is Associate Professor of Engineering at Hokkaido University, where he has been at his present post since 1984. He received the degree of Bachelor of Agriculture in Forest Resource Science in 1967 and Master of Agriculture in 1969. In 1970, he started his vocational career at the Faculty of Engineering, Hokkaido University where he took the research instructor post of Department of Sanitary Engineering. Meanwhile, he obtained a Ph.D. in Engineering from Hokkaido University in 1984 on Design of Taxonomy for the Evaluation of Water and Wastewater Processes. From 1981 to 1982, he executed his study at the University of North Carolina as a research associate. Again he was invited overseas, to Thailand, from 1995 to 1997. He worked for the Asian Institute of Technology (AIT) in Bangkok as Associate Professor. His two-year dedication in AIT resulted in an Excellent-in-Teaching Award from the Institute. Since 1997, he has been installed at Environmental Risk Engineering Laboratory, Department of Urban Environmental Engineering where his research topic covers coagulation and flocculation, absorption and adsorption, membrane technology, and health risk issues including halogenated hydrocarbons, arsenic, and endocrine disrupting chemicals.

Dr. Kamei has written books on chlorination, organic removal, and humic substances of water. He has been the author or co-author of more than 100 research articles. He was awarded by the Japan Water Works Association for his research of water quality matrices.

He is the member of Japan Society of Civil Engineers, Japan Water Works Association, and Japan Society of Water Environment.

Katsuyoshi Tomono is Senior Engineering Adviser of the Environmental Planning Institute, Tokyo Engineering Consultants, Co., Ltd., where he has worked since 1999. He graduated from Hokkaido University and received the degree of Bachelor of Engineering in Sanitary Engineering in 1961. After graduation, he worked for Nihon Suido Consultants Co. Ltd. from 1961 to 1980. He served as Manager of Design Division with responsibilities for planning, design and construction supervision of water supply and sewer system projects in Japan and abroad, and studies on water treatment engineering and economic evaluation on projects. He then spent seven years as Project Engineer at Infrastructure Department, Asian

Development Bank, until 1987. He was responsible for appraisal and evaluation of bank-financed loan projects in the water supply, sewerage and sanitation sectors. From 1987 to 1999, he worked for Japan Water Works Association as Senior Researcher for several fields, which include development studies on advanced water treatment, high-pressure water service, risk management, etc.

He has authored or co-authored many research articles for the Japan Water Works Association and American Water Works Association for more than 20 years. His subject of study includes the art of water treatment in Japan, the costs and benefits of risk management in water supply, and the economies of scale in water supply.

Naoyuki Funamizu is Associate Professor of Engineering at Hokkaido University, where he has been at his present post since 1989. He obtained the Bachelor Degree and the Master Degree in Sanitary Engineering in 1975 and in 1977, respectively. Since 1978, he worked for Department of Sanitary Engineering as a Research Associate until 1986, then as Lecturer until 1989. Meanwhile, he obtained a PhD in Engineering from Hokkaido University for a thesis entitled "Analysis of Hindered Settling". His field of research covers 1) integrated watershed management, 2) wastewater reclamation and reuse, and 3) operation of wastewater treatment process. From 1994 to 1995, he worked for the Department of Civil and Environmental Engineering, University of California at Davis as Visiting Scholar.

Doctor Funamizu has written and edited books on municipal wastewater treatment and wastewater reclamation policy. He has been the author or co-author of approximately 80 research articles.

He is a member of Japan Society of Civil Engineering, Japan Water Works Association, Japan Sewage Works Association, Japan Society on Water Environment, and International Water Association (IWA).

Takuro Endo is Chief of Protozoology Laboratory at National Institute of Infectious Diseases, where he has been at his present post since 1985. He graduated from Department of Pathology, Tokyo University of Fisheries in 1970. He then continued his research as a research student of the Department of Parasitology at National Institute of Infectious Diseases (NIID). From 1971, he served as Assistant Professor of Department of Parasitology, School of Medicine at Jikei University. From 1974, he became Technical official of Department of Parasitology at NIID, He took a Senior Researcher's post in 1984. In the meantime, he obtained a Ph.D. from Nippon Veterinary and Zootechnical College for the thesis "*Toxoplasma gondii*: Electron Microscopic Studies on the Dye Test Reaction." Today, his main research interest is cell biology and molecular epidemiology and diagnostics of *Coccidia* and pathogenic free-living amoebae.

Doctor Endo has executed several overseas activities. He served as Guest Professor of Department of Medical Parasitology at Bonn University, West Germany funded by the Alexander von Humboldt Foundation from 1979 to 1981. He then worked for University of Philippines as Visiting Professor from 1992 to 1995, and for Szeged University, Hungary from 1994 to 1995. He was a Japanese delegate to WHO Guidelines for Drinking-water Quality in 1998 and 2000, and since 1998, he has been a member of the Steering Group of OECD Workshops on Molecular Technologies for Safe Drinking Water.

He is a member of the Japanese Society of Ophthalmology, American Society of Protozoology, a Committee Member of Japanese Society of Parasitology, and an Executive Committee Member of Japanese Society of Protozoology.

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. He also obtained a Ph.D. in Engineering from Hokkaido University in 1979 and was conferred an 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 for 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 a 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.