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The Status and Challenges of Water Infrastructure Development in China

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1 Status of Water Infrastructure

1.1 History of water and wastewater infrastructure in China

The history of water infrastructure in China can be tracked back to almost 130 years ago. In 1879, the first water supply facility in China was built in Lvshun, a northeastern seashore city. Its capacity was 1500 m^3/day for a population of about 20,000. The water infrastructure construction developed slowly before 1949 for the country was in continuous war chaos. Before the founding of the People's Republic of China, only about 60 cities had water supply plants with a capacity of 1.86 million m^3/d. There were even less wastewater treatment plants, maybe less than 5. Between 1949 and 1978, the water supply facilities rose to nearly 500, which produced over 63 million m^3/d. However the wastewater treatment still remained sluggish. There were almost no newly constructed ones. The real rapid development occurred after 1978 when China began its "opening and reform". In the recent 30 years, thousands of water and waste water plants have been built and put into use all over the country with the economic booming. Up to now, the water supply system has covered 97% of the urban population in 661 Chinese cities with a total water production of 270 million m^3/d. At the mean time, more than 200 million rural people are getting benefits from the tap water. The overall water supply coverage percentage for the whole country is about 43%. Considering the large population of 1.3 billion in China, this is a great achievement. Wastewater treatment infrastructures have also made great progresses. Only from 1999 to 2005, the wastewater treatment capacity was increased from 2.24 million m^3/d to 13.09 million m^3/d. Now, there are 1178 wastewater treatment plants in China. The treated wastewater percentage was raised to 60% for the urban areas in 2007, which contributed substantially for the country's pollution control goals.

1.2 The characteristics of the water and wastewater facility and important ones in China

One of the most remarkable results of the high-speed development in China was the urbanization. The urban population was about the 42.99% of the total population in China at the end of 2005 and this percentage is expected to over 50% in 2010. The booming of urban population results in the booming of the urban infrastructures. Now, besides the large-scale water plants in 661 cities, there are also 13828 intermediate and small scale water supply facilities are interspersed among 13922 towns all over China. Different from the prevalence of water treatment plants, wastewater treatment plants could be seldom seen in the small towns, most of them are in big cities. The more an area is urbanized, the more wastewater is treated in the area. Most of the water purification plants in China apply the conventional treatment processes consisting of coagulation, sedimentation, filtration and disinfection. While, some new technology has been induced into China and more plants with polluted source water or in important areas begin to use novel processes and thus supply safer water to the local population. In Beijing, the No.9 water plant was one of the largest in China, also in Asia. It was built in 3 stages. The water supply capacity is 1.50 million m^3/d. Besides the conventional technique, granular activated carbon was applied, and the water after treatment is <0.5 ntu in turbidity, <5 degree in color. In another super metropolis, Shanghai, Yangshupu water plant is a symbol of the country's water industry. This history of the plant is from 1881. Now its service population has exceeded 2 million with the startup of its newly constructed product line which has take pre-ozonation and O_3-BAC to remove the organics and guarantee the water quality. Also in Shanghai, Bailonggang wastewater treatment plant, the largest in China and Asia, has put into use recently. This plant can treat 2 million m^3 wastewater per day and will contribute 96% of the COD discharge reduction of Shanghai. Its treatment capacity will be increased to 3 million m^3/d at the end of 2020 and eventually become one of the largest municipal wastewater treatment plant with nitrogen and phosphorus removal and sludge digestion stabilization in the world. In Beijing and Tianjin, Gaobeidian and Jizhuangzi wastewater treatment plants are very famous, for they are the largest in China once and the first modern wastewater facility in China. Now, they are still play

important roles in the sustainable development of Beiing-Tianjin metropolitan. The service population of the former is 2.4 million with 40% of the total wastewater in Beijing.

1.3 Financing and management mechanisms of water infrastructure

Conventionally, all most all of the water infrastructure was invested, run and controlled by the government in China since 1949. In fact, this was the common situation for almost all the industrial sections in this country. Known to all, the economical structure has been greatly reformed after 1978. The planning economy has already been taken place by the so-called “socialistic market economy” for many years. The non-public ownership capitals were allowed to enter to the circulation domain, light industry, manufacturing industry and even other public services such as medical and education. But because of the importance of the urban infrastructure, the foreign and private capital was allowed until 1999. In that year, Vivendi from France invested about $100 million on a 0.4 million m^3/d water supply plant in Chengdu. This can be viewed as a milestone to China water industry. In the following yeas, the investment structure for water infrastructure has been greatly changed. For water supply facilities, the government input was no longer the sole source. In recent years, the investment by the central government can reach 15%-20% of the total investment. The loans from foreign and domestic banks are about 30% of the total investment. The financial input from local government can responsible for 20%-30%. Water charge collected by the water supply companies can occupy for 20%-35%. Besides these sources, other financing mode includes: (1) franchising, (2) BOT by foreign companies (3) Invested by domestic enterprises.

About the management, in the government of different levels, there is always a division in charges of water infrastructure. 10 years ago, this division is the ministry of construction in the central, the department of construction in provincial and the bureau of construction in the lower government. However, the construction administrations in China can only manage the water supply and wastewater treatment. The affairs concerning about water resource facilities were governed by the division of water resources. Because of source water pollution, a useable source is getting more important. Some cities such as Shanghai, have to spent several billions of RMB yuan to construct a water

transported line to use the source meeting the national standard. So in recent years, many cities prefer to establish a new kind of government agency, bureau of water affairs, which govern all the affairs associating with water including water resources, water supply and wastewater treatment to avoid a situation described as “several dragons manage water (in Chinese culture, dragon is the natural governor of water)”. In some cases, the bureau of water affairs are taken place by “water affair group incorporation”. The later was run as a modern enterprise and not a government agency. Up to now, most of the water affairs administration was setup in city levels. In provincial levers, only Beijing and Shanghai has such a department. But the establishment of bureau of water affairs is the trend for water infrastructure in China.

1.4 Most important constraints in water infrastructure development

Enough quantity and good quality of source water is the basic requirement for water infrastructure development. While both are difficult for many places in China now. Environmental pollution has burst out in recent 30 years along with the great economic achievements. In fact, large quantities of wastewater still remain untreated before their entering the receiving waters. It was reported that over 90% of unban waters was polluted at different levels and nearly 50% of the sources for the key cities and town can not meet the standard for the source for concentrated drinking water plant. Nearly 100 cities have seriously polluted source water, which mainly distributed in the relatively developed areas in China. The direct consequence of the water pollution is the abandon of the water source resulting in aggravating the lack of water or spending huge amounts of money on seeking and construction new water sources. The indirect consequence is the deterioration of the water quality and the adverse effect on human health. The contamination of the source water is so serious a problem that the shortage of qualified source water even occurrs in the traditionally so-called "water-town" areas, e.g., Jiangsu and Zhejiang Provinces. A famous extreme example is the Taihu Lake drinking water crisis in last Summer. Taihu watershed is the richest and most dynamic area in China. Also the environmental capacity in this area is almost saturated. The odour materials from alga degradation resulted eventually in the temporary cutoff of the water supply for millions of people in Wuxi city. Actually, even if there is no such outbreak of pollution, the so-called "micro-pollution", the micro-level or

trace-level organic pollutants including POPs, Endocrine Disrupting Chemicals and mutagenic disinfection byproducts (DBPs) can also result in the genetical toxicological damage for human health. Nowadays, most of the China water plants apply the conventional process, which is not active in removing the micro-pollution matters. The countermeasure to this problem will be discussed in the following.

The second constraint is the very weak basis for water infrastructure in China. China has a large population of about 1.4 billion, of which 56 % are living in rural areas. As mentioned above, most of the water infrastructure in China are built in urban areas. However, in rural areas, only less than 60% drinking water was treated in water plants. Nearly half of the rural water supply is lower than the required criteria mainly because of the microbial contamination. The disinfected drinking water can only reach 1/6 of the total rural drinking water, which would be a great problem if Chinese people did not boil water before drinking. Another serious problem is that there is almost no wastewater treatment plant or other treatment facilities in rural areas in China. Besides the domestic wastewater, the nitrogen and phosphorus from the non-point source like farmland is also a great contribution to the eutrophication of the water bodies, which results in the decrease of the water quality. Even in the urban areas, the water infrastructure construction still needs great promotion. Large quantities of wastewater should be treated or further treated. The processes in both of the water and wastewater treatment plant need to be improved. For drinking water treatment, advanced processes such as O_3-BAC, membrane filtration may be the solution to the micro-pollution. For wastewater treatment, tertiary treatment are necessary for stringent water discharge standard. All of these need construction fund, operational experience and advanced technology.

The third constraint is associated with the second one. For the poor background of the water infrastructure in China, flexible management and operation mechanisms are necessary. However, the operational mechanism in the current water infrastructure in China can not fit the rapid development of the economics and the increase of the demand by urban and rural people. As mentioned above, the infrastructure industry is mainly state-owned and state-run in China. This mono-mechanism may be due to the specialty and the importance of the water supply and wastewater treatment, but is an important

constraint for the development of water infrastructue to a great extent. In fact, besides as a commonwealth, water infrastructure is also a industry obeying the economic rules. So various economic and management patterns should be introduced to this domain to make its development sustainable. However, the situation is changing better. Now, both foreign and domestic capitals are allowed to enter water infrastructure. Especially that, some of Chinese private companies grow faster in this area. The huge market of China's water infrastructure is not only a challenge but also a opportunity since the door for various operational mechanism has been opened.

1.5 Themes necessary to be improved for China's water infrastructure

The conversion of the conception on water utilization, increase of R&D activites, and promotion of wastewater treatment may be prior themes. That water is free and enough has long been an axiom to Chinese, which leads to a wasteful pattern of water utilization. With the gradually increased water pollution and water shortage, this conception has been changed greatly these years. More and more people recognize that water is a valuable resource and should be used in a saving way. In order to accelerate this conversion, some measures should be taken including: (1) Increase the responsibility of the water users; (2) Establish a unified management system including water resources, water environmental protection and water & wastewater treatment; (3) Transfer the supply-centered pattern to demand-centered pattern; (4) Induce a more reasonable pricing system and guide the people to save water from the terminal users. Like other disciplines, the status in quo of the water and wastewater treatment technology in China needs great improvement in many aspects. For drinking water treatment, the trace-level chemical contaminants and bioavailable materials are big problem to many of the water purifying plant. Furthermore, because of the industry-transferring from the developed countries to the developing ones, the industrial wastewater in China is very complicated in the components and levels. Many new processes should be developed and applied. In fact, China’s R&D investment has been greatly increased in recent 5 years, especially after some environmental crisis. Several years ago, it is difficult for scientists to obtained grant over million RMB yuan (about $0.15 million). But now, the central and local government had sufficient financial support for R&D activities. Many research institute have

enough funds to replace their obsolete instruments and carried out the ambitious scientific and technical research programs. Compared with drinking water treatment, wastewater treatment is much laggard in China. So there is great space to promote it. The existed wastewater treatment plants are mainly located in big cities. While, many Chinese live in towns and villages, for these areas, the wastewater treatment plants or facilities will be an effective cleaner for their deteriorating environment.

2 Challenging issues for eco efficient water infrastructure

2.1 Efforts on eco efficient water infrastructure

An eco efficient water infrastructure should be environmental friendly, which can satisfy the demand of economic and social development of the people, and meanwhile, does not damage or minimize the damage to the ecosystem. Such a infrastructure should be: (1) have a high efficiency in the removal of contaminants in both drinking and wastewater; (2) consume as low as possible energy; (3) minimize the production of sludge and other secondary pollutants including noise and odour or use alternative techniques to provide their production; (4) Minimize the effect on landscape or even promote the landscape. Because China now is facing serious environmental problems, the perception of sustainable development has been widely propagated all over the country. In the recent years, a new term has been brought forward as “eco civilization”, which suggests China is trying to find a novel developing way different from the western countries and adapting to its own national conditions. Eco efficient water infrastructure can be put into this framework and has no conflict with this idea.

The core of the eco efficient water infrastructure is the water pollution control and the drinking water safety. China has planned to reduce 10% of the total pollutant discharge into water environment in its 11^{th} 5-year economic and social development plan. In order to realize this goal, Chinese central government has initiated the Key Science and Technology Project on Water Pollution Control and Remediation and other related programs with total R&D funds of over 30 billion RMB yuan (about $4.2 billion). These projects are focused on the water environment improvement, reduction of the pollutant discharge and the guarantee of drinking water safety. The projects will be conjunct with other national key pollution control engineering and the

watershed planning, and make the local governments as the primary responsible agencies, utilize the human resources of the academic institutes, universities and companies all over the country. This project included all the typical polluted water bodies including rivers, reservoirs, lakes and non-point pollution. Through the implementation of these projects, China's R&D ability in water pollution control and water treatment should be greatly improved. Many new techniques matching China's conditions should come out and provide the solution plans for an eco efficient water infrastructure.

The above efforts are mainly focused on the civil or municipal engineering aspects. While, some efforts have been done directly on the protection of the water source reserves. For example, Sanjiangyuan area contains the headstreams of Huang River and Yangtze River, is very important for the water environment quality and drinking water safety of the downstream areas. From 2000 to now, about 1.17 million hektares of natural forest, and 2.73 million hektares of grass lands in this area have been protected and remediated, respectively. More than 0.54 million hektares of soil-losing lands have been treated, 1.66 million hektares of land with ecological problems had been restored. These measures has reduced 10% of the total sand into Huang River.

In many Chinese cities, the urban design and planning are emphasizing the ecological based design or planning. Under this idea, the development of water infrastructure, along with other urban infrastructures, is naturally incorporated into the unified urban design and be harmonious with other urban elements. Also, China has implemented its plan on "energy-saving and pollutant-discharge reduction" at both national and local levels, which has very stringent requirement for the local government for different levels. In China's political atmosphere, there is a special term "veto power". It means that if an important mission is not completed, the other completed missions will be neglected. "Energy-saving and pollutant-discharge reduction" is just endowed with this power in recent years.

Also some new policies are made and become the important legislation guard and economic guide for the promotion of eco efficient water infrastructure. For example, the Ministry of Environmental Protection has issued several financial policies together with the central bank, the national bank supervision committee and other ministry in charge of finance on the

green credit and loans, on environmental pollution responsibility insurance, on compensation for the excellent enterprises in pollutant discharge reduction.

2.2 Achievements in promoting eco efficient water infrastructure

On this June 5th, the World Environmental Day, the Chinese Ministry of Environmental Protection has announced with excitation that China has realized the reduction of COD and SO_2 discharge simultaneously for the first time. COD discharge has been reduced by 3.2% compared with the previous year. This is a great achievement for an emerging economics such as China. Most of the COD discharge reduction came from wastewater treatment, e.g., the newly constructed plants and the increase of the performance. In the year of 2007, China's wastewater treatment power has been increased by 12 million tons/day, and the wastewater reclamation power has been increased by 1 million tons/day. Some outdated process in paper-making, alcohol, monosodium glutamate, and other heavily polluting industries has been washed out. The COD discharge reduction from these efforts was 1.22 million tons annually.

2.3 Measures in water infrastructure to address the treat of climate changes

Climate change is a great challenge that every country in the world should directly face to. In fact, as a large and economic-booming country, China has suffered a lot from this problem and has made many efforts on it including agreeing the "Kyoto Protocol". In recent 10 years, China has met several great floods and related climate disasters. A lot of people may still remember the snow and icy disaster happening in Southern China last Winter. Many scientists believe that it should be connected with the global connected change.

The State Council of China issued "the national environmental protection plan for the 11th economic and social development" on 11 Nov. 2007. In this plan, the control of greenhouse gas emission has been brought out as a key point. Though this theme is mostly connected with the energy-saving and policy regulation, something can still be done in water infrastructure. Many Chinese scientists are working on novel techniques to treat water and wastewater consuming as little as possible energy. At present, most of the

water treatment process transfer organic matters into CO_2 and H_2O. Some alternative process, such as microbial fuel cell, can transfer the energy into chemical energy. Another example is biological hydrogen production from wastewater anaerobic treatment. Besides these processes directly on the CO_2 and CH_4 emission control, other new techniques are also takes energy-saving as an important purpose and thus indirectly reduce the greenhouse gas emission.

3 Regional Cooperation for Development of Eco Efficient Water Infrastructure

Since Asia and Pacific Region is very active both in economics and social development, it is important to enhance the international cooperation and share the experience and lessons in water infrastructure development.

(1) Firstly, a frequent and regular workshop on policy and for decision makers should be established. The workshop can held in the related countries in turn and every time a theme should be pointed out based on the temporal situation. The workshop can be at different levels of officials.

(2) Promote the cooperation and interactions between the universities, research institutes and the R&D departments in the companies. The innovation of technology is the fundamental activity for a sustainable water infrastructure. Especially for that in this region, some specific countries may have the same history background, and may have more common sense.

(3) An international committee should be set up to solve the possible urgent water accident / crisis. Besides the senior officials from the water related ministries from the countries in this region, scientists and experts should also be included, and they should meet regularly to prevent and give an early warning on the possible accident / crisis.

(4) Some detailed suggestions, such as an electronic journal on this theme; giving offers for the members in the framework opportunities to visit other country’s water facilities and so on.

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Acknowledgement

The authors have cited many materials from the related web pages. For this report is a brief and informal one, the web pages are not listed here one by one. The authors are grateful to the authors or data providers of the materials.