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Studies on Management Mechanisms of Environmental Safety for Recycled Water in China

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Abstract: As the shortage of freshwater resources is getting worse and worse, recycled water has gradually become the secondary water resources for non-potable usages. However, potential threats to environmental safety were stimulated along with the utilization of recycled water. This study is focusing on potential problems of environmental safety resulted from the usages of recycled water and the causes of these problems. Furthermore, management mechanisms of environmental safety for recycled water were proposed, which are the foundations of safety management system for recycled water. There are four major components within this safety management system for recycled water, such as policy, law, and regulation subsystem, standard subsystem, technical supporting subsystem, and safety management measures subsystem.

Key words: recycled water; non-potable usages; environmental safety; management mechanisms

1. INTRODUCTION

As highly industrialized, rapidly expanding urbanization and overcrowded populations, freshwater shortage has become a severe crisis and drawn increasing attention, worldwide. As a solution, many recycling water plants and projects have been implemented as part of the infrastructure for many metropolitan areas. Recycled water is, now, a very important water resource for non-potable usages, for example, flushing toilet, car washing, landscape, particulate control, fire fighting, and agricultural irrigation. In China, there are still lack of systemized laws, rules, regulations, standards and guidelines

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for recycled water usages. Most of the recycling water plants and projects were driven by promotional policies issued by local government and carried out according to the conclusion of feasibility study and environmental impact assessment.

The source of recycled water is mainly from domestic wastewater containing quite amount of various pollutants, for examples, suspended solids, chemicals, heavy metals, organic compounds, pathogens, virus, solids and certain impurities. Through the applications of some wastewater treatment techniques, such as secondary treatment, advanced tertiary treatment and disinfection, these harmful materials shall be removed and eliminated, but not completely, to a certain safety level. However, the quality requirement for recycled water is determined according to the purposes of reusage. On the other side, there are restrictive quality assurance and management systems for potable water quality to insure the public health. Hence, there are environmental, ecological, and environmental safety concerns about the reusage of treated wastewater, as well as public health. Therefore, further guidelines and relevant laws, criteria, and standards regarding to the reusage of recycled water should be developed, regulated and promulgated by local governments and environmental authorities, as soon as possible.

2. POTENTIAL THREATS TO ENVIRONMENTAL SAFETY FROM RECYCLED WATER

There are two ways, direct route and non-direct route, to utilize recycled water. For direct route, wastewater is treated by wastewater treatment plant and recycling water plant, and then delivered to users directly through pipelines. For non-direct route, wastewater shall be treated by wastewater treatment plant or recycling water plant, and then discharged into water bodies and/or underground reservoirs, and shall be acquired by users through various means, such as wells, at remote sites. In either way, there are some potential threats to environmental safety resulted from organic compounds, chemicals, and microorganism, that might be contained in recycled water.

Using recycled water as a non-potable water resource, there are some serious public health concerns about people might be infected by bacteria, virus, and other contagious or nosogenic pathogens, through direct contact with recycled water. Many pathogens cannot be detected by currently used tests. Currently existing wastewater treatment technologies are sufficient to reduce the number of infectious materials to a certain safety level. Ideally, the recycled water should be bacteria-free. However, the water quality requirement for recycled water is determined according to the purposes of reusage, as mentioned previously, as well as the rationalization and feasibility from both economic and technical aspects. On the other hand, the water quality requirement for potable water is completely determined by the demands of human health. Some bacteria might be contained in the aquatic products from recycled water and should become serious potential threats to environmental safety.

Major sources of recycled water are mainly from domestic wastewater, retentive precipitation, such as rainfall, snow, and some treated industrial wastewater. Some chemicals within treated industrial wastewater will be discharged into urban sewer system to mingle with domestic wastewater to adversely intervene or endanger biological treatment processes of recycling water, and eventually impair the quality of recycled water. Therefore, reusage for agricultural irrigation, industrial practices applications and other non-potable domestic applications shall be affected by these chemicals. In addition, underground aquatic reservoirs (aquifer) will be contaminated by the infiltration from the agricultural irrigation, Recharging of underground water and other applications. Potential threats to environmental safety resulted from reusage of recycled water are listed in Table 1.

Table 1. Potential treats to environmental safety from reusage of recycled water

Purpose	Category	Potential Threats to Environmental Safety
Industrial Applications	Cooling (direct, recycling)	✧ Rusting, erosion and colligation of microorganism and mote to cause potential safety problems
	Washing (solids, dust, and smoke)	
	Boilers	
	Engineering (bathing, steaming, fulling, hydraulic exploitation, mining, hydraulic transportation, and humidification)	
Urban Non-potable Applications	Gardening	✧ Cross infection with potable water system ✧ Human infection through direct contact ✧ Damaging urban environmental quality ✧ Endangering public health
	Toilet Flushing, Street Washing	
	Car Washing	
	Dust Controlling & Equipment, Components and Building Washing at Construction Sites	
Landscaping Applications	Recreational Usage	✧ Endangering aesthetic value of water bodies ✧ Eutrophication of water bodies ✧ Affecting public health
	Scenic Usage	
	Wetland Usage (Natural Wetland Rehabilitation, Artificial Wetland Creation)	
Agricultural, Forestry, Animal Husbandry and Fishery Applications	Agricultural Irrigation	✧ Ground water and soil contamination by trace metals ✧ Affection to crops by salinity
	Foresting and Breeding	
	Aquatic Products Breeding	
Water Bodies Recharging	Surface Water Recharging	✧ Microelements and toxicology
	Underground Water Recharging (Water Resource Recharging, Preventing Sea Water Invasion and Surface subsiding)	

3. CAUSES OF POTENTIAL THREATS TO ENVIRONMENTAL SAFETY FROM RECYCLED WATER

3.1 Reliability of Wastewater Treatment Plants and Recycling Water Plants

Treated industrial wastewater, containing various chemicals, will be finally discharged into urban sewer system. These chemicals might have adverse impact on biochemical treatment for domestic wastewater and then eventually endanger the quality of recycled water. Therefore, reliability of wastewater treatment plants is the key to insure the quality of recycled water.

Stable water supply is essential and critical to water resource safety. For recycled water, incoming water supply frequently fluctuates due to various reasons, such as construction, power failure and seasonal instability. The quantity variation of incoming water supply will definitely trigger the quality fluctuation and affect the quality of recycled water and related services, which will cause a serious threat to environmental safety.

3.2 Design and Operation of Transmission & Distribution Network for Recycled Water

The design and operation of transmission & distribution network for recycled water is an important factor to assure the quality and supply of recycled water. The transmission & distribution network of recycled water should be installed underneath the network of tap water (potable water) to prevent any leakage of recycled water to contaminate potable water. Therefore, the transmission & distribution networks for recycled water and tap water should be clearly marked to prevent any potential threat to environmental safety during network operation & maintenance and construction of new network.

3.3 Storage of Recycled Water

Normally, there is no need to store recycled water for direct route, since recycled water is delivered to the end user directly through specific transmission & distribution network. However, for agricultural irrigation and landscaping applications, recycled water is acquired from river channels, lakes or other water bodies within the metropolitan areas. Thus, the storage of recycled water is exposed to the open air. As the consequence, there might be some unpleasant situations happening, such as odor, color change and quality deterioration of entire water bodies. Though these events might be accidental and unexpected, the potential threats to environmental safety could be monitored and controlled by corresponding measures to prevent or reduce risks. Nevertheless, for agricultural irrigation and recharging for surface/underground water bodies, recycled water could cause deterioration of soil quality and underground water quality which are the long term potential risks.

4. TO ESTABLISH SAFETY MANAGEMENT MECHANISM FOR URBAN RECYCLED WATER

The major purpose and main objective for utilization of recycled water is to provide a long term and reliable water resource to meet the needs for sustainable development economy and environment. Therefore, there is an urgent need to establish a safety management system for recycled water to promote recycled water policies. This safety management system is composed of four major subsystems, such as policy, law, and regulation subsystem, standard subsystem, technical supporting subsystem, and safety management measures subsystem, as shown in Figure 1.

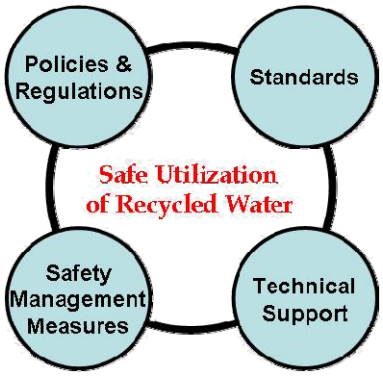

Figure 1. Safety Management System for Recycled Water

4.1 Standards for Recycled Water Reusage

In December 2002, three national standards for urban recycled water were promulgated by National Standardization Management Committee, namely, “The Usage Classifications of Urban Recycled

Water" (GB/T18919-2002), "Water Quality for Urban Non-Potable Applications of Urban Recycled Water" (GB/T19820-2002) and "Water Quality for Landscaping Application of Urban Recycled Water" (GB/T19821-2002), and were implemented since May 1st, 2003. Currently, there are no specific water quality standards for industrial cooling and agricultural irrigation applications of urban recycled water, where related national standards could be adopted, as shown in Table 2, based upon practical experience. For recycled water engineering, samples of recycled water should be provided to user for confirmation. As for multi-level applications, recycled water should be delivered to various users according to different quality standards. On the contrary, recycled water should be delivered to users according to highest quality standards requested by users. Hence, the unique character for recycled water engineering is the water quality should be determined by the evaluation on various users' needs.

Table 2. Water Quality Standards of Recycled Water for Various Applications

Applications	Water Quality Standards
Domestic Applications, Urban Virescence, Car Washing, Street Washing, etc.	"Water Quality Standards for Urban Non-Potable Applications of Urban Recycled Water" (GB/T19820-2002)
Landscaping Applications	"Water Quality Standards for Landscaping Application of Urban Recycled Water" (GB/T19821-2002)
Industrial Cooling Water	"Standards for Urban Recycled Water Designing" (CECS61:94)-Recommended Water Quality Standards of Recycled Water for Industrial Cooling Water
Agricultural Irrigation	"Water Quality Standards for Agricultural Irrigation (GB 5084-2005)
Fishery	"Water Quality Standard for Fishery" (GB11607-89)

4.2 Promulgation of Corresponding Policies and Regulations for Recycled Water

Presently, the policies regarding to recycled water were mostly seen in the work reports from local governments as promotive strategies. At the end of 80s, "Construction Management Rules for Recycled Water" were promulgated in Beijing, Shenzhen, and Dalian cities. On August 31, 1991, "Standards for Recycled Water Construction Designing" (CECS30:91) was promulgated by the Committee of Chinese Engineering Construction Standards. In 1996, "Planning for Recycled Water in Tianjin" was issued. And "Codes of Urban Recycled Water Planning in Beijing" was proclaimed in 2001. Yet, the corresponding regulations system for recycled water is not completed. There is lack of specific guidelines for recycled water implementation, especially for the planning of recycled water usages. Under this circumstance, there are certain potential threats among the booming recycled water business. Therefore, to establish the regulation system for recycled water engineering is the most urgent task. It's specifically stated in "China's Agenda 21": *Wastewater treatment and water recycling should be closely integrated to utmostly utilize treated wastewater for non-potable usages, such as agricultural irrigation, water body landscaping, industrial cooling, and washing. And then, an integrated coordination and management system for water supply, water usages, wastewater treatment and water recycling should be gradually established.*

Presently, there are two regulations, "Standards for Recycled Water Construction Designing" (CECS30:91) and "Standards for Urban Recycled Water Designing" (CECS61:94), under revision by Ministry of Housing and Urban-Rural Development. It's recommended that policies and regulations system regarding recycled water resource should be promoted and well organized according to related laws, by corresponding authorities, as shown in Figure 2, where supervision on facilities operation for recycled water and penalties for violations should be precisely documented. From the aspect of environmental safety, it should be clearly stated in the regulation that "untreated wastewater is absolutely forbidden for irrigation." In addition, for some particular business entities, especially for high water demanding business, the activities of water utilization should be explicitly regulated and strongly

restricted.

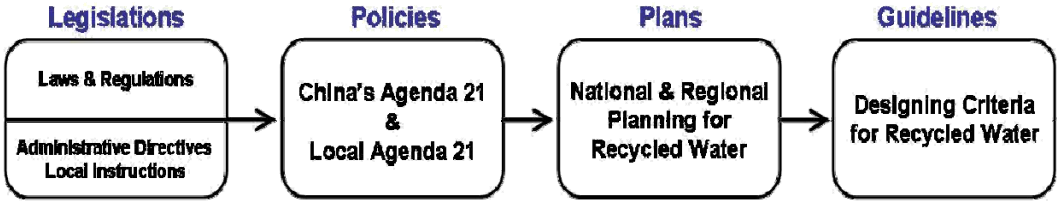

Figure 2. Policies and Regulations System for Recycled Water

4.3 RESEARCH ON WATER RECYCLING TECHNOLOGIES

Up to now, urban wastewater treatment and recycling technologies include:

i. Secondary treatment - Disinfection
ii. Secondary treatment – Filtration & Disinfection
iii. Secondary treatment – Coagulation, Sedimentation (Clarification and Aeration), Filtration & Disinfection
iv. Secondary treatment – Microfiltration & Disinfection

As for higher quality requirement for recycled water, more advanced technologies should be applied in tertiary treatment, such as activated carbon absorption, ozone combined with activated carbon, deamination, ion exchange, ultrafiltration, nanofiltration, reverse osmosis, ozonation, to generate high quality recycled water. Nevertheless, the cost to apply these technologies is too high to be implemented widely and has become a major obstacle for recycled water safety. Therefore, for environmental safety, it is a critical task to significantly reduce the cost to implement these more advanced technologies for recycled water treatment.

4.4 Safety Management Measures for Recycled Water

4.4.1 Management of Industrial Pollution Sources

Some treated industrial wastewater will be discharged into urban sewer system as a source for recycled water. However, it should be guarantied that these treated wastewater will not induce or produce any damages to later utilizations. Usually, there are some materials, for example, chlorine ions, turbidity, dissolved solids, sulfates, hardness, alkalinity, un-degradable organic compounds and microorganism, contained in industrial wastewater. These materials might not be treated and removed by biochemical treatment or tertiary treatment and should result adverse impact on the safety of recycled water. Therefore, industrial wastewater, as a source of recycled water, should be well treated to attain the quality requirement of related standards, prior to being discharged into urban sewer system. So, online monitoring to industrial pollution sources shall be an essential factor to insure the resource safety of recycled water.

4.4.2 Design of Transmission & Distribution System/Network

There are tow types of transmission & distribution network for recycled water, namely, closed conduit and open channel. For closed conduit, there should be some safe distances between networks of tap water, wastewater and recycled water. For instance, tap water network should be installed on the top layer, wastewater network should be put in the bottom and recycled water network should be positioned in between tap water network and wastewater network. Each underground pipeline network should be explicitly marked, or example, the pipelines for recycled water is in light purple, in the States. And,

"Recycled Water" should be founded on the cover of the well gate. No faucets shall be installed within the network. For open channel, the effluent on the river channel should be smooth and fluent. In addition, sludge should be excavated from the bottom of the river channel, regularly, to prevent secondary contamination to recycled water.

4.4.3 Construction of Safety Early Warning System

Several issues, water sources, wastewater treatment plants, water recycling plants and end users, are involved in the safety management of recycled water. Hence, convenient communication system and regulated safety early warning system are very important to the safety management of recycled water. The concept to establish the safety early warning system is illustrated in Figure 3. Local environmental protection bureaus or environmental monitoring centers, as the coordinating agents of environmental safety affairs for local governments, play the key role for entire safety early warning system.

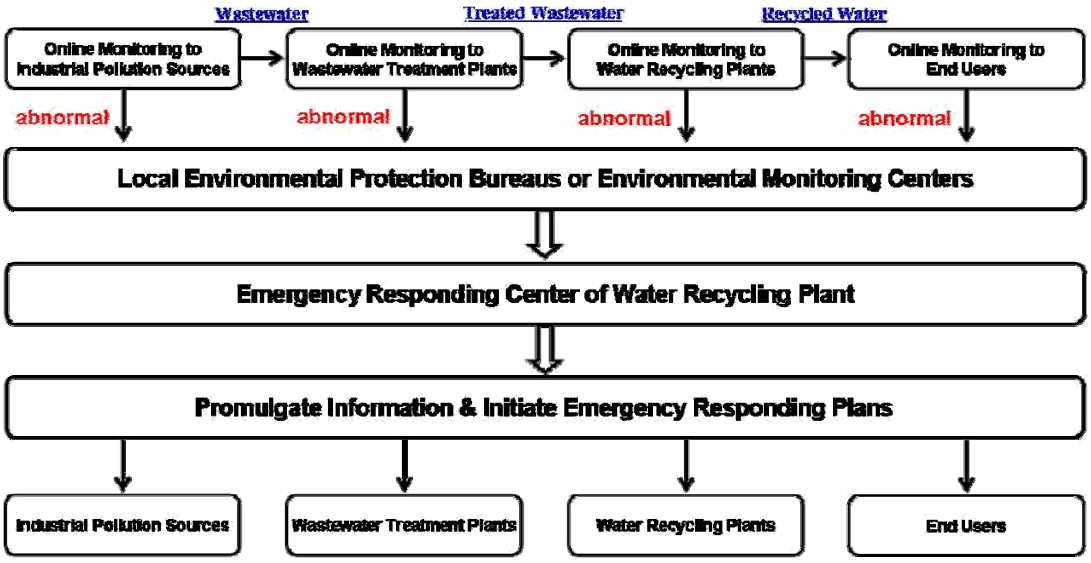

Figure 3. Early Safety Warning System for Recycled Water

4.4.4 Management of End Users

Management of end users is quite crucial to environmental safety, due to the unique characters of recycled water resources. For cooling applications, appropriate water quality stabilizer & algae killer, and proper operation condition will alleviate the adverse impact resulted from the nature of recycled water. Thus, specific management requirement should be proposed for different end users to guaranty users' safety.

5. CONCLUSION

Severe water pollution and serious shortage of water resources have become major obstacles to the sustainable development in China. Though, with more advanced technologies and instrument for wastewater treatment, great concerns about environmental safety are induced from the reuse of treated reclaimed wastewater. For sustainable water resources, it's necessary to establish applicable and feasible management mechanisms of the environmental safety for recycled water through four schemes: (1)

management of industrial pollution sources, (2) design of transmission and distribution system/network, (3) construction of safety early warning system, and (4) management of end users, to ensure the public health and environmental friendly.

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