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Use of Reclaimed Water in China:

management issues and strategies

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Abstract: As one of the fastest economic growing country in the world, China faces many water challenges. While there is no magic bullet to solving those challenges, a diversified selection of alternative water resources to help stretch traditional freshwater supplies is one of the optimal solutions. For this reason, the view of managing wastewater is moving from safe disposal of the treated product to incorporating it into the water supply. Since reclaimed water is increasingly consider being a valuable resource, the management of reclaimed water is also going to play a significant role in China's future water management. This paper aims to give an overview of reclaimed water used activities in China and outline some issues arise from the management defect. And the innovative management strategies relevant to the management that put forward in this paper may become a part of the journey towards sustainable management of water resources in China.
Key words: Reclaimed water; Historic and modern applications; Issues; Strategies

1. INTRODUCTION

While Americans fret over rising gas prices and global tension over oil, Chinese government is struggling to secure access to another, even more basic resource. The signs of water stress can be seen on every front in China. A recent Chinese survey reports that the water table beneath much of the North China Plain has fell an average of 1.5 meters (roughly 5 feet) per year over the last five years . Water scarcity in China is fueling conflict and thwarting development while growing in step with local populations and rising global temperatures, and the challenge to develop alternative water sources to satisfy future needs has become critical. Accordingly, the production of reclaimed water using in lieu of potable water for non-potable water uses has begun to receive considerable attention.

Over the past few decades, science and technology have been striving to develop economical ways to approach fresh water scarcity issues. Reclaimed water is now recognized as an outstanding trendsetter in China's water management and proven method of conserving fresh water supplies

Reclaimed water, sometimes called recycled water, is highly treated wastewater which is clear in

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appearance, odourless and is safe for a variety of beneficial uses. Reclaimed water is an important source of additional water supplies for times and areas where water is short on supply. Although not suitable for drinking, however, it's great for many other uses such as:

- Irrigation
- Street-sweeping operations
- Power generation
- Decorative fountains
- Fire fighting and protection (purple fire hydrants)
- Aquifer recharge
- Cooling or makeup water for a variety of industrial processes
- Decorative ponds and fountains
- Groundwater and river recharge
- Toilet and urinal flushing
- Stream and wetland enhancement
- Fire protection
- Median strips and dust control
- Concrete mixing on construction sites
- Car washing and any other commercial washing purposes
- Soil dampening for compaction

There are a number of uses for reclaimed water. Essentially, any situation in which water will not be consumed is appropriate for reclaimed water, with potable water being reserved for cooking, bathing, irritating edible plants, and washing clothes. And apart from conserving our drinking water, the use of reclaimed water also offers benefits in the following ways:

- Costs less than drinking water
- Reduces fertilizing costs because reclaimed water is rich in nitrogen and phosphorous
- Reduces disposal into waterways by eliminating direct discharges of nutrients, salt and Blue Green Algae (BGA), which can help reduce nutrient loads in bays and rivers

These in turn bring about advantages to sustainable development and environmental protection. With these benefits that brought by reclaimed water in mind, many regions around the world promote the use of it to conserve water supplies, ensuring that access to potable water will always be available.

Reclaimed water originates from highly treated municipal wastewater. Typical wastewater undergoes two treatment processes and disinfection before being released into a nearby river or stream. Reclaimed water receives a third, more advanced level of treatment (tertiary) so that it can be reused for non-potable or non-drinking purposes. This third treatment is a highly engineered, multi-step treatment process which normally includes the following procedures:

- Screens and other processes remove sand and debris
- Sedimentation removes large solids
- Microorganisms break down organic materials
- Clarifiers remove microorganisms and remaining solids
- Filtering makes water clear
- Disinfection, usually with chlorine, kills the remaining microorganisms

2. HISTORIC AND MODERN APPLICATIONS OF RECLAIMED WATER IN CHINA

The practice of wastewater reclamation and reuse had its modem birth in Europe in the mid-19th century (Daniel A. Okun, A History of Nonpotable Water Reuse through Dual Distribution Systems, Reclaimed water conference, 1996). However, untreated wastewater used for agriculture irrigation only started in the mid-20th century, and the 20 years short history of reclaimed water from 1980s can be divided into three periods:

In the initial stage, Specialized Researche Plan on wastewater reclamation, which is supported by Ministry of Construction, carried out in Qingdao and Dalian in 1960s as the first try of reclaimed water use in China.

After these two cities received the acceptance certificate on their test projects of reclaimed water reusing system and became the pioneer of wastewater reclamation in China in 1980s, another series of projects were planed to launch forth on in certain cities such as Tianjin, Taiyuan. The technological achievements obtained from these projects were summarized to reorganize and optimum theirselves in order to make them become demonstration projects in the field of reclaimed water use in China. An integrated comprehensive technological system is the fruit borne by these test projects in the second stage.

The third stage started with an upsurge in the construction of wastewater reclamation projects. As the demand for fresh water increases, scores of cities in China devoted a considerable portion of their efforts to develop their own city reclaimed water system. The use of reclaimed water has become a long term strategy that carries with it significant meanings in this country since then. Local governments increase financial supports for wastewater reclamation by a margin larger than ever, and preferential policies are also offered to promote the use of reclaimed water. Great achievements have been made on technical researches which in turn provide a further boost for the possible uses of reclaimed water includes cleaning roads and vehicles, irrigating parks and sport fields, flushing toilets, fire fighting, industrial productions, groundwater recharge, urban development and landscaping. Pilot schemes to explore reclaimed water project were transformed into a large scale construction rush that still running on all cylinders now. Table 1 shows some major reclaimed water projects that are in progress now or just been finished:

Table 1. Major Construction Projects of reclaimed water in China from 2007 to 2010

Sewage treatment plant	Secondary treatment technology	Tertiary treatment technology	Daily capability (10^4m^3)	Application
Kunming First to Sixth sewage treatment plants	● Improved anaerobic/anoxic/aerobic (A^2/O) ● Activated sludge ● Intermittent cycle extended aeration system (ICEAS)	filtering, disinfection	2.9	● Irrigation water for ornamental landscape and golf course ● Non-potable domestic water use
Yandong sewage treatment plant of Ningbo	Oxidation ditch	coagulation sedimentation, filtering, disinfection	10	● Car washing ● Decorative fountains and ponds ● Agriculture irrigation ● Industrial process water ● Dust control ● Landscaping irrigation
Sanwayao sewage treatment plant of Chengdu	Activated sludge process	Filtering by fiber ball filter, disinfection	35	● Landscaping irrigation ● Natural system restoration ● Non-potable domestic water use

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Sewage treatment plant	Secondary treatment technology	Tertiary treatment technology	Daily capability (10^4m^3)	Application
of Tianjin economic development area	extended aeration system (ICEAS)	Matched Filter (CMF) and reverse osmosis (RO)		● Industrial process water ● Landscaping irrigation
Sewage treatment plant	Intermittent cycle	Classical	2	● Toilet flushing
Tielin sewage treatment plant	Biofilm activated sludge (BAS)	coagulation sedimentation, filtering, disinfection	8	● Cooling or makeup water for power plants ● Rivers and lakes enhancement
Sewage treatment plant of Beijing economic development area	Cyclic Activated Sludge Technology (C-TECH)	Classical Matched Filter (CMF) and reverse osmosis (RO)	2	● Industrial process water
Lugang sewage treatment plant of Baoding	Improved anaerobic/anoxic/aerobic (A^2/O)	biological aerated filter (BAF), coagulation sedimentation and filtering	5	● Cooling water ● Boiler make-up water ● Industrial process water ● Landscaping irrigation
Sewage treatment plant of Changshou industry park	Improved anaerobic/anoxic/aerobic (A^2/O)	Filtering by ultrafiltration membrane	4	● Cooling water ● Boiler make-up water ● Industrial process water
Qian'an sewage treatment plant	biodegradation/adsorption combined processes	coagulation sedimentation, filtering by active carbon filter, disinfection	4	● Industrial process water ● Landscaping irrigation
East zone and west zone sewage treatment plants of Yining	Oxidation ditch	coagulation sedimentation, filtering	6.5	● Cooling water ● Boiler make-up water ● Industrial process water

3. Management Issues of Reclaimed Water in China

Since reclaimed water has been taken as new water resources in China, changes must be made to our water management practice. But the truth is China hasn't prepared enough to face these shifts in management system. And apparently the related legal and regulation also has not kept pace with the development of reclaimed water. Growing problems keep showing up in the implementation and management of reclaimed water which will be described in details below.

3.1 Reclaimed Water Pricing

The pricing of reclaimed water faces a difficult dilemma at the very beginning. On one hand, due to the immure technology that still undergoing development, the cost of reclaimed water is relatively higher than acceptable price. In the case of small or medium-sized enterprises, the costs sometimes are even higher than the water price. On the other hand, although the overly low prices of domestic water which, were indeed, too low to reflect its value in such a country that plagued by severe water shortage, but the keen price of water price shape the price of reclaimed water at a very low level.

But for the purpose of promoting the use of reclaimed water, the prices of reclaimed water set by local government are normally lower than the average production costs which make the water reclamation enterprises have difficulty to maintain their business or debase the qualities of their effluent to minimize the financial loss. Once the reclaimed water plants lower the qualities to struggle to get out of red, the second issue comes along.

3.2 Quality of Reclaimed Water

Within many cities of China, numerous communities already receive reclaimed water service for outdoor irrigation purposes. City management usually promotes its reclaimed water based on the "it's-almost-clean-enough-to-drink test." While this seemingly lighthearted analysis is sometimes true, reclaimed water are actually poor choices for irrigation or industry water use.

None of the three treatment processes reclaimed water goes through diminish either the total salinity or the sodium content of the water. But in fact, the total salinity of municipal water can increase by as much as threefold from the fresh-water source to the final effluent. These increases in salinity have caused problems for golf course and vegetative landscape. High concentration of salt will speed up soil crust and killed the plants grown in. So the most profound change in management dictated by the use of reclaimed water is to deal with total salinity and the sodium's effect on the soils. However, agronomists in charge of urban landscaping haven't adjust cultural programs in time, they may be forced to change turf species or replant trees and ornamentals once the salts accumulate in the root zone over time.

Besides high salinity, the high level of nutritious materials as N, P and K contained in reclaimed water is another problem that bred in the use of reclaimed water. Questions would be raised as to the potential for nutrient loading into lakes or rivers that recharge by reclaimed water. Some awkward things happen when reclaimed water was introduced into Grand View Garden at first time. The pools and lakes that recharged by reclaimed water all had "A Dream of Red"----turn reddish black. But it seemed that their dreams did not so sweet because the offensive odour they carried. The vice chief of Grand View Garden said that it was fine when the reclaimed water being used in fire protection and dust control, but when it came to landscaping and lake recharge, water quality deteriorated within a week. And almost all of the aquatic organisms in the lakes were dead except some aquarium fish which are also misshapen in this awful reddish black lake. It came out that the contents of nitrogen, phosphorus and potassium are failed to meet the standards. Nutrient levels specific to reclaimed water are not monitored routinely by related department or users, and the unqualified reclaimed water can raise a rumpus that can be easily avoided under a more efficient management. Even though different quality standards have been specified in < *Standards of Reclaimed Water Quality (SL3682006)*> to regulate the different use fields of reclaimed water, most of the users, suppliers, sometimes even the managers believe that reclaimed water has a universal use without caring about its specific quality. As a result, general permits for the direct use of reclaimed water in any way are authorized by simply meeting the lowest quality criteria of reclaimed water, which in turn, breed another potential risk.

3.3 Safety of Reclaimed Water

Clearly, even reclaimed water that receives high level disinfection could often pose an acute health risk if drinking water standards were applied. Sometimes it is even not classified as permissible for full body contact. It is necessary to erect warning signs at the property linked to the reclaimed water for reasons of

safety. Unfortunately, most of the current reclaimed water related properties rarely equipped with a warning sign, which makes the recognition of the areas that utilize reclaimed water is next to impossible. Reclaimed water coming out from sprinkler heads that located in lawn or park is often used by innocent people to feed their thirsty pet dog, some may even take it for drinking or face washing. And update local ordinances issued recently normally define green, which stand for safe, as the warning color that colored to the reclaimed water related properties. May be some more bright and stand out warning color can do a better job of sending the warning message.

Furthermore, in the case of household use of reclaimed water, customers will be provided with both potable and reclaimed water to their properties, there is a possibility that the two systems could be inadvertently cross-connected. A backflow prevention device installed on the property side of the potable water meter is a safety device to protect the city's water supply from the possibility of cross-connection. In China, however, the responsibility of the suppliers to install a backflow device on the drinking water supply line before reclaimed water service hasn't been required by any related regulation. The vacancy of this indispensable protection device puts one site in safety jeopardy on the reclaimed water use.

3.4 Capital Financing for the Construction of Reclaimed Water System

As we mentioned above, the reclaimed water system shall have no connection to any potable water system, which demands a completely independent pipeline system for the transportation of reclaimed water. Small size reclaimed water plants that built up in and only service for a residence community or an industry factory has to collect, which is not always easy, the capital for construction by itself. On the other hand, although formal baking is given from local governments, large reclaimed water enterprises are still over head and ears in debt under the current pricing of reclaimed water. The revenues they received are hardly to live on, let alone taken as capital for the construction of pipeline system. Reclaimed water that has been produced goes to no where without a match up pipeline system, which puts the reclaimed water enterprises in an awkward position.

Besides financial problems, the existing infrastructure in city is another obstacle for the construction of reclaimed water pipeline systems. Current road construction, for instant, did not take the arrangement of reclaimed water pipeline into account formerly, which makes it inaccessible to built up any pipeline for the distribution of reclaimed water now.

4. STRATEGIES FOR THE FUTURE MANAGEMENT OF RECLAIMED WATER IN CHINA

A growing body of evidence suggests that water reuse will play an expanded and critical role in water management in the 21st century China. For all of the advancements made in the management of reclaimed water, there continue to be challenges that need to be addressed. Great efforts must be made to find out some foresighted utility management strategies for a better future of reclaimed water.

4.1 Legislative Updates and Unified Management

For the sake of better development, a reclaimed water law is expected to be submitted for review to the State Council in the next few years. Major issues such as responsible department, authorization, reclaimed water safety, market-oriented allocation, scientific and technological innovation, service and cooperation must be construed, controlled, and interpreted in the law.

And besides the existing Standards of Reclaimed Water Quality (SL3682006), a more comprehensive national regulation should be drafted to establish requirements, prohibitions, standards and concentration limits for the use of reclaimed water to protect public health and the environment

while encouraging the use of reclaimed water. Local guidelines must build in flexibility to encourage innovation, without ever lowering standards on the environment, health, safety, and protection. These guidelines should focus on desired performance objectives and outcomes through appropriate management practices,

Principle of unified planning, general management, and market-based under governmental control should be the foundation of reclaimed water management. The establishment of a national ministry and local sectors is essential for sound reclaimed water governance. Authorities are empowered according to related low or regulation. Government agencies related to the use or the project construction of reclaimed water should have their functions streamlined to ensure unified reclaimed water administration. Maintain communication and partnerships with all relevant agencies involved in management of water resources

In planning for future reclaimed water needs, a wide strategic framework should be established by local government. Use strategic water demand management to encourage efficient use of reclaimed water and extend the life of existing supply infrastructure. Risk-based approaches should be used to reclaimed water supply management to identify and deal effectively with risks associated with water quality and supply.

4.2 Access Control

All reclaimed water pipelines, valves, and other appurtenances, including all irrigation systems pipelines, valve and control boxes shall be color-coded and embossed or integrally stamped or marked “CAUTION: RECLAIMED WATER-DO NOT DRINK”. The size of the warning sign must be adequate to provide easy visibility to visitors and stamped on every side of the pipe and tape and be repeated every three feet or less.

Any large-size reclaimed water project shall coordinate with the water department to establish and obtain approval from local department of health. Where both reclaimed water and potable water are supplied to a use area, a backflow prevention device shall be installed at the connection. An initial and subsequent annual cross-connection inspection and test shall be performed on both the potable and reclaimed systems. Make sure the suppliers have the legal right and perform the responsibility to enter the customer’s property for checking and testing of cross connections.

In the case of business/enterprise use, employees with direct contact to the reclaimed water distribution system must be made aware of the presence of reclaimed water, and proper actions for spill response.

4.3 Quality Monitoring

Like drinking water, reclaimed water also must undergo extensive quality monitoring to ensure the quality of this recycled product. On-line monitoring equipment will provide continuous feedback about the quality of reclaimed water throughout the treatment process and also after it leaves the plant. A double check test should be provided to ensure that the on-line monitoring is working. If monitoring indicates that reclaimed water does not meet health standards, the distribution and use of reclaimed water must be shut down until its quality is acceptable.

Furthermore, an analysis of these monitoring results would provide valuable information about the level of substances commonly found in reclaimed water temporally and spatially, which in turn offer convenience to the manager to administering at a macro-level. And, withal, data collected from the monitoring are given to verify the qualifications of reclaimed water supply.

4.4 Permit System

The best way to ensure reclaimed water is used safely and effectively is the establishment of a permit

system. Through this permit system, authorized department allows permit to provide reclaimed water to designated users. A reclaimed water permit should be required when it comes to:

- An owner or operator of a sewage treatment facility that generates reclaimed water for direct reuse
- An owner or operator of a reclaimed water enterprises
- A reclaimed water agent
- An end user

For the reclaimed water enterprise or facility, information about the facility that is supplying reclaimed water and the process of the treatment should be provided in its application. Permits are only granted when it's ability to comply with the reclaimed water effluent standards and operational requirements have been demonstrated. Different kinds of permits are given to reclaimed water with different quality class. Reclaimed water in the highest quality category can have its permission to provide the broadest range of reuse.

Entities must apply for permit if seeking delegation for the distribution of reclaimed water. A reclaimed water agent operates under such a permit has the legal right to allow end users to receive reclaimed water for appropriate reclaimed water applications without having to notify the related government department to obtain permit coverage.

Application should also be made by the individual and community users. The volume of reclaimed water applied monthly for each category of direct reuse activity should be stated in the application fully and truly.

4.4 Justified Price

Although the government-controlled price may be preferable in the beginning stages of reclaimed water development, but all government must remove themselves from trying to bring the price down once the reclaimed water market has matured. As a matter of fact, metering the reclaimed water and providing it at an economical price is much better for the future development of reclaimed water.

Even though during a promotion period, an arm's length price is much better than a price valorized by local government. An arm's length price can make sure that the rates or prices extended will still reflect fair market value even under government intervention. An arm's length price for reclaimed water essentially accomplishes two things. First, this form of pricing structure is good for the seller. Second, an arm's length price helps to prevent appearance of monopoly price under oligopoly. If the price set by government fall within an acceptable range of arm's length prices, then no adjustment should be made. Otherwise, governments need to consult with both suppliers and customers to agree what adjustments should be made to replace the current price.

4.5 Public Education

Public education is recognized as an important aspect of developing community support for reclaimed water reuse. It is also a very efficient way to avoid any safety issues induced by people's sheer ignorance of reclaimed water. Conduct enough public meetings, business forums, and water quality advisory meetings in the course of the planning process to get enough public understanding, not just for support, but also for the use of reclaimed water in an efficient and safe way. In advance, public education should be developed as one elements of any reclaimed water program. The provision of information on issues should include:

- the beneficial use of reclaimed water;
- the customer's responsibilities in using the reclaimed water;
- the customer's use of reclaimed water in a safe and responsible manner consistent with the supplier's guidance information;
- the warning signs that equipped with reclaimed water related properties;
- a list of reclaimed water allowed use and uses not allowed;

- Tips on good practice garden watering and maintenance of healthy plants with the reclaimed water;
- what to do and who to contact for emergencies (for example pipe bursts)

Further information about the use of reclaimed water can be provide in a variety of ways, such as public service announcement on television, informational mailer or poster attached to the water deposit demand note.

5. Conclusions

China began its initial impetus for reuse came from efforts in the early 1980s, and after decades of efforts, reclaimed water is gradually viewed as a valuable and available resource in China. There has been a significant increase in use of reclaimed water in the last few years, and reclaimed water has been an important component of water resources and water management in China.

The overall objective of the reclaimed water management is to maximize the reuse of reclaimed water through minimizing and managing any risks associated with its use. Given the complexity of reclaimed water use and a host of problems with existing management, some follow-up adjustment and supplementary to the current management to meet this objective as stated above. Various complementary management systems including legislative updates, access control, quality monitoring, fair pricing, public education, and so on.

Since start to be recognized as being of paramount importance for sustainable development of water resources in China, continual improvement in the management of reclaimed water, and a sound management system can be expected in the future. But before that, there is still a long way to go.

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