comment

Urban river pollution control in developing countries

The development of sewer systems hasn't caught up with the urbanization speed in developing countries, with serious consequences for urban river water quality. The experience of urban river restoration in China can offer useful lessons to other countries in the Global South.

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In 2015, the United Nations members agreed on 17 sustainable development goals to be achieved by 2030[1]. Goal 6 is "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally." Such a focus on water quality suggests a great concern about urban river pollution control worldwide.

By the 1970s, countries in Europe and the United States had ended the direct discharge of sewage into urban rivers by developing almost complete sewer systems and wastewater treatment plants (WWTPs)[2]. As a result, water deterioration in many urban rivers slowed down significantly while water quality gradually recovered[3]. In China, at the beginning of rapid urbanization in the 1980s, the focus was only on constructing storm water drainage systems. The same was true in most other developing countries. It was not uncommon that a large amount of sewage directly discharged into rivers. Consequently, urban rivers were seriously polluted. With rapid economic development and population increase, there was more urgent demand for restoration of polluted urban rivers in developing countries, thereby driving the construction of sewer systems. However, there wasn't proper coordination between the existing urban storm water drainage pipe network and the newly developed sewage pipe network, resulting in illegal connection of sewer pipelines with storm water pipelines in some places. In addition, poor quality of pipe materials and construction also caused serious leaking problems. These problems resulted in the deficiency of the storm water pipes and sewage pipes and could explain current urban river pollution. Although ecological restoration of urban rivers has been of strong interest and received a great deal of attention[3–5], effects of sewer-related issues on urban river pollution are still not fully understood; this undermines urban river restoration efforts.

Currently, the Chinese government is making great efforts to restore the highly polluted rivers that resulted from inappropriate development during rapid urbanization. The Chinese experience and practices can be valuable, especially to other developing countries that are in a similar situation of tackling urban river pollution.

Sewage treatment infrastructures in China

The investment in sewage treatment infrastructures keeps increasing in developing countries in order to meet the global goal of halving the proportion of untreated wastewater. China is no exception (see Fig. 1a). China's investments in sewage treatment infrastructures have reached 148.6 billion Chinese Yuan (RMB) in 2016, accounting for 1.2% of the nation's gross domestic product. According to the environmental bulletin of China, about 93.4% of wastewater in urbanized area is sent to WWTPs (see Fig. 1b), almost the same level as in European and US cities nowadays[6]. This has obviously improved water quality of urban rivers.

It is reported that around 9% of total rivers in China are still seriously polluted[7]. Furthermore, river pollution is generally more severe and widespread during wet weather, including in European and US cities[8]. In 2016, China's Ministry of Housing and Urban-rural Construction identified 2,100 black and stink rivers (with unpleasant colours or odours) in more than 220 cities, 64% of them are located in southeast coastal areas, where rapid development and urbanization occurred[9].

We argue that much urban river water pollution is explained by the deficiency of the urban drainage systems. This situation is even more serious in cities that have been experiencing rapid urbanization over the past decades.

Sewer-related urban river pollution

Looking at sewer system development at present, there exist three types of sewer deficiency: incomplete system, damaged pipelines, and illegal connection of sewer systems to storm water systems.

Incomplete sewer system. Developing countries often prioritize the construction of the main pipelines that transport sewage into WWTPs, ignoring the supporting construction of the collecting pipelines that move sewage into the main pipelines and of the interception pipelines that prevent sewage discharging into rivers. Although the sewer network coverage in China reached nearly 90%, the density of sewer network per km^2 is only 10.61 km (see Fig. 1c, d), much lower than the reported data of the US and Japan, where the average sewer network densities are 20~50 km per km^2 (ref. [10]). In addition, municipalities tend to focus on collecting sewage from main rivers in urban areas, while ignoring suburban areas.

Damaged sewer pipelines. Due to damaged sewer pipelines and misconnection of storm water pipelines to sewer systems, a large amount of groundwater and storm water enters sewer pipelines and is sent to WWTPs in areas where groundwater level is higher than the depth of buried pipes. This has artificially inflated the proportion of sewage treatment in China (reported at 93.4%). Chemical oxygen demand (COD) is a common indicator to describe the level of pollution in water. The higher the COD, the worse the pollution. In general, COD concentration of domestic sewage is about 350 mg per L. However, more than 1,000 WWTPs — that's 25% of WWTPs in China — have an influent COD below 150 mg per L (ref. [11]) because of dilution by groundwater and storm water. This water intrusion increases the water flowing into the WWTPs during wet-weather days, sometimes doubling the inflows, and so exceeding the capacity of and resulting in overflow of WWTPs[12].

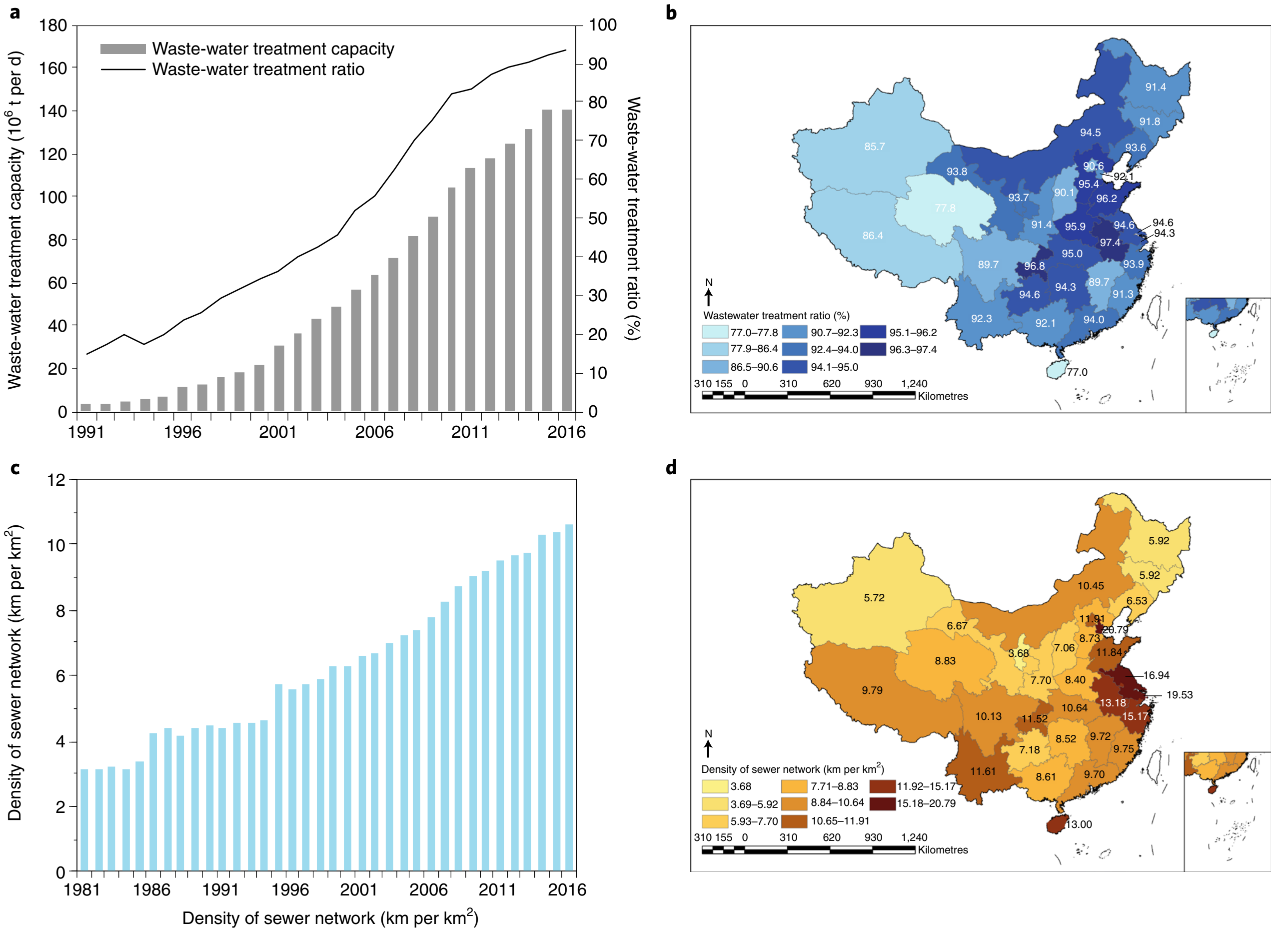

Fig. 1 | Basic information on sewage treatment infrastructures in China. a, Wastewater treatment capacity and wastewater treatment ratio from 1991 to 2016. **b**, Wastewater treatment ratio of different provinces in 2016. **c**, Density of sewer network from 1981 to 2016. **d**, Density of sewer network in different provinces in 2016. Source: China Urban Construction Statistical Yearbook.

Sewage pipes illegally connected to storm water drainage system. It is common to illegally connect sewage pipes to storm water pipes in developing countries, because sewer systems were constructed much later than storm water pipes. We have surveyed 23 storm water drainage systems in China, and found that more than half could be illegally connected to sewer pipes[13]. This condition explains the severe pollution of the flow from the storm water pipes, and therefore the deterioration of river water quality during wet weather (see Fig. 2). In southern China, storm water discharged by illegally connected storm water pipes could explain the higher pollution levels compared to the United States and Germany[8,14].

River pollution during wet weather can also be caused by overflow of combined sewer systems (CSSs). CSSs are designed to collect both sewage and storm water. In wet-weather days, the flow in excess of the capacity of CSSs will discharge mixed sewage and storm water into rivers, resulting in overflow pollution. This problem occurs not only in developing countries, but also in developed countries. Generally, it is more serious in the former because of poor sewer maintenance. In wet-weather condition, sediments previously accumulated in storm water pipes are re-suspended and flushed into rivers, leading to serious river pollution. In southern China, COD concentration of overflow from CSSs could be up to 1200 mg per L and the pollution is much worse than in Germany[8,15], for example.

Technology demand for improving sewer systems

In order to effectively abate urban river pollution, technology advancements for sewer inspection, repair and maintenance are urgently needed in large cities.

We argue that preventing illegal connection of sewage to storm water pipelines is essential for restoring urban river pollution. For quickly urbanizing areas in developing countries, identifying illegally connected sources is key and will benefit from cost-effective pipeline inspection approaches to prioritize high-risk areas and perform system-wide condition assessment[16]. It is also very important to develop technologies for correcting illegal connections and restoring wet-weather flows rapidly.

Repairing damaged sewer systems in densely populated urban areas is much more difficult than constructing new ones. Development of equipment or robots to detect pipe defects is very important. Once damaged pipes are detected, they should be repaired promptly and therefore there is an urgent need to develop adequate repairing technologies to minimize disruption to surface traffic. Trenchless technology has incomparable advantages, because it can replace damaged pipes with new ones and repair broken pipes without digging in cities with heavy traffic.

Sediment cleaning is essential to alleviate wet-weather overflow pollution. Current

Fig. 2 | **River pollution in southeastern China.** **a**, Photograph taken during dry weather on 15 July 2018. **b**, Photograph taken during wet weather on 25 May 2018.

sediment cleaning is mainly operated manually, and is very labour intensive. Solutions to prevent sediment deposition, and development of dredging machines, automatic hydraulic flushing equipment, and other technologies to remove sediments should be explored.

Low impact development (LID) aims to return the developed catchments to pre-development hydrological conditions and may be used to reduce the stress on urban storm water infrastructure. LID could play a critical role in reduction of peak flow, runoff volume and pollutant loads, especially during light and medium rainfall[17]. China's population density in urbanized area is 3–4 times that of the western countries, and it is impractical to develop large-scale storm water detention facilities in densely populated areas. The integrated design and operation both of urban drainage systems and LID facilities are viable options.

Smart storm water systems can enable a new generation of intelligent urban sewer systems. In developing countries, management of sewer systems still largely depends on technician expertise. There is an unprecedented opportunity to improve river water quality by equipping the existing sewer systems with low-cost sensors and controllers. This approach will help improve river water quality at a catchment scale by optimizing the urban sewers, WWTPs and urban rivers as a whole system.

Market outlook for improving urban sewers in China

Currently, in China, sewers in one third of urbanized areas are damaged, and in another third of urbanized areas, sewers need to be built. It is estimated that sewer construction cost in China is about 1.03–2.71 million US$ per km (ref. [18]). Therefore, the investment for constructing complete sewer systems in China will exceed 1 trillion RMB in the coming decades.

With limited government budgets, innovative approaches are needed to finance these projects, for example via Public–Private Partnerships (PPP). In April 2015, the Chinese Ministry of Finance and Ministry of Environmental Protection jointly issued a document[19] encouraging private capital involvement in the treatment of highly polluted rivers. As of July 2018, there are 131 river rehabilitation projects financed through PPP, worth 226 billion RMB in total[20].

Considering the huge demand for and importance of repairing, upgrading and maintaining urban drainage and sewer pipe systems in China, there could be a big market for specialized companies to develop and employ new technologies, equipment and management modes for sewer operation and maintenance, if supported by PPP projects.

We argue that urban sewer problems will be tackled along a development path similar to China's, and the experiences gained in China could benefit other developing countries in need of similar interventions. ❐

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