Chapter 13
Water Reuse for Irrigation in Rural Areas in Japan Experience from Japan to Central Asia

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Abstract As distinct from Central Asia, Japan has three types of wastewater treatment systems: municipal wastewater treatment, rural sewage treatment, and domestic wastewater treatment systems. Municipal wastewater systems are large-scale systems and the treatment plants are constructed at the downstream end of urban areas. Farmlands are usually far from treatment plants. In contrast, middle-scale rural sewage systems were installed in rural areas with the purpose of conserving the quality of irrigation water for farmland located around these treatment plants. The results of our test cultivation, the water quality of treated rural sewage effluent (TRSE) is suitable for agricultural reuse, and its negative effect on soil environments would be insignificant if any. Further, it is even suitable for reuse in greenhouses in Central Asian region. Positive reuse of TRSE, provided it is supplied close to farmlands, will secure a comparatively stable and safe water resource. Utilizing TRSE for irrigation purposes has the potential to be one of the solutions for water-stress improvement and aquatic environmental conservation around rural areas.

Keywords Rural sewage system · Municipal wastewater · TRSE · Greenhouse · Central Asia · Water recycle first section

13.1 Introduction

Japan, located in Monsoon Asia, receives relatively high rainfall by seasonal rain fronts and typhoons. Geographically the latitude location of Japan is the same as in Central Asia. Annual rainfall is high, around 1800 mm, but rainfall patterns have been changing in recent years. Rainfall patterns all over Japan indicate trends of increasing downpours and increasing 'no-precipitation' days. In this situation, efficient rainwater use is difficult, and restrictions on water intake from some rivers sometimes must be enacted. The Tone River, flowing near Tokyo, is an example of where these restrictions had to be enacted [1]. Changing rainfall patterns can

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potentially cause water stress in a wider area beyond the generally recognized water-stressed regions. Under water-stressed conditions, restrictions on water intake can lead to a shortage of irrigation water, and there is an urgent need for alternative water resources for sustainable agriculture.

In recent years, efficient utilization of treated wastewater for irrigation has been globally focused on as a useful alternative water resource and many international guidelines regarding this have been published [2–4]. Japan has also been focusing on reusing treated wastewater as a useful alternative water resource in water-stressed regions such as remote islands. Positive reuse of treated wastewater should secure comparatively stable water resources, because water supply is of utmost priority. Furthermore, treated wastewater, which is usually nutrient rich, is one of the methods to bring nutrient loads to aquatic environments. If treated wastewater is utilized for irrigation, then the nutrients contained within it will be utilized for cultivation and should contribute to aquatic environmental conservation. Therefore, treated wastewater reuse for irrigation helps with both the alleviation of water stress and the conservation of aquatic environments.

13.2 Treated Municipal Wastewater Reuse

Japan has three types of wastewater treatment systems: municipal wastewater treatment, rural sewage treatment, and domestic wastewater treatment systems. Municipal wastewater systems are large-scale systems and the treatment plants are constructed at the downstream end of urban areas. Farmlands are usually far from treatment plants. In contrast, middle-scale rural sewage systems were installed in rural areas with the purpose of conserving the quality of irrigation water for farmland located around these treatment plants. Rural sewage systems are usually managed to only allow for the indirect usage of treated wastewater for irrigation. Domestic wastewater treatment systems are independent systems in individual houses simply to prevent water pollution by households.

Approximately 190 million tons per year of treated municipal wastewater, which was 1.4% of total treated municipal wastewater, was reused in 2008 [5]. According to the main applications of treated municipal wastewater, the utilization percentages were the following: 23% for landscaping, 23% for maintaining a minimum river flow, 23% for snow melting, and 9.4% for office use. Utilization for irrigation use accounted for only 1.4% of reused treated municipal wastewater.

Central Asia refers to the five former Soviet Union states Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, and Kyrgyzstan [6]. Central Asia stretches from the Caspian Sea in the west to China in the east and from Afghanistan in the south to Russia in the north.

Consequently, all five Central Asian states have experienced the crumbling of the Soviet Union in 1991, the following collapse of the economic system, and the subsequent socioeconomic upheaval [7].

The transition from a state planned to a market economy has meant changing patterns for basic services such as water supply and sanitation [8]. At present, Central Asia is home to a population of about 74 million (Kazakhstan 18.8 million, Kyrgyzstan 6.6 million, Tajikistan 9.6 million, Turkmenistan 5.8 million, and Uzbekistan 33.6 million) [9]. By 2040, the total population is expected to have increased to about 86 million. This together with countryside migration to urban areas will put enormous stress on water and infrastructure. Water supply availability in Central Asia is complicated due to that the region's two major rivers, the Syr Darya and Amu Darya, are transboundary. Thus, continual conflicts over the region's water resources have characterized the Central Asian states since the collapse of the Soviet Union [9].

13.3 Reuse of Treated Rural Sewage Effluent in Rural Areas

Rural sewage systems, which are middle scale and target to serve 20–1000 inhabitants, are installed in many rural areas in Japan. The annual amount of treated rural sewage volume is 350 million tons. One of the main purposes of rural sewage systems is the conservation of water environments in rural areas, including irrigation water quality, and 78% of rural areas use treated rural sewage effluent (TRSE) in agriculture [10]. TRSE flows into an irrigation canal and then the water is taken from the canal; this usage of TRSE is usually called 'indirect use for irrigation.' In this process, there is insufficient and ineffective utilization of nutrients of TRSE. Only the direct use of TRSE can lead to more effective utilization.

In Japan, application guidelines for irrigation water allow for 94% of water to be used for rice paddy cultivation and the other 6% for other crops. Crops other than rice are generally rain-fed due to relatively high precipitation, and the fact that irrigation equipment such as spray, sprinklers, and drip irrigation are not common in the fields. If we use TRSE for irrigation directly, greenhouse irrigation can become the major application. Valuable crops can be cultivated using high-cost TRSE.

Water resources in Central Asia are constituted by surface water and groundwater. The major part of potentially usable water comes from the large rivers of the region. All these rivers, however, are transboundary. The largest, the Amu Darya and the Syr Darya, flow through more than three countries.

The Amu Darya and Syr Darya account for 90% of Central Asia's river water. Especially, Turkmenistan and Uzbekistan are vulnerable due to that a major part of the water resources is generated outside of their respective territory. The Central Asian water problem is thus complex and also involving other transboundary stakeholders such as Russia, China, Afghanistan, Iran, and Pakistan. Other large rivers are the Irtysh and Ishym located in the eastern parts of Central Asia, the Chu and Talas located in the south, in the west the Ural can be found, and finally the Ishim and Tobol are found in the north [7]. The by far largest withdrawal of water for irrigation is done from the large rivers of the region. However, the area also contains countless smaller rivers and creeks that contribute to irrigated agriculture. The information on this, however, is often absent.

13.4 Reuse Test for Greenhouse Cultivation

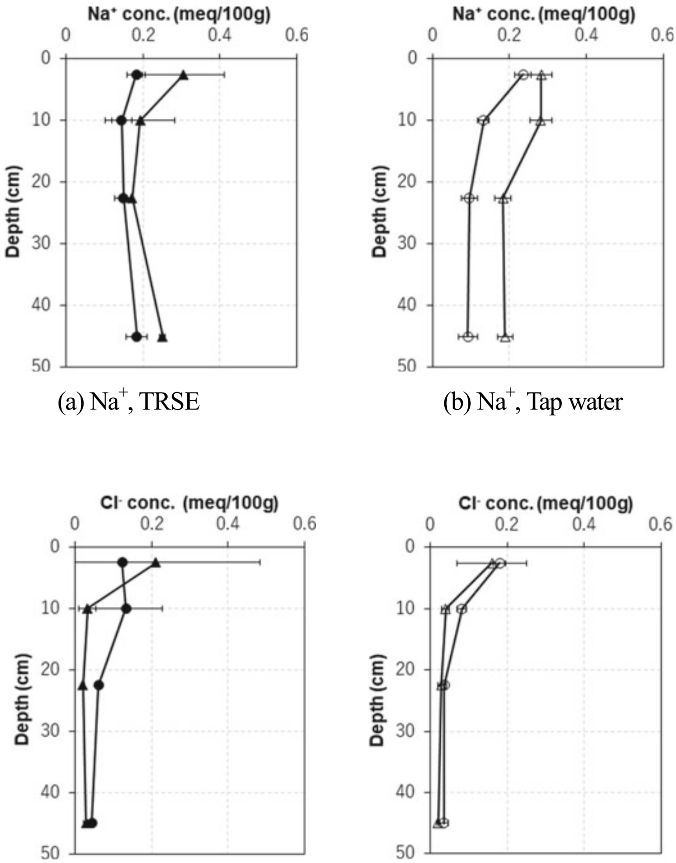
Direct reuse of TRSE is effective in nutrient utilization even in greenhouses, but it could lead to another issue. TRSE has the possibility to impact soil environments in greenhouse irrigation. TRSE has higher ion concentrations, such as sodium and chloride, than water from natural resources. When TRSE is reused for open-field irrigation, the salts supplied by irrigation water to the farmland soil surface will be leeched-out by rainfall, and it is difficult for salt to accumulate in the soil. However, soil in greenhouses can have salt accumulation, as there is no rainfall in greenhouses. The effects of greenhouse irrigation on soil environments were examined by testing cultivation. We conducted two irrigation cases with TRSE and tap water for tomato cultivation and examined the effects of greenhouse irrigation on the soil environments (Fig. 13.1). We measured the sodium and chloride ion concentrations in soil extracts before and after cultivation.

Tomato cultivation:

- Irrigation by direct use of TRSE,
  (control: tap water)
- Drip irrigation in greenhouse,
- Irrigation control: pF value in the soil.
  (start point: pF 2.1).

The sodium and chloride ion concentrations were decreased by cultivation in both cases (Fig. 13.2). There were no significant changes in these concentrations between either cases. This result suggests that there is almost no negative effect on the soil environments, even in greenhouses, when using TRSE for irrigation through

Fig. 13.1 Test cultivation experiment, photo by Hamada



(a) Na^+, TRSE (b) Na^+, Tap water

(c) Cl^-, TRSE (d) Cl^-, Tap water

Fig. 13.2 Water-extracted ion concentrations from soils

the short term. The water quality of TRSE is suitable for agricultural reuse, and its negative effect on soil environments would be insignificant, if any. Further, it is even suitable for reuse in greenhouses. We evaluated only the short-term effects, but we require further evaluation on long-term irrigation. Positive reuse of TRSE, provided it is supplied close to farmlands, will secure a comparatively stable and safe water resource. Irrigation utilizing TRSE has the potential to be one of the solutions for water-stress improvement and the conservation of aquatic environments around rural areas in Japan.

13.5 Treated Rural Sewage Effluent Reuse Arbitrability for Crop Cultivation

The WHO and other guidelines indicate that health-related risk management is of the utmost importance when utilizing treated wastewater for irrigation, and pathogens are the main cause of concern with health risks. Rural sewage treatment plants generally employ a secondary treatment using an activated sludge and chlorination process for disinfection.

Fecal coliforms are one of the indicators for health risk related bacteria in TRSE, and they were only detected a few times with the maximum value of 500 cfu/100 mL during the above experimental period. This indicates that the water quality of the observed TRSE belongs to Category B of ISO 16075-2, and it is suitable for irrigating crops that are eaten only after cooking. Additionally, TRSE has the potential to irrigate crops that require higher safety standards such as the crops that are eaten raw by contriving ways that prevent direct contact between irrigation water and crops, according to the ISO guidelines. Hence, TRSE is potentially suitable even for direct irrigation.

13.6 Summary

From the results of our test cultivation, the water quality of TRSE is suitable for agricultural reuse, and its negative effect on soil environments would be insignificant, if any. Further, it is even suitable for reuse in greenhouses. Positive reuse of TRSE, provided it is supplied close to farmlands, will secure a comparatively stable and safe water resource. Utilizing TRSE for irrigation purposes has the potential to be one of the solutions for water-stress improvement and aquatic environmental conservation around rural areas.

Densely populated area in Central Asia (i.e., Ferghana basin) is required for using TRSE and it is suitable for agricultural reuse. Nowadays, considering growing number of greenhouses in Central Asian countries, therefore it is even useful for reuse in greenhouses.

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