

# **The Status and Challenges of Water Infrastructure Development in China**

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## **1. Introduction**

As the urbanization and industrialization speed up and the socialist market economy becomes more and more mature in mainland China, the water infrastructure and services become a very important element for the social and economic development by the issues such as water shortage, water pollution, water quality deterioration and water environment improvement requirements. In the past 30 years, there was a great progress with the water infrastructure development in China, but the inadequate financial sources, technology limits and unsatisfied management for the water supply and wastewater treatment are still the major bottleneck factors which restrict the further development of water service in China.

Without question, the China water service industries are facing challenges with water shortage, water quality improvement and water pollution control issues. The annual average water resource per capita is about 2300 cubic meters, only  $\frac{1}{4}$  of global average, and there is also a serious situation with quality deterioration of drinking water sources. In this context, it is all the more essential that water resource protection and environment improvement be put on the important agenda through intensified development and reform of water services to provide strong support to the economic development and social progress of the country.

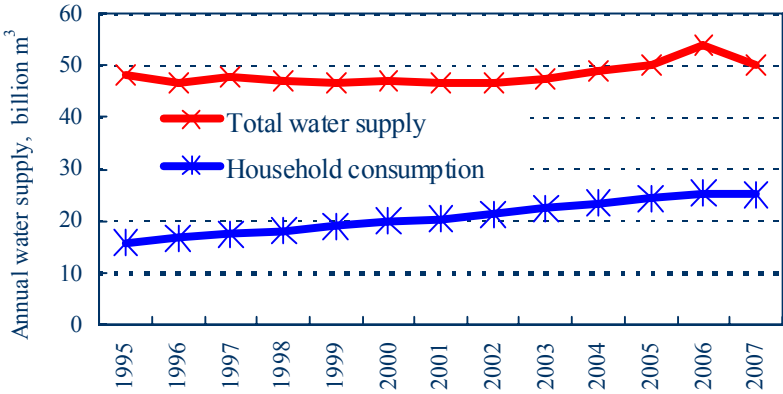
Therefore, the China central and local governments call for establishment of the resource-saving society as one of major strategies. The water conservation management and pollution control have been implemented as a long-term policy for many years, by the

establishing of national and local policies and regulations, the promoting of water conservation with various ways. This paper will focus on some aspects of urban water supply and wastewater treatment development to discuss the status and challenges of water infrastructure development in China.

**2. The development of urban water supply infrastructure**

With the rapid urbanization comes a higher demand for urban water supply. The urbanization transfers annual average of over 15 million people from the countryside to the cities and towns at the present GDP growth rate over 10%. In mainland China, there are 655 cities with urban population of about 350 million in 2007, and the GDP increased to 4.2 times as much as in 1995, most of which came from urban areas.

To realize the goal of “attaining a minimum national urban water supply coverage ratio of 95% by year 2010”, there is a steadily growing demand for the domestic water consumptions, and the total water consumptions start to increase again in recent years. The data from Ministry of Construction has showed that the total water consumptions nearly keep even in the past 10 years while industrial water consumptions still continuously decrease. As shown on Table 1, the total urban water supply volume was 50.2 billion cubic meters in year 2007. It is just a slight increase of 4.3%, when comparing to 48.2 billion cubic meters usage of year 1995, while the population served has a significant increase of 57%, that’s 220 million in 1995 and 350 million in 2007.

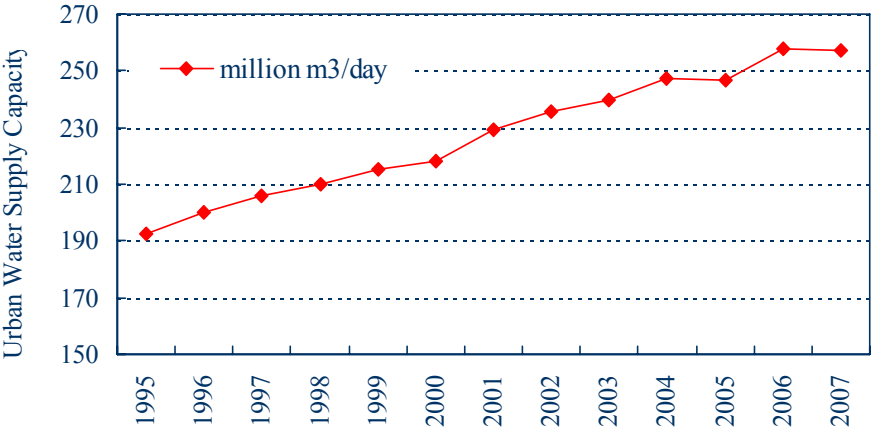


**Table 1 Total annual urban water supply in mainland China**

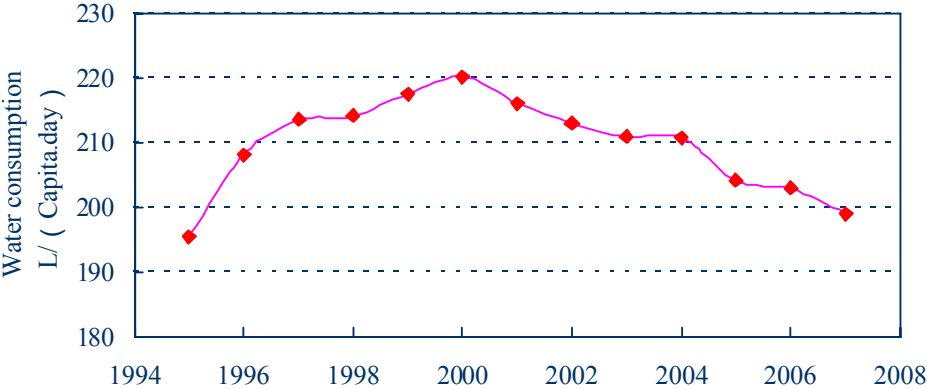
Current total capacity of water purification and supply facilities in mainland China has

reached 250 million cubic meters per day, with a significant growth of 34% from year 1995 to year 2007, as shown on Table 2. The data shows a great improvement of water supply capacity by the water infrastructure development, with the capacity/consumption ratio up to 1.8 on national average and 1.4 for the peak day situation.

From Table 3, it can be seen that the daily household water consumption per capita went up in 1995-2000, and then started to go down, from 220 L/p in 2000 to 199 L/p in 2007. The decrease of 9.6% indicated the water conversation management has made a positive contribution to the improvement of water utilization efficiency in China.



**Table 2 Total urban water supply capacity in mainland China**



**Table 3 the domestic water consumption per capita per day**

There are very serious water leakage problems in many Chinese cities as the leakage percentage of the water supply pipelines can sometimes reach 20%. Furthermore, the pipeline aging and leakage problems have sometimes resulted in inferior water quality

problem at the user end. Therefore, the urban water distribution pipelines urgently need to be improved and rehabilitated so as to save water and guarantee the water quality. For the leakage percentage to be kept under 15% through pipeline improvement and for China to have an edge in terms of leakage control, the public financial inputs will be considerable to which the Central Government will render necessary support.

In the other hand, the government's attentions have started to shift from water quantity demand to the water quality concerns. The traditional techniques and skills need to be updated to improve the overall quality of water supplied. In 2005, the Ministry of Construction enacted a new "Water Quality Standard of Urban Water Supply", which increasing the water quality monitoring parameters from 35 to 103 items in reference to the international standard. In 2006, the newly-revised National "Quality Standard for Drinking Water" was enacted and the number of the required monitoring parameters has increased from 35 to 106 items. Besides, the problems caused by organic pollutants and algae to water sources are aggravating in some regions, and there are more frequent outbreaks of unexpected water pollutions ,posing a serious threat to water safety, especially the industrial effluent discharge. All these challenges call for speedy technological improvement and establishment of water quality safeguard, and emergency response mechanisms also.

In recent years, several modified or newly-development technologies have been employed for urban water quality improvement, including the enhancement of the traditional water purification processes, applications of ozone oxidation and activated carbon adsorption, biological pretreatment of source water, membrane technology applications by micro- and nano-filtration, etc.

There must be a balanced consideration of the urban and rural areas in developing the regional water supply system. Currently, the insecure drinking water can be a very serious problem in some rural areas in China. To improve and secure safe drinking water for these areas, we are giving balanced consideration of the urban and rural needs in developing the regional water supply system and reaching out to the rural area to help improve the quality of drinking water there. At the same time, we are intensifying efforts to find more water source in regions short of water supply and to find solutions to reduce fluorine and remove

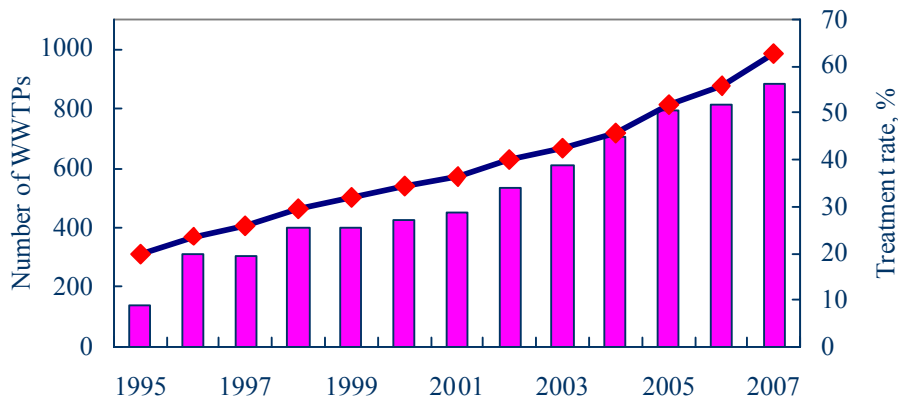
arsenic in drinking water.

China aims to have safe drinking water for its 160 million rural populations by 2010. The Ministry of Construction already set up a Construction Plan for the improvement of urban water supply services, including water quality control, pipeline renovation, rural water supply, water security control, water loss control, etc., and the estimated investment is about 300 billion RMB.

### **3. The development of wastewater treatment infrastructure**

The urban wastewater volume had rapidly increased for more than 10 years in mainland China from 1980's to the middle of 1990's, and then keeps nearly stable since 1995. In 2007, it was 36.1 billion cubic meters of municipal wastewater, with a slight increase of 3.1%, when comparing with year 1995. The proportion of industrial wastewaters decreased gradually while the ratio of domestic wastewater is going up continuously. Meanwhile the construction of wastewater treatment plants significantly speed up since 1998, because of high attention of central and local government and the financial support from national debt fund. Up to 2007, there were 883 municipal wastewater treatment plants in operation, which are 6.3 times of that in 1995. The urban wastewater treatment capacity also keeps increasing rapidly, reaching 71.37 million cubic meters per day in 2007, which is almost 10 times of that in 1995.

Correspondingly, the municipal wastewater volume treated continuously increased and up to 22.7 billion cubic meters in 2007, which is 3.3 times of that in 1995. As the following diagram shown (Table 4), the rate of wastewater treatment increased continuously and up to 63% in 2007, a significant growth, when comparing to year 1995.



**Table 4 the number of WWTPs and urban wastewater treatment rate in China**

The average operation loading rate of the urban wastewater treatment plants national-wide is only about 65% in 2006, and the influent concentration in most plants are lower than design volumes. The design capacity and potential removal ability of the wastewater treatment facility have not been fully utilized, mainly resulting from following aspects:

(1) The wastewater in the service area can not be fully collected and transferred to the treatment plants since delay of construction of the urban wastewater collection networks.

(2) The variations of wastewater volume were not adequately investigated during panning and feasibility study stage, so that the influent flowrate of WWTPs may not be projected in right way and right data output during the design and construction of urban wastewater treatment plants. Another reason can be the over-design capacity of the wastewater treatment plants because of incorrect consideration and/or decision-making.

(3) The water usage went down in the service area of the WWTPs, because of adjustment of city planning, relocation and upgrading of industrial enterprises, influence of water tariff rising, and the wastewater treatment charge to the water consumptions.

(4) The wastewater tariff level and the collecting ratio are still too low in some of cities, and the WWTPs can not afford to pay the full operation costs, without enough financial sources from local government for the operation cost recovery.

#### **4 . The development targets of urban wastewater treatment**

According to *National plan for the construction of urban wastewater treatment and*

*reuse facilities*, by the end of 2010, the national urban wastewater treatment capacity will be higher than 101.6 million cubic meters per day, and the annual wastewater treatment volume will be able to reach 30.2 billion cubic meters. The urban wastewater treatment rate should be above 70% in average national-wide, in which the wastewater treatment rate should be higher than 80% for provincial capital cities on average, 60% in prefecture-level cities on average, 50% for county level cities, and 30% for the county towns. The volume-based operation loading rate of WWTPs should not be lower than 75%. The utilization rate of reclaimed water in water shortage cities in northern China should be above 20% of wastewater treatment volume. The sewage sludge in larger cities should implement the stabilization treatments, and the dewatered sludge from all WWTPs should be properly disposed or utilized, based on location situation and needs. According to this eleventh five-year construction plan, the total investment for the wastewater treatment facility constructions is estimated to be about 330 billion RMB.

The construction of urban wastewater treatment facilities and accessories with high standard will be sped up in coming years. Firstly, construction and reconstruction of the urban wastewater treatment plants will create an additional wastewater treatment capacity of 35 million cubic meters per day and upgrade the existing wastewater treatment capacity of 20 million cubic meters per day. Secondly, improvement on the existing pipeline network and construction of new wastewater facilities will be intensified so that the existing wastewater treatment plants can operate more efficiently with separate rainwater and wastewater systems and that an extra 200,000 kilometers be added to the existing pipeline network. At the same time, the drainage system and the rainwater harvesting facilities will be strengthened to ensure urban safety and rainwater utilization.

During eleventh five-year (2006-2010), all projects inside the tenth five-year plan will be completed to form the treatment capacity of 37 million cubic meters per day. And will start to construct the new wastewater treatment plants inside the eleventh five-year plan with output of additional capacity of 45 million cubic meters per day, so that the new treatment capacity can be put in operation during late eleventh five-year and twelfth five-year period. It will make the wastewater treatment rate of 75% on national average

possible by the end of year 2015.

There will be a higher input in sludge treatment facilities. As most of the urban wastewater treatment plants do not have enough sludge treatment facilities, sludge incurred in wastewater treatment is not properly disposed, creating serious re-pollution threats. With improved urban wastewater treatment capacity in China, there has been increased use of the stable and pollution-free sludge treatment techniques such as dehydration, incineration and landfill. The construction plan also pay attention to the sludge treatment and proper disposal, in which, regarding sludge harmlessness as the principal target for the sludge treatments, and stabilization treatment as the principal way, landfill as the current major disposal way. It is necessary to form about 20000 ton (as dry solid) per day of sludge treatment and disposal capacity by the end of 2010 to avoid the secondary pollution.

Wastewater treatment and recycling have been strongly advocated since 2000. Wastewater recycling as a major solution to urban water shortage was incorporated into the development plan of the urban wastewater treatment plants. The uses of reclaimed water are promoted for industrial application, urban landscaping, public utilities, eco-landscape, public toilets, car wash and other sectors as the goal of wastewater treatment has shifted from attaining discharge standards to reuse standards.

The Construction Plan requires local governments and water industry to promote the utilization of the reclaimed water by incentive policies and financial supports. The northern water shortage cities are required to make use of reclaimed water with more than 20% of municipal wastewater treated by the year 2010, and the planned construction capacity of reclaimed water facilities are about five million cubic meters per day. For the cities in other regions, especially on the coastal areas, should consider and implement the facility construction for the reclaimed water, based on local situation and client's demand, the estimated total construction capacity is about 1.8 million cubic meters per day.

## **5. Stringent effluent discharge standards for municipal WWTPs.**

According to operation data of WWTPs in recent years, most of WWTPs can steadily meet the effluent discharge standard of COD, BOD<sub>5</sub> and SS, but there is a widely-existed

difficulty that nitrogen and phosphorus can not meet the stringent standards, or can not meet the standards in both. On the other hand, the present effluent discharge standards did not consider the regional difference, the scale of WWTPs and the influent concentration difference, and then impacts the proper design and operation to compliance with the effluent limits of WWTPs in some degree. With the continuous development and applications of municipal wastewater treatment technologies, the effluent discharge standards of WWTPs also made its evolution process correspondingly. The current discharge standards are shown on Table 1, and the future discharge standards will be more stringent.

**Table 1 the current effluent discharge limits for WWTPs (unit: mg/L)**

Discharge standards	BOD <sub>5</sub>	SS	COD	NH <sub>3</sub> -N	TP	TN
Second class	30	30	100	25	3.0	
First Class B	20	20	60	8	1.0	20
First Class A	10	10	50	5	0.5	15
future	5	5	40	1	0.1	5

As for application of municipal wastewater treatment technologies, most of the wastewater treatment plants applied conventional activated sludge process (or only primary treatment) before 1980's, and started to push the secondary biological treatment process in the middle of 1980's. In the middle and late 1980's China started to study and apply biological phosphorus and nitrogen removal technologies, and then municipal wastewater treatment entered a rapid development period in 1990's. Some of biological phosphorus and nitrogen removing technologies such as modified A/A/O process were widely practiced in the design and operation of WWTPs. The reactor configuration and choice of aeration/mixing also showed a diversity selection in design of wastewater treatment plants.

After entering the new century, as a legal substitute water source, the reclaimed water begins to obtain wider and wider application in many water use areas. At the same time, the removal of special pollutants and the trace contaminants having impacted on environment in wastewater and WWTP's effluent become a public concern attracting a great deal of

attentions. With the higher discharge standard and the demand of water environment quality improvement, the application of the membrane technologies significantly increases. However, the phosphorus and nitrogen removal technologies with high operation performance, low effluent concentration and low operation costs are still the focus of research and development in municipal wastewater treatment field.

The national *Discharge standard of pollutants for municipal wastewater treatment plant* (GB18918-2002) issued in 2002, set up the stringent effluent limits for the WWTPs. Besides the second class and third class discharge limits, it adds a more stringent limits of first Class A ( $BOD_5 \leq 10$  mg/L ,  $SS \leq 10$  mg/L ,  $COD \leq 50$  mg/L , phosphate  $\leq 0.5$  mg/L , ammonia nitrogen  $\leq 5$  mg/L), and first Class B ( $BOD_5 \leq 20$  mg/L ,  $SS \leq 20$  mg/L ,  $COD \leq 60$  mg/L , phosphate  $\leq 1.0$  mg/L , ammonia nitrogen  $\leq 8$  mg/L).

In 2006, the State Environmental Protection Administration issued the Notice No. 21 to approve the revised version of the Discharge standard of pollutants for municipal wastewater treatment plant (GB18918-2002), further requests that, the effluent of urban wastewater treatment plants discharging into the state and provincial defined key watersheds and the closed or semi-closed water bodies such as lakes and reservoirs, should meet the first class A standard. When discharging into GB3838 Class III surface waters (except for conservation areas of drinking water and swimming area) and GB3097 Class II of sea waters, the effluent should meet the first class B standard.

## **6. Technical policy for municipal wastewater reclamation and reuse**

On April 25, 2006, the Ministry of Construction and Ministry of Science and Technology jointly issued the *Technical Policy for the Wastewater Reclamation and Reuse*, to promote the technology development and application of wastewater reclamation and reuse, making clear the development direction and technical principle, guiding each region to develop the water reuse plan, facility construction, operation and management, technical research and application, accelerating the sustainable utilization and protection of urban water resources, and promoting the establishment of water-saving city positively.

The Technical Policy is mainly composed of eight parts which reflects different segments of the content in the process of the use of reclaimed water as follows: general principles, target and principle, water reuse planning, facilities construction, operation and supervision, safety guarantee, technology innovation, and safeguard measures.

From the point of view of urban water beneficial recycle, the water reuse should include water volume utilization and pollution load reduction in both, and these two parts can be supplement each other and indispensable, therefore the policy puts forward such guiding principle as the water resources shortage cities should positively implement the wastewater reclamation and reuse projects whose main objective is to increase the water quantity available, while those cities lack of water resulting from water quality pollution should implement the water reclamation and reuse projects with main objective of water pollution reduction and improvement of urban water quality or functions.

The development target set by the Policy is that the direct utilization of reclaimed water should achieve 10% ~ 15% of urban wastewater volume in northern water shortage cities and achieve 5% ~ 10% in southern water shortage cities by 2010; achieve 20% ~ 25% of urban wastewater volume in northern water shortage cities and 10% ~ 15% in southern water shortage cities by 2015. The design capacity of urban wastewater reclamation facilities for direct reuse will reach 6.8 million cubic meters per day by 2010, and the estimated additional capital input for water reuse projects will be up to one billion RMB.

For the choice of the reclaimed water uses, we must consider the economic efficiency and social benefits in both, and should preferentially select such water uses as large volume usage, relatively lower water quality requirements, technically feasible, low comprehensive costs, and with remarkable economic and social benefits. The uses for urban landscape and gardening can usually be the first choice. As to industrial uses and other urban miscellaneous uses, the user's water consumption flow is relatively constant and is also affordable for the charge of reclaimed water services, so meet the large-scale application.

As to reclaimed water entering households, the majorities don't agree with the suggestions or hold cautious attitudes. So the Policy put forwards that the urban landscape

and environment water uses should give a priority to reclaimed water, industrial and other urban miscellaneous water uses should utilize the reclaimed water positively. As to the new residential quarters or public buildings which have a certain scale water usage and beyond the centralized reclaimed water supply system, advocate comprehensive planning of district reclaimed water system and apply the grey water reuse system reasonably. The agriculture should make use of secondary effluent of WWTPs as much as possible.

The reclaimed water system is divided into centralized system, onsite or district system and building-based grey water reuse system. The main restrictive factor for centralized system is the high investment of the distribution pipeline system. The Beijing city is a typical example, in which the reclaimed water contribution system still can't be met the actual demand even though the proportion of pipe network investment to the total investment already quite higher. The centralized system is suitable for the water using region close to the wastewater treatment plant, and group of different customers with similar water quality requirements. The centralized system is also suitable for industrial application, landscaping, river supplement and environmental uses with larger usage. For the water using region far away from the wastewater treatment plant or not covered by sewerage, the onsite (district) system and grey water reuse system can be a practical choice.

## **8. Reform of water tariff and wastewater treatment charge**

Great progress has been achieved in the water price reform in last 10 years. The urban water supply is no longer considered a social welfare but a commodity when it comes to pricing and the sector manages to make the ends meet. Waste water treatment is now a charged service in most places. The next objective in the water price reform is to establish an all-cost pricing system and to strictly control the cost of the monopoly enterprises.◦

More water sources will be charged and at a higher rate so as to promote water saving practices. Those who reside in areas covered by the public water supply system but use self-drawn underground water will have to pay a price higher than the tap water. The urban water supply price will be modified continuously. The price charged must be able to meet

not only the needs of normal business operation but also certain profits as well as the cost to improve the water quality, pipelines and restructuring of the measurement system. At the same time, the price of the recycled water will be readjusted to promote its utilization to cover the cost and leave room of reasonable amount of profit.

The price for wastewater treatment entities need to be readjusted to an extent that allows meager profits. Wastewater treatments have been charged across the nation at basic rate of 0.8 RMB per cubic meters in principle. This aims to keep the wastewater treatment plants under smooth operation with some profit. In one or two year's time, users of self-drawn underground water will be charged a water supply and waste water treatment fee. The operation costs of these enterprises will be under strict supervision to safeguard public interests with the help of a performance evaluation system, cost verification system and the intensified public hearing system.

At present the urban wastewater treatment development mechanism is basically formed in China. The reform of urban wastewater treatment mechanism will be further implemented continuously in the coming future, especially the establishment of incentive policy for urban wastewater treatment. There are five aspects as follows:

- (a) Adjusting the government assessment criteria from wastewater treatment rate to total pollutants eliminated or removed;
- (b) Changing the channel of public financial input from project construction subsidization to environmental output allowance;
- (c) Strengthening the wastewater charge system and changing the enterprises default into payment in advance;
- (d) Promoting the specialization and socialization of wastewater treatment services to make local government fully taking role as supervisor for the local pollution control practices;
- (e) Improving the support policy to the wastewater industry by enhancing the social support.

The current urban wastewater charge includes three components: reasonable costs for wastewater treatment, fair profit and tax. The State Development and Reform Commission

and Ministry of Construction required that the urban wastewater charge level should not be lower than 0.8 RMB per cubic meters. The request have already been implemented in many cities, such as 1.30-1.60 RMB per cubic meters in southern Jiangsu province, 1.00-1.20 RMB per cubic meters in central and northern Jiangsu province, 0.9 RMB per cubic meters in Beijing and Shanghai, over 0.9 RMB per cubic meters in Zhejiang province.

## **9. Supervision and planning for the development of urban water services**

With the “Recommendations on Accelerating the Market-Oriented Operation of the Public Utility Sector” Management of the Franchised Operation of the Public Utility Sector” enacted in December the same year, and “Recommendations on Strengthening Supervision of the Public Utility Sector”, a policy framework for the reform of the urban water service sector has come into being. The reform priorities include: identification of the supervision functions of the governments and the establishment of the legal basis for effective supervision of the investment, operation of the water service entities.

Strict market access and withdrawal rules are need to be established. Public bidding must be used to identify the best stakeholder in accordance with the market access conditions and procedures. A whole set of rules for market withdrawal must be worked out. Upon the expiration of the operation term, a new round of bidding shall be started. The intensified quality and service quality supervision system must be established to have on-spot supervision on the product sand services provided by the enterprises. Incentives need to be used to cut down cost and raise efficiency, by the better cost and price monitoring and regulation. The public participation mechanism and efforts will improve the transparency of information disclosure with the establishment of water quality newsletter and price public hearing as well as the reliance on social and public supervision.

In recent years, the urban planners and managers have put water environment improvement into agenda, such as urban water system management, water ecological rehabilitation, river and lake sludge dredging, construction of landscape waters, protection of urban wetlands. China is witnessing intensifying water environment rehabilitation in large cities and human settlement improvement everywhere at present.

It is estimated that China is going to invest more than a trillion RMB in urban water service in the five to ten years to come: approximately 270 billion RMB for protection of water sources and security of water supply; 330 billion RMB for wastewater treatment and water reuse; 250 billion RMB for constructing of long-distance water transfer facilities; 150 billion RMB for repairing and restoring of the water environment. Such a large market demand offer enormous market potentials to domestic and overseas water service entities.

In addition, the National Wastewater Treatment Information System has been established and successfully operated for several years. The system can provide various statistics analyses for national, provincial, city level in different details. The system also include the detail information of individual wastewater treatment plant, such as influent quantity and quality data, main facilities and treatment processes, investment and operation costs, energy and chemical consumptions, pollutant removal, and other data. The detail data of the system upgrade monthly by wastewater treatment operators and city supervision department through WEB-based technology.