CONJUNCTIVE USE OF WATER

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Summary

The word of conjunctive use of water was used so far for referring the coordinated and planned use of surface and groundwater. Now, it is recognized that reclaimed wastewater is a water resource developed right at the doorstep of the urban environment. So, in the watershed, there are three water resources for water supply: surface water, groundwater, and reclaimed wastewater. Conjunctive use of water is an integrated management and wise use of these three water resources.

The input of water to the watershed is precipitation. In turn, this rainwater flows through the surface and groundwater system. The surface water system responds to rain event faster than the groundwater system. The water storage capacity of groundwater system is usually greater than that of the surface water system. In conjunctive use of surface and groundwater, the difference in response time between surface and groundwater system and large storage capacity of groundwater system are utilized.

In the holistic water management, three water resources are used conjunctively. Reclaimed wastewater can be used for artificial groundwater recharge and for surface stream augmentation, and directly for several water uses. The direct use of reclaimed wastewater includes agricultural irrigation, industrial reuse, and urban use. The treatment goal for wastewater reclamation depends on the water reuse applications.

The health protection from the use of reclaimed wastewater is one of the most critical objectives in any wastewater reclamation and reuse project. It is clear that un-treated wastewater contains pathogenic microorganisms and toxic materials. Even if the adequate treatment system is adopted for wastewater reclamation, there is the risk to expose to pathogens and toxic chemicals in reclaimed wastewater, because the system does not have the 100 percent of treatment performance. The management of health risk associated with using reclaimed wastewater is achieved by reducing concentrations of contaminants and/or limiting contact chance to the reclaimed wastewater.

It is recognized that the contaminants of greatest concern in wastewater reuse project are the enteric microorganisms from an acute disease standpoint. Pathogenic microorganisms detected in raw wastewater are classified into four groups: bacteria; protozoa; helminthes; and viruses. So far, there have been no recorded incidents of infectious disease transmission associate with engineered wastewater reclamation and reuse project, excluding outbreaks caused by raw sewage or primary effluent.

Since the extent of exposure to reclaimed wastewater strongly depends on the type of wastewater reuse, required quality of reclaimed water is specified to each reuse type. Water quality criteria or guidelines address water quality and treatment requirements. It is recognized that use of water quality criteria specified by the upper value of indicator bacteria concentration alone is not adequate for controlling health risks, because numerous studies and operational data showed that there is little correlation between the concentrations of indicator organisms and pathogenic organisms, particularly viruses and parasites.

1. Introduction

Conjunctive or integrated water use is recognized as an effective strategy for development and management of water resources. Conjunctive use programs are designed to increase the total usable water supply. The word "Conjunctive Use of Water" was used for referring the coordinated and planned utilization of surface water and groundwater, but this word has the broad concept now. The concept of deriving beneficial uses from treated municipal and industrial wastewater coupled with increasing pressures on water resources has prompted the emergence of wastewater reclamation, recycling and reuse as integral components of water resource management. As shown in Figure 1, there are three sources for water supply: surface water, groundwater and wastewater reclamation/reuse. The new concept of "Conjunctive Use of Water" is a wise use of water resources in an integrated manner. New water resource development is increasingly costly and often environmentally prohibited. Two types of conjunctive use of water will be discussed: conjunctive use of surface water and groundwater; and wastewater reclamation/reuse.

It is obvious; however, that wastewater contains pathogenic microorganisms and toxic substance. Therefore, once the contaminated water is reclaimed and used for several purposes such as irrigation, non-potable urban use, industrial use, or groundwater recharge, it may cause the outbreak of waterborne diseases. The health protection from the use of reclaimed water is one of the most critical objectives in any water reuse project. The potential health risks associate with wastewater reclamation and reuse are related to the extent of direct exposure to pathogenic organisms and chemicals in reclaimed water. The procedures for protecting public health is summarized in the Guidelines for Water Reuse by United States Environmental Protection Agency as follows; (1) reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the reclaimed water, (2) controlling chemical constituents in reclaimed water, and/or (3) limiting public exposure (contact, inhalation, ingestion) to the reclaimed water.

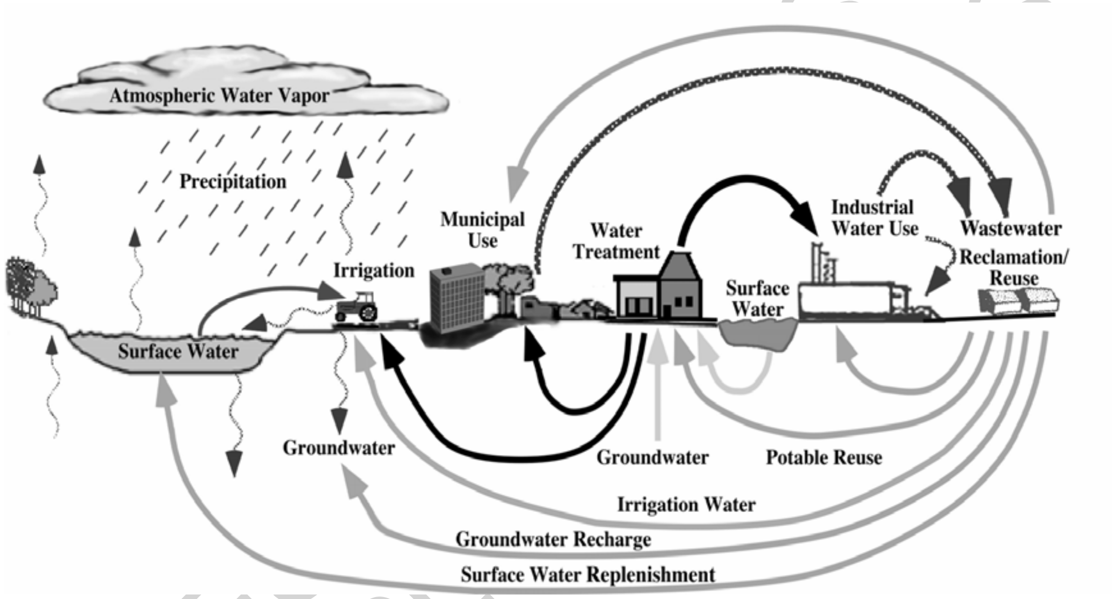

Figure 1. The cycling of water through the hydrologic cycle

2. Conjunctive Use of Surface Water and Groundwater

2.1. Groundwater and Surface Water, and Their Interaction

The hydrologic cycle shown in Figure 1 has three basic parts: the atmosphere, the surface water, and the groundwater. To understand the hydrologic cycle, the concept of flow and stock of water is important. It is said that the amount of water stored in the atmosphere is 5.6 percent of the total surface water and is 0.0009 percent of the sum of global water in the global water budged. Water flows through the atmosphere are the precipitation and evaporation. The balance between these two flows controls the water resource in a region. The variation of precipitation and evaporation is significant and seasonal. The fluctuation of precipitation results in variation of flow in surface water network. In order to withdraw constant amount of water from surface water flow, it is essential to compensate variation of flow rate in surface water. This operation is storing water in reservoir.

The groundwater moves much more slowly than the surface water, and flow rate often measured in meters per year. The residence times for a groundwater system may range from months to hundred years. Notably, the movement of groundwater is dependent on the media of aquifer.

There is an interaction between surface water and groundwater. If the water table stands higher than the river stage, groundwater may enter the stream as base-flow. Normally, groundwater discharge can make up most of the stream flow during dry months. Many perennial streams recharge the subsurface formation in some portion upstream of their reach, while groundwater discharge appears in the streams farther downstream.

2.2. Conjunctive Use of Surface Water and Groundwater

Most conjunctive use of surface and groundwater systems has developed for one of those two reasons: (1) Water resource of either surface water or groundwater could not meet the water demand or (2) the quality of groundwater was poor and mixing of groundwater with surface water was required to improve the water quality.

In the viewpoint of the watershed, there are two parallel stocks and flows: one is the surface watershed and the other is the underlying groundwater watershed. The surface watershed has quick-response characteristics (surface runoff). The groundwater system response slowly (groundwater movement), but it has large storage capacity. The capacity of underground aquifer as a reservoir and the difference in response characteristics are utilized for wise use of water resource.

Supposing the following watershed;

- In this region, there are two seasons; dry and wet season.
- Unfortunately, this watershed does not have enough capacity for surface water storage.
- In dry season, stored water in the reservoir cannot meet the water demand.
- Due to the slow response character of groundwater system, enough water cannot penetrate into groundwater system in wet season. In dry season, groundwater system cannot support surface water well.

The introduction of the conjunctive concept to the watershed;

- Use excess water for recharging groundwater in the wet season.
- Use the large storage capacity of groundwater system,
- Withdraw water stored in the groundwater system in dry season.

This concept is applicable also to the yearly variation of precipitation. The basin is directly or indirectly recharged in years of above-average precipitation so that groundwater could be extracted in years of below-average precipitation when surface water supplies are below normal.

2.3. Artificial Groundwater Recharge

The purposes of artificial recharge of groundwater include: (1) to arrest the decline of groundwater levels due to excessive groundwater withdrawals, (2) to protect coastal aquifers against saltwater intrusion from the ocean, and (3) to store surface water, including flood or surplus water, and reclaimed wastewater for future use. The advantages of storing water underground are summarized as; (1) the cost of artificial recharge may be less than the cost of equivalent surface reservoirs, (2) the aquifer serves as an eventual distribution system and may eliminate the need for surface pipe lines or canals, (3) water stored in surface reservoir is subject to evaporation, potential taste and odor problems due to algae and other aquatic productivity, and to pollution, which may be avoided by underground storage, and (4) suitable sites for surface reservoirs may not be available or environmentally acceptable.

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Biographical Sketches

Naoyuki Funamizu is Associate Professor of Engineering at Hokkaido University, where he has been at 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 Research Associate until 1986, then as Lecturer until 1989. In the meantime, he obtained the PhD in Engineering from Hokkaido University for the 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.

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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.