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An Investigation Into Wastewater Treatment in the Three Gorges Reservoir Basin

A Probe International Study

By

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Introduction

The Three Gorges Reservoir basin area is 490,000 square kilometres. The water quality of this basin directly affects the safety of all those who use and depend on it. Though the Chongqing Municipal Government[1] has invested in more than 40 new large and medium-sized wastewater treatment plants in important cities in the Three Gorges Reservoir Region along the Yangtze River, the decreased flow rate of water caused by the construction of the Three Gorges Dam has robbed the river of its ability to self-purify. This decline in the rate of flow also means that pollutants carried by tributaries cannot be diluted or flushed away quickly by the Yangtze River, causing serious eutrophication in some tributaries.

The Three Gorges Dam has robbed the Yangtze River of its ability to self purify.

In 2010, Metropolitan Chongqing[2], the old city within the Municipality of Chongqing, dumped 451,800,000 tonnes of industrial wastewater and 829,330,000 tonnes of domestic wastewater into the Yangtze. The chemical oxygen demand (COD) of this wastewater was 234,500 tonnes.[3] The sewage treatment capacity of Metropolitan Chongqing is an important factor affecting the water quality and ecology of the Three Gorges Reservoir.

In addition, downstream of Metropolitan Chongqing, hundreds of towns and chemical complexes are dumping industrial and domestic waste into the Yangtze, adding to the grave threat to water quality in the 600 km long reservoir area.

This paper reviews wastewater production and treatment in the Three Gorges Reservoir Region with a special focus on Metropolitan Chongqing, which sits at the head of the reservoir created by the Three Gorges Dam. It also recommends institutional and regulatory reforms to reduce pollution, expand wastewater treatment, and protect water quality for all riparians living downstream of Metropolitan Chongqing,

Basic Information on Metropolitan Chongqing

Area and Population

Located at the confluence of the Yangtze River and the Jialing River, Metropolitan Chongqing lies at the tail of the Three Gorges Reservoir Region. Spanning an area of about 5,500 square kilometres, Metropolitan Chongqing is home to a population of over 7.4 million (excluding its floating population). Metropolitan Chongqing consists of nine districts: Yuzhong, Dadukou, Jiangbei, Shapingba, Jiulongpo, Nan'an, Beibei, Yubei, and Ba'nan (see Table 1).

Table 1: Districts of Metropolitan Chongqing

District	Area (km^2)	Population (in thousands)
Yuzhong	22.56	630
Dadukou	103	300
Jiangbei	213	738
Shapingba	396.2	1,000
Jiulongpo	432	1,080
Nan'an	265	759
Beibei	755	684
Yubei	1,452	1,340
Ba'nan	1825	918
Total	5463.76	7,449

Industry Overview

The economic and technological development zones in Metropolitan Chongqing include:[4]

1) Chongqing Chemical Industrial Park
2) Chongqing Economic & Technological Development Zone
3) Chongqing Hi-Tech Industry Development Zone
4) Chongqing New North Zone (CNNZ)
5) Chongqing Export Processing Zone
6) Jianqiao Industrial Park

More than 3,000 km^3 of wastewater is produced daily in Metropolitan Chongqing, while the treatment plants in the region are only designed to treat 1,416.4 km^3 of wastewater per day.

Wastewater Treatment in Metropolitan Chongqing

Information Sources[5]

We obtained sewage treatment information on Metropolitan Chongqing using the following means:

1) Interviews with government officials and administrative staff at sewage treatment plants;
2) Visits to government departments such as the environmental protection department, water resources department, water authority, and municipal administrations;
3) Field trips to sites, and interviews with residents living near sewage treatment plants;
4) Searches of archived documents.

The information collected includes the locations of sewage treatment plants in the nine districts of Metropolitan Chongqing; the construction status of future and expanding sewage treatment plants; the capacity, process, and efficiency of sewage treatment; the wastewater disposal and the treatment of sludge from sewage treatment plants; the sewage drain infrastructure; the rate of sewage collection; and the role of the sewage treatment administration department.

We experienced several obstacles in collecting this data, namely, securing permission to enter sewage treatment plants, as non-staff are prohibited from entering these plants. Once granted access, we faced problems accessing data, taking photos in plants, and organizing transportation to sewage treatment plants in remote areas.

Basic Information

More than 3,000 km^3 of wastewater is produced daily in Metropolitan Chongqing, half of which comes from domestic sources, while the other half comes from industrial sources. The industrial wastewater is pre-treated before being delivered to the wastewater treatment plants. There are 19 large and medium-sized wastewater treatment plants in the nine districts we studied. Together, they are designed to treat 1,416.4 km^3 of wastewater per day.

The actual volume treated daily of 1,609 km^3 represents about 54% of the total wastewater produced in Metropolitan Chongqing each day. Meanwhile, up to a hundred small treatment plants run by villages, towns, streets, and small and medium-sized industrial park zones treat an additional 510 km^3 of wastewater on a daily basis, accounting for 17% of the total wastewater produced in Metropolitan Chongqing. Thus, of the 3,000 km^3 of wastewater produced in Metropolitan Chongqing every day, only 2,119 km^3, 71% of the average daily wastewater volume produced, is treated.

With the recent economic growth and urban expansion of the city, the population in Metropolitan Chongqing is expected to increase to more than ten million by 2020. As a result, the amount of wastewater is also likely to increase. To manage the city's projected needs, the Chongqing municipal government is planning to expand existing wastewater treatment plants and build new ones. Currently, 14 new wastewater treatment plants are either under construction, being expanded upon, or are in the planning stages, which will increase the daily treatment capacity by 830 km^3. If completed as planned, the total designed daily wastewater treatment capacity will be 2,246.4 km^3 (830 km^3 + 1,416.4 km^3 = 2,246.4 km^3). If those 33 plants can operate at 13.5% over capacity, as the existing 19 treatment plants have been doing, the total daily treatment capacity will total 2,549.4 km^3 (2,246.4 km^3 + 303 km^3). Adding the 510 km^3 treated by the hundred small treatment plants run by villages, towns, streets, and small and medium-sized industrial park zones mentioned above, the total daily wastewater treatment capacity will be 3,059.4 km^3. This level of wastewater treatment meets the current level of wastewater production of 3,000 km^3, but does not allow for the inevitable increase in wastewater that will come from the population and economic growth expected by 2020. It also assumes that the plants can continue to operate at 13.5% over capacity *and* continue to meet water quality standards. Meeting these conditions is possible, but challenging. In Metropolitan Chongqing, treatment plants have been designed to meet high standards, and wastewater treated has generally met the Grade 1 water quality standard[6] with COD below 60 mg/L (milligrams per litre). Presently, all of the 19 large and medium-sized treatment plants currently operating are treating water to a level of COD below 60 mg/L, with the majority of the plants investigated by this study meeting COD levels between 30-60 mg/L. Whether or not they will continue to meet the COD standard of 60mg/L and continue to run the plants at 13.5% over capacity will depend on management standards.

Only 71% of the wastewater of the 3,000 km^3 of wastewater produced in Metropolitan Chongqing every day is treated.

Whether or not treatment plants will meet COD standards in the future will depend on management standards, which are contingent on incentives, penalties, and accountability to the Chinese public.

Management standards, in turn, depend on incentives and penalties for failing to meet standards; transparency of operations to the press and the public; and the accountability of the wastewater treatment enterprises, their regulators, and lawmakers to the Chinese public.

Sewage Treatment Plants

Wastewater treatment plants are situated according to characteristics of geography and topography, population density in urban areas, and the planning of industrial zones. The sewage treatment plants in Metropolitan Chongqing are divided into four categories, depending on their financing, ownership, and purpose. These categories include: large and medium-sized sewage treatment plants financed by the central government for point-source[7] pollution treatment, medium and small-sized sewage treatment plants financed by local governments, sewage treatment sites built in factories and industrial zones, and sewage treatment sites built in small towns in the suburbs.

The construction funds for wastewater treatment plants in Metropolitan Chongqing come from three major sources: the state, World Bank loans (which were used to build wastewater treatment plants such as Jiguanshi and Tangjiatuo), and district and municipal governments.[8]

1. *Large and medium-sized sewage treatment plants financed by the central government*

These plants are run by state sewerage companies – such as the Chongqing Water Group Co. Ltd. and Chongqing Water Resources Investment Group Co. Ltd.– and are built and financed by the government. Details on the services of these two companies are provided in Table 2. The standard of sewage treatment at these plants is higher and better regulated than at wastewater treatment plants financed by local governments. There are 11 such treatment plants, including the Jiguanshi Sewage Treatment Plant (Nan'an District) with a daily treatment capacity of 600 tonnes, the Tangjiatuo Sewage Treatment Plant (Jiangbei District) with a daily treatment capacity of 300 tonnes, and the Tuzhu Sewage Treatment Plant (Shapingba District) with a daily treatment capacity of 50 tonnes.[9] These state-run plants are subject to very specific, standardized operational requirements and regulated management, meaning that they have high rates of compliance to the regulated treatment standards.

The Chongqing Downtown Drain Company, Three Gorges Water Company and Haoyang Water Company (under the Chongqing Water Resources Investment Group Co. Ltd.), and Chongqing Water Group Co. Ltd. are the companies that operate these plants. The eleven treatment plants have a total daily treatment capacity of 1,285 tonnes, accounting for two-thirds of the point-source pollution treatment in Metropolitan Chongqing.[10]

Table 2: Treatment Plants Managed by Chongqing Water Group Co. Ltd. and Chongqing Water Resources Investment Group Co. Ltd.

Company	CHONGQING WATER GROUP CO. LTD.	CHONGQING WATER RESOURCES INVESTMENT GROUP CO. LTD.
Service Area Covered	***Districts:*** Yuzhong, Jiangbei, Shapingba, Jiulongpo, Dadukou, Nan'an, Ba'nan, Yubei, Beibei, Wanzhou, Peiling, Changshou, and Wansheng	***Districts:*** Shuangqiao, Qianjiang Longbaopian (sub-district in Wanzhou district), Chayuan (sub-district in Nan'an district), and the western side of the Zhongliang Mountain (between Jiulongpo and Shapingba Districts)
	Counties: Zhong, Wulong, Wushan, Dianjiang, Tongnan, Pengshui, and Liangping	***Counties:*** Rongchang, Bishan, Tongliang, Dazu, Chengkou, Xiushan, Youyang, Fengjie, Shizhu, Kaixian, Yunyang, Fengdu, Wuxi, and Qijiang
	Cities: Jiangjin City, Nangchuan City, and Hechuan City	***Cities:*** Yongchuan City

Note: Sewage treatment projects in Yongzhou City, Bishan City, Tongliang City, Dazu City, Chengkou City, Youyang County, and Qijiang County will be transferred to Chongqing Water Resources Investment Group Co. Ltd. once construction of new plants and the expansion of existing plants is completed.

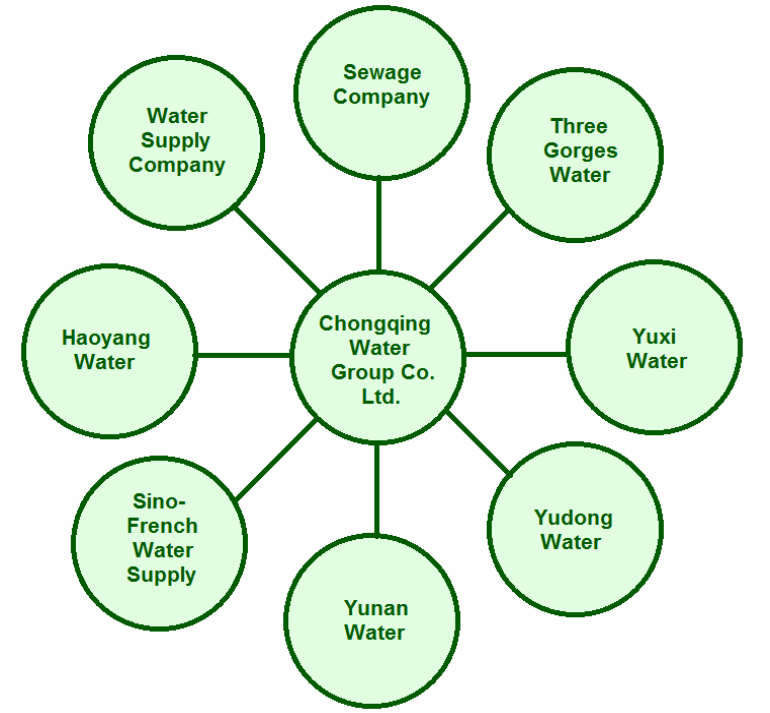
Chongqing Water Group Co. Ltd. treats their wastewater according to state environmental protection standards, contributing to improved water quality on the Yangtze River upstream, and in the Three Gorges Reservoir.

- **Chongqing Water Group Co. Ltd.**

Chongqing Water Group Co. Ltd. (see Figure 1 for information on its subsidiaries) collects domestic sewage, industrial and commercial wastewater, rainwater, and other wastewater from municipal sewage pipe networks, and treats their wastewater according to state environmental protection standards, contributing to improved water quality on the Yangtze River upstream, and in the Three Gorges Reservoir. After treatment, the wastewater is dumped directly into the Yangtze. The Group's area of service includes the nine districts in Metropolitan Chongqing, as well as many districts outside of Metropolitan Chongqing. Within the larger Municipality of Chongqing, they service Wanzhou District, Fuling District, Changshou District, Wansheng District, Nanchuang District, Zhong County, Wulong County, Wushan County, Dianjiang County, Hechuan City, Jiangjin City, Tongnan County, Pengshui County, Liangping County, Yongchuan City, Tongliang County, Dazu County, Chengkou County, Fengjie County, Wuxi County, Kaixian County, Yunyang County, Fengdu County, Shizhu County. The Group's area of coverage does not include the region covered by the Sino French Tangjiatuo Wastewater Treatment Co., Ltd., which is authorized by the Municipality of Chongqing to service a population of approximately 1 million people covering a 90km^2 area.[11]

By December 31, 2009, the company serviced 8.9 million urban residents in an area covering 755.2 km^2, representing 72% of the market share for Metropolitan Chongqing's wastewater treatment. The company monopolizes the wastewater treatment business with the permission of the Municipality of Chongqing. Thus, it receives payment from the government of Chongqing Municipality under the condition that it provides sufficient, continuous, and standardized wastewater treatment service.[12]

Figure 1: Chongqing Water Group. Co. Ltd. and its Subsidiaries



- **Chongqing Water Resources Investment Group Co. Ltd.**

The Chongqing Water Resources Investment Group Co. Ltd. was established on November 28, 2003, with the approval of the municipal government. It was the first provincial-level water resources investment company in China.

The company is responsible for, among other things, the operation and management of state-owned water resource assets, water supply, and wastewater treatment services in cities and towns. It is also responsible for the investment and operation of wastewater treatment projects, river management, water and soil conservation projects, as well as for the development of renewable resources such as hydropower and wind power. Currently, the company has 45 subsidiary companies, with more than 4,500 employees, and project offices in 34 districts and counties in Chongqing Municipality.[13]

Smaller wastewater treatment plants use wetland biotechnology, a technique well worth promoting in Chongqing because these facilities are small in size, have low capital requirements, low operating costs, and achieve high rates of treatment efficiency.

The company constructed 16 water treatment plants in Kaixian, Tongliang, and Qijiang counties, providing an additional 700 million tonnes of water which benefit 4.5 million people in more than 20 districts and counties by improving the quality and accessibility of potable water. With the construction and operation of drainage projects in 11 districts and counties, the company added an extra daily wastewater treatment capacity of 200,000 tonnes, which plays an important role in improving the urban living environment and promoting the "healthy Chongqing" and "livable Chongqing" campaigns. According to its own estimate, the company will accrue total assets of 70 billion RMB, a gross income of 3 billion RMB, and a net profit of 1.07 billion RMB, by 2015.[14]

2. *Medium and small-sized wastewater treatment plants financed by local governments*

Compared to the kinds of plants described above, medium and small-sized wastewater treatment plants tend to be of poorer quality in terms of construction, management, and operation. These plants are located mainly in the districts of Shapingba, Jiulongpo, and Yubei, and are responsible for one-third of the total treated wastewater in Metropolitan Chongqing.

3. *Wastewater treatment facilities operated by enterprises within industrial zones*

There are eight treatment facilities that are operated by enterprises within industrial zones. Of the eight treatment plants, those plants constructed and operated by state-owned enterprises are running well, while those plants constructed and operated by medium and small-sized factories and industrial zones are not. The latter routinely discharge industrial wastewater without any treatment at all, resulting in incidents of wastewater contamination.

4. *Wastewater treatment facilities built by small towns in suburban areas*

There are more than 30 wastewater treatment facilities built by small towns in suburban areas, with a combined daily treatment capacity of over 100 tonnes. They mainly use wetland biotechnology to treat the wastewater, a technique well worth promoting in Chongqing, because these facilities are small in size,[15] have low capital requirements and low operating costs, and achieve high treatment efficiencies.

Figure 2: The Distribution of Wastewater Treatment Plants in Metropolitan Chongqing

In many districts [of Metropolitan Chongqing], low-quality wastewater drainage networks and poor maintenance has resulted in broken pipes and even sewage leaks, leading to contamination and a further lowering of the wastewater collection rate.

Current Challenges to Wastewater Treatment in Metropolitan Chongqing

Geographical challenges to Metropolitan Chongqing's wastewater treatment infrastructure

Chongqing's mountainous terrain and numerous rivers and lakes make it particularly difficult for Metropolitan Chongqing to build centralized wastewater collection systems. In addition, construction of water treatment facilities in different parts of the region has been staggered, leading to infrastructure inconsistencies. Thus, in the context of the total treatment needs of the large and populous Metropolitan Chongqing, most wastewater treatment plants are fairly small. The daily treatment capacity of these plants ranges from 20,000 to 100,000 tonnes, with very few plants having a daily treatment capacity over 100,000 tonnes.

Low collection rates of wastewater and slow construction of new water treatment plants in Metropolitan Chongqing

Due to Metropolitan Chongqing's mountainous terrain, the collection rate of wastewater is estimated to be as low as 79%. In many districts, low-quality wastewater drainage networks and poor maintenance has resulted in broken pipes and even sewage leaks, leading to contamination and a further lowering of the overall collection rate of wastewater.

In terms of the construction of new wastewater treatment facilities, Jiulongpo District has completed 41.7% of the planned projects, the highest percentage of any of the nine districts. The construction of new sewage treatment facilities is slower in Yuzhong District, Dadukou District, and new development zones in the northern area, such as the Chongqing New North Zone.

Meanwhile, wastewater treatment expansion projects are being carried out more slowly than planned, including the third phase of the Tangjiatuo wastewater treatment plant in Jiangbei District, the Caijia wastewater treatment plant in Beibei District, and the Xipeng wastewater treatment plant in Jiulongpo District.

Moreover, wastewater treatment projects in 19 townships in the districts such as Jiulongpo, Beibei, and Ba'nan have not even started yet.

Low collection rate of wastewater in the outskirts of downtown and urban-rural fringe areas, and shortage of finances for infrastructure and operating expenses

In industrial zones on the outskirts of downtown areas and in residential zones in urban-rural fringe areas, fewer wastewater treatment projects have been constructed because of a lack of funding – local governments are strapped for cash – and sewage treatment plants are expensive. Wastewater is dumped directly into small streams as a result.

Difficulties Paying for Wastewater Treatment

Municipal wastewater treatment authorities have found it difficult to cover the high costs of water treatment simply through wastewater treatment fees collected from residents. Chongqing has developed rapidly since it became a municipality directly under the central government fifteen years ago, but the city has had difficulty reforming and modernizing its social services and physical infrastructure fast enough to keep up with the growth of the city. As a result, high unemployment rates and low social security payments (payments are as low as 320 RMB per month in Chongqing) make it difficult for some citizens to afford the tap water fee, which has increased from about 1 RMB/tonne to more than 3 RMB/tonne.[16]

Chongqing has developed rapidly since it became a municipality fifteen years ago, but the city has had difficulty reforming its social services and physical infrastructure fast enough to keep up with the growth of the city... high unemployment rates and low social security payments make it difficult for some citizens to afford the tap water fee.

Of the 3 RMB/tonne tap water fee that urban citizens currently pay, 1.1 RMB/ per tonne is for wastewater treatment. Many people still feel that this rate is difficult to pay as most citizens earn a monthly income of less than 2,500 RMB, and are faced with relatively high prices for all goods and services.

Therefore, wastewater treatment plants have difficulty making the necessary investments to upgrade their facilities, let alone repaying the debts incurred from investing in their initial fixed capital. The operation and maintenance costs are even higher if the investment and operation costs of sludge treatment are taken into account. If the price of wastewater treatment was based on its full cost, urban residents would have to pay two to four times as much as they pay now, which is unfeasible.

Currently, the widely used wastewater treatment process includes conventional activated sludge processes, oxidation ditch, AB, A/O, A2/O and the newly developed SBR[17] process in Metropolitan

Chongqing.[18] These treatment methods require expensive infrastructure and incur high operational costs, which means there are fewer funds available for the construction of more wastewater treatment facilities and for routine maintenance expenses of the existing infrastructure in Chongqing.

Lack of knowledge, experience, measures, and funds concerning pollution control has led to unabated pollution and inefficiencies in wastewater management

...the government — both at the municipal and local level — lacks the administrative means and regulatory clout to properly enforce the [wastewater treatment] standards.

First, the key to improving water quality in the Three Gorges Reservoir Region lies in stopping the pollution at its source.

Second, most wastewater treatment plants in China are financed by the central government, but the responsibility to run them and maintain them is handed over to local governments. These local governments lack the financial means and state-of-the-art technology to ensure high-quality water and sound water ecology in the Three Gorges Reservoir Region on the Yangtze River. To put this into perspective, in 2009, the revenue of Chongqing Municipality was only a quarter of Shanghai's.

The wastewater needs of Metropolitan Chongqing are growing at a faster pace than its wastewater treatment capabilities

Due to rapid economic development in Chongqing, both environmental protection planning and supporting facilities in some industrial zones and new developing zones are not up to code. The quality of the wastewater collection pipe network is also quite poor, resulting in pollution accidents such as broken pipes and wastewater leakages.

The growth of medium and small-scale private enterprises in Chongqing is rapid and most are not properly disposing of their wastewater. Additionally, the government — both at the municipal and local level — lacks the administrative means and regulatory clout to properly enforce the standards.

The total number of Metropolitan Chongqing's permanent residents, coupled with its floating population is almost ten million people, who altogether produce more than 200,000 tonnes of feces and wastewater a day. Before the 1990s, sewage for the most part was used to fertilize crops in rural areas, but now all of it is dumped directly into rivers along with wastewater, resulting in a level of E. coli levels exceeding the normal standard in the Yangtze and Jialing Rivers.

Wastewater Treatment in the Three Gorges Reservoir Region (Below Metropolitan Chongqing)

Wastewater treatment plants have been built in each of the districts and counties along the Three Gorges Reservoir below Metropolitan Chongqing. They are owned and operated by four companies: the Yudong, Yuxi, Sanxia and Urban Chongqing Drainage Companies respectively. Wastewater treatment plants were also built in each county seat along the Three Gorges Reservoir, with a designed treatment capacity of less than 50,000 tonnes daily. They are constantly faced with a shortage of operation funds. There are hundreds of towns with populations of more than 10,000 in the reservoir area. They produce millions of tonnes of sewage daily, most of which is dumped directly into rivers, making them the main sources of wastewater pollution in the Three Gorges Reservoir Region on the Yangtze River.

Currently, there are three big chemical complexes in the Chongqing section of the reservoir area – Changshou Natural Gas Chemical Plant, Fuling Pharmaceutical and Agricultural Chemical Plant, and Wanzhou Salt Chemical Plant – all of which are big polluters. Currently, only the Changshou Chemical Industrial Zone has a wastewater treatment plant, which has a daily treatment capacity of 40,000 tonnes.

The next most important source of pollution in the Municipality of Chongqing section of the reservoir area is agricultural pollution. It flows into the main channel of the Yangtze River along with surface water and has caused eutrophication in the reservoir, which adversely affects water quality.

Finally, both industrial wastewater and domestic sewage flow into the Three Gorges Reservoir from provinces such as Yunan, Guizhou, and Sichuan, upstream of Metropolitan Chongqing, and pose yet another serious threat to the water quality in the reservoir area. These include, most notably, the industrial pollution from phosphorus chemical plants in Mianzhu, petro-chemical plants in Chengdu, chromium salt chemical plants in Anxian County, and medical chemical plants in Leshan, all located in Sichuan Province. Natural gas chemical plants in Yunan Province and natural gas chemical plants in Chishui City in Guizhou Province are also notable polluters. Additionally, domestic waste produced by more than 100 million people in Chengdu, Mianyang, Zigong, Yibin, Neijiang, and dozens of other medium and large-sized cities, also flows into the Three Gorges Reservoir area.

Before the 1990s, sewage for the most part was used to fertilize crops in rural areas, but now all of it is dumped directly into rivers along with wastewater, resulting in a level of E. coli levels exceeding the normal standard in the Yangtze and Jialing Rivers.

Recommendations

The desperate need for adequate water treatment in the Three Gorges Reservoir Region is faced by municipalities and city regions around the world. Whether their infrastructure is aging and in need of repair and replacement, or is simply inadequate to meet the needs of a growing population, the challenges for many cities are similar. The good news is that there are solutions.

Public wastewater management systems lack the resources to correct current failings and address future challenges. They lack the professional capacity to plan infrastructure improvements, and the capital to finance them.

Municipal water and wastewater utilities around the world — the majority of which are publicly financed, publicly owned, and publicly operated — do not serve their customers well. In this regard, China is no exception. Many of the systems that treat and distribute drinking water perform poorly, and many of those that collect and treat wastewater for re-entry into the water cycle are among the worst polluters. These problems are likely to worsen as infrastructure ages and as populations grow.

There are a number of reasons why municipalities are unable to provide water that is safe for human consumption and industrial use, and treated wastewater that does not degrade water systems. Often they lack the resources to correct current failings and address future challenges. They lack the professional capacity to plan infrastructure improvements, and the capital to finance them.

They also lack the skilled labour to operate infrastructure. Most important, they lack the political will to overcome their deficiencies. Few municipalities are willing to set water and wastewater rates that are high enough to pay for sustainable systems. And few feel real pressure to improve their performance — especially that of their wastewater treatment systems — since conflicts of interest prevent public regulators from vigorously enforcing environmental laws and regulations against public utilities. It is nigh impossible for governments to regulate themselves: they rarely do so successfully, wherever they are in the world. It is human nature to avoid culpability, opprobrium, and liability.

Private water and wastewater service providers are, on the other hand, well positioned to help municipalities address the challenges they face.[19] Many have access to large pools of capital. Many have been in the business for decades and have developed extraordinary operating expertise. Engaged through competitive contracting and governed by performance-based contracts, private providers have incentives to find efficiencies and perform well. Competition can also improve publicly run operations.

To ensure that private water operators provide safe water and protect the water environment, their operations must be governed by the rule of law and they must be held accountable through transparent and independent regulation that is itself subject to judicial review. The governments that issue contracts to private providers must have true arms-length relationships with those providers: if they do not, cronyism in the assignment of risks and rewards will result and wastewater treatment providers will not be held liable for their failure to deliver clean and safe water.

In addition to enlisting the capital and technology of the private sector in meeting municipal water needs, water must be priced to reflect scarcity. To that end, full-cost pricing for all water used by residential, commercial, and industrial users must be employed. No sectors – including agriculture – should be exempt from water charges. Municipal water charges should fully recover the costs of providing water and wastewater services.

Private water operators … must be governed by the rule of law and they must be held accountable through transparent and independent regulation that is itself subject to judicial review.

Provincial water charges should fully recover the costs of managing the resource. They should also reflect the value and scarcity of the raw resource and the amount of water consumed.

Pricing should involve several components. Prices should be designed to fully recover administrative costs, to reflect the value of the water used, and to reflect the extent to which the water is consumed. (These charges should, of course, be in addition to any charges imposed by municipalities or other suppliers to recover the costs of treating and distributing water.)

Water's value depends on many factors, including where the water is located, how plentiful or scarce it is, and how much competition there is for it. Charges should vary across geography to reflect such factors.

Water charges should be substantially higher for water that is consumed than for water that is returned to the source. (The former is in effect being purchased, while the latter is merely rented.) Whenever possible, consumption should be assessed for specific users rather than estimated for an entire sector. Furthermore, the customary definition of consumption should be broadened.

The conventional definition counts consumptive use as the portion of a withdrawal that is lost or otherwise not returned to the source due to evaporation, incorporation into products, or other processes. The consumptive use of water should be redefined to include any use that makes water unavailable for other uses. Pollution, or any other use that precludes water from being used in other ways, should be considered a consumptive use.

To ensure that pollution sources do not continue to grow unchecked along the Three Gorges Reservoir region, the rule of law, public oversight, and market discipline must prevail.

Only by charging the true cost of water will jurisdictions with constrained water resources be able to conserve water.

Conclusion

To ensure that pollution sources do not continue to grow unchecked along the Three Gorges Reservoir region, the rule of law, public oversight, and market discipline must prevail. Empowering citizens with good laws that are enforceable in a credible judicial system will help them make polluters pay and thus protect the Yangtze River, China's Golden Waterway. The alternative is to allow pollution sources to grow, unchecked and with impunity, at incalculable cost to the health of China's environment and its citizens.

Endnotes

[1] The Municipality of Chongqing, created in 2007, is a "direct-controlled municipality." In the People's Republic of China, a province-level Municipality (of which there are four: Beijing, Shanghai, Tianjin, and Chongqing) is the highest classification level for cities and is controlled directly by the central government. According to the Chongqing Municipal government website, Chongqing is the only municipality directly under the central government in western China. Located on the upper reaches of the Yangtze River, the Chongqing Municipality is southwest China's biggest industrial and commercial center, communication hub, and inland port.

[2] Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It is comprised of liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture, and can be affected by a wide range of contaminants. "Wastewater" commonly refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewater from homes, services, businesses, industrial areas, and often storm drains, especially in older sewer systems. Sewage is the subset of wastewater that is contaminated with feces or urine, though the term is sometimes used to mean any wastewater. In this report, they are used interchangeably.

[3] Chongqing Statistical Yearbook, 2011.

[4] For more information, please see the Chongqing Municipal Government website at <http://en.cq.gov.cn/>.

[5] All figures in this paper, unless noted otherwise, were collected during on-site visits and interviews with plant personnel. Any questions about the figures presented should be relayed to Probe International.

[6] China has established a water quality classification system based on purpose of use and protection target, following Environmental Quality Standard GB3838-2002:
Grade I Applies to water sources and national nature reserves
Grade II Applies to class A water source protection areas for centralized drinking water supply, sanctuaries for rare fish species and spawning grounds for fish and shrimp
Grade III Applies to class B water source protection areas for centralized drinking water supply, sanctuaries for common fish species and swimming zones
Grade IV Applies to water bodies for general industrial water supply and recreational waters in which there is no direct human contact with the water
Grade V Applies to water bodies for agricultural water supply and for general landscape requirements
Grade V+ Not to be used
Sources: Beijing's Water Crisis 1949 — 2008 Olympics, Probe International Beijing Group, June 2008; CHINA: Water Quality Management— Policy and Institutional Considerations, Environment and Social Development — East Asia and Pacific Region, Discussion Papers, The World Bank, September 2006.

[7] According to the US Environmental Protection Agency website, nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. The term "nonpoint source" is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.
That definition states:
The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.
This term does not include agricultural storm water discharges and return flows from irrigated agriculture. Unlike pollution from industrial and sewage treatment plants, nonpoint source (NPS) pollution comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally

depositing them into lakes, rivers, wetlands, coastal waters and ground waters.

[8] Provided by the Chongqing Development and Reform Commission.

[9] See http://www.cncqsw.com/.

[10] Provided by the Chongqing Downtown Drain Company.

[11] See http://www.cncqsw.com/.

[12] Ibid.

[13] See http://www.cqstjt.com/waterweb/.
[14] Ibid.

[15] Wetland biotechnology wastewater treatment facilities can be installed in small scale facilities. This makes them particularly well suited to Chongqing's irregular and mountainous terrain where a decentralized water treatment system is more technically and economical viable than a centralized system.

[16] As of November 2012, the rate is set at 3.5RMB/tonne.

[17] The Sequencing Batch Reactor (SBR) process has been extensively used in Europe and the United States in the past two decades. The SBR process is an activated sludge process in which the sewage is introduced into a Reaction Tank (or SBR Tank), one batch at a time. Wastewater treatment is achieved by a timed sequence of operations which occur in the same SBR Tank, consisting of filling, reaction (aeration), settling, decanting, idling, and sludge wasting. For further information, see ABL Environmental Consultants Limited description of the SBR process <http://www.ablenvironmental.com/prod/prod_sbr_stages.htm>.

[18] For further technical details, see http://www.gec.jp/jsim_data/water/water_2/html/doc_231.html.

[19] See http://water.epa.gov/polwaste/nps/whatis.cfm.

For an excellent description of how private municipal wastewater treatment services can solve municipal needs see *The Economic Water Cycle* by Elizabeth Brubaker, Executive Director, Environment Probe, the 2007 EPCOR Distinguished Lecture to the Centre for Applied Business Research in Energy and the Environment in Edmonton, Alberta, October 18, 2007. Ms. Brubaker explains that there are three common problems that commonly plague publicly financed and publicly operated water utilities: inadequate infrastructure, insufficient operating expertise, and a lack of accountability. Greater private-sector involvement, and a more competitive market for water services, can help address each of these problems.

Some of the infrastructure problems reflect chronic underinvestment. Neither municipal governments, nor those at a higher level, have shown a willingness to invest the capital required, while the private sector has. Indeed, some water companies have the capacity to invest enormous sums. In England and Wales, water companies have invested more than £50 billion. Infrastructure funds also have the capacity for large investments. In 2006, globally, approximately $100 billion in new money was raised for such funds. In Canada, two large pension funds are putting their money into water utilities: in 2006, the Canada Pension Plan (the national pension plan) offered $1 billion to buy one-third of a water utility in the UK. In August of 2007, the Ontario Teachers' Pension Plan announced its second investment in Chilean water utilities.

The benefits are numerous: private capital reduces the conflicts of interest that prevent governments from demanding improvements to inadequate infrastructure; competition for contracts creates incentives to design and operate systems efficiently; the contracting process can also create incentives for good performance; municipalities can write incentives into the contracts. They can structure contracts to reward good performance and to penalize bad performance; and, contracts can set tough operating standards. They can guarantee water quality, monitoring and reporting procedures, maintenance levels, and customer

service levels. They can guarantee schedules and costs. And they can provide for steep fines – or even termination – if they aren't met. Enforceable contracts give municipalities meaningful control over their utilities. They enable municipalities to compel compliance.

In short, they are invaluable accountability mechanisms.

Contracting out the operations of water utilities creates other levels of accountability as well. One of the most important of these is regulatory accountability (i.e. eliminates the old boy networks.)

Involving private partners in the financing and operation of water utilities will help to solve that problem. It will put greater distance between utilities and regulators. It will help resolve the conflicts of interest that so often prevent regulators from doing their jobs. In other words, it will free up regulators to regulate.

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APPENDIX 1: Wastewater Treatment in Metropolitan Chongqing

District	Population (in thousands)	Daily Wastewater Production (km^3)	Wastewater Collection Rate	Daily Wastewater Treatment (km^3)	Treated Effluent Disposal	Number of Large and Medium-sized Wastewater Treatment plants
Shapingba	1000	210	90%	195	Jialing River	4
Jiulongpo	1080	230	90%	210	Yangtze River	4
Nan'an	759	180	94%	170	Yangtze River	2
Jiangbei	738	200	97%	195	Yangtze River	1
Ba'nan	918	120	92%	110	Yangtze River	2
Dadukou	300	110	88%	97	Yangtze River	2
Yubei	1340	290	90%	261	Yangtze River	3
Beibei	684	160	85%	136	Jialing River	1
Yuzhong	630	250	95%	235	Yangtze River	n/a*
Total	7449	1750	91%	1609		19

* The wastewater produced by Yuzhong District is treated by Jiguanshi Sewage Treatment Plant in Nan'an District.

APPENDIX 2: Large and Medium-sized Wastewater Treatment Plants in Metropolitan Chongqing

District	Wastewater Treatment Plant	Address	Wastewater Treatment Capacity (km^3)	Year Built	Treated Effluent Disposal	Owner
Shapingba	Xiyong Wastewater Treatment Plant	Tuzhu Town, Shapingba District	30	2008	Jialing River	Chongqing Water Group Co. Ltd.
Shapingba	Tuzhu Wastewater Treatment Plant	Tuzhu Town, Shapingba District	50	2006	Jialing River	Chongqing Water Group Co. Ltd.
Shapingba	Jingkou Wastewater Treatment Plant	Jingkou Town, Shapingba District	20	2006	Jialing River	Chongqing Water Group Co. Ltd.
Shapingba	Huilongba Wastewater Treatment Plant	Huilong Town, Shapingba District	2.4	2010	Jialing River	Shapingba Drain Company
Jiulongpo	Caiyunhu Wastewater Treatment Plant	Chenjiaping Street, Jiulongpo District	17	2005	Yangzte River	Jiulongpo Drain Company
Jiulongpo	Yangsheng Wastewater Treatment Plant	Chenjiaping Street, Jiulongpo District	12	2006	Yangzte River	Jiulongpo Drain Company
Jiulongpo	Baihan Wastewater Treatment Plant	Hangu Town, Jiulongpo District	25	2008	Jialing River	Jiulongpo Drain Company
Jiulongpo	Xipeng Wastewater Treatment Plant	Tongguanyi Town, Jiulongpo District	35	2008	Yangzte River	Jiulongpo Drain Company
Nan'an	Jiguanshi Wastewater Treatment Plant	Jiguanshi Street, Nan'an District	600	2003	Yangzte River	Chongqing Water Group Co. Ltd.
Nan'an	Chayuan Wastewater Treatment Plant	Yinglong Town, Nan'an District	30	2008	Yangzte River	Chongqing Water Group Co. Ltd.
Dadukou	Jiazixi Wastewater Treatment Plant	Jiazixi Street, Dadukou District	50	2005	Yangzte River	Chongqing Water Group Co. Ltd.

Note: *All wastewater is treated in accordance with Water Treatment Discharge Standard GB18918-2002 Class 1, Standard B*

(Appendix 2 continued)

District	Wastewater Treatment Plant	Address	Wastewater Treatment Capacity (km^3)	Year Built	Treated Effluent Disposal	Owner
Dadukou	Dajiu Wastewater Treatment Plant	Tiaodeng Town, Dadukou District	35	2007	Yangzte River	Chongqing Water Group Co. Ltd.
Jiangbei	Tangjiatuo Wastewater Treatment Plant	Tangjiatuo Street, Jiangbei District	300	2005	Yangzte River	Sino French Water Investment Co. Ltd.
Ba'nan	Yudong Wastewater Treatment Plant	Yudong Street, Ba'nan District	50	2003	Yangzte River	Chongqing Water Group Co. Ltd.
Ba'nan	Lijiatuo Wastewater Treatment Plant	Lijiatuo Street, Ba'nan Treatment Plant	40	2007	Yangzte River	Chongqing Water Group Co. Ltd.
Beibei	Beibei Wastewater Treatment Plant	Tianshengqiao Street, Beibei District	50	1996	Jialing River	Chongqing Water Group Co. Ltd.
Yubei	Chengnan Wastewater Treatment Plant	Shuangfengqiao Street, Yubei District	20	2002	Yangzte River	Yubei Drian Company
Yubei	Chengbei Wastewater Treatment Plant	Qianshuitan, Gangshang Village, Yubei District	30	2004	Yangzte River	Yubei Drian Company
Yubei	Xiaojiahe Wastewater Treatment Plant	Agricultural Zone, Yubei District	20	2004	Yangzte River	Yubei Drian Company

APPENDIX 3: Wastewater Treatment Plants under Construction, Extension and Proposed for Nine Districts of Metropolitan Chongqing

District	Wastewater Treatment Plant	Status	Daily Treatment Capacity (km^3)	Owner
Shapingba	Tuzhu Wastewater Treatment Plant	Extension	50	Chongqing Water Resources Investment Group
Shapingba	Xiyong Wastewater Treatment Plant	Planned to Expand	70	Chongqing Water Group Co. Ltd.
Jiangbei	Tangjiatuo Wastewater Treatment Plant	Extension	300	Chongqing Sino French Water Investment Co.
Jiangbei	Yufu Industry Zone Wastewater Treatment Plant	Planned to be built	100	Jiangbei Drain Company
Jiangbei	Gangcheng Industry Zone Wastewater Treatment Plant	Under Construction	10	Jiangbei Drain Company
Beibei	Xiema Wastewater Treatment Plant	Under Construction	10	Beibei Drain Company
Beibei	Caijia Wastewater Treatment Plant	Under Construction	40	Beibei Drain Company
Jiulongpo	Baihan Wastewater Treatment Plant	Under Construction	25	Jiulongpo Drain Company
Jiulongpo	Tongguanyi Wastewater Treatment Plant	Under Construction	30	Jiulongpo Drain Company
Dadukou	Jiazixi Wastewater Treatment Plant	Extension	50	Chongqing Water Group Co. Ltd.
Dadukou	Dajiu Wastewater Treatment Plant	Planned to be built	35	Chongqing Water Group Co. Ltd.
Ba'nan	Lijiatuo Wastewater Treatment Plant	Extension	40	Chongqing Water Group Co. Ltd.
Ba'nan	Yudong Wastewater Treatment Plant	Extension	30	Ba'nan Drain Company
Ba'nan	Jieshi Wastewater Treatment Plant	Planned to be built	40	Ba'nan Drain Company