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Short Communication

Past and Future Trends of Wastewater Treatment in Beijing

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Abstract

An analysis is made on the past and future trends of wastewater treatment in Beijing. Over the past several decades, great efforts have been made by Beijing to improve the urban wastewater treatment technology, reclaim municipal wastewater, and promote water reclamation and reuse. Until now, the utilization volume of reclaimed water has been increasing continuously. Generally, there are four categories of wastewater treatment plants (WWTPs) in Beijing. And the most mainstream wastewater treatment method in Beijing is aerobic biological process, thereinto the advanced treatment methods of WWTPs, including membrane bioreactor (MBR), biological aerated filter (BAF), and chemical oxidation. However, both the existing conventional and advanced treatment processes mainly aim at the remediation of COD, ammonia nitrogen, total nitrogen, total phosphorus, and other conventional organic pollutants. Micro pollutants such as persistent organic pollutants (POPs) are not considered in the design of WWTPs. The treatment and disposal issues of sludge have become an important agenda item for Beijing's municipal government. In the future, the priority technologies for wastewater treatment in Beijing should have the features of high efficiency and stability, and lower energy consumption, and operational cost. Suitable small-scale technologies are necessary for rural areas. The existing wastewater treatment facilities must be strengthened and improved to reduce the micro-pollutants in wastewater.

Keywords: wastewater treatment, advanced treatment, sludge disposal, wastewater reclamation, water reuse

Introduction

As the capital of China, Beijing covers about 16,410.54 km^2. The population in 2012 was about 20.693 million. With rapid social and economic development, the increasing amounts of wastewater have been a prime environmental issue in Beijing. Over the past several decades, Beijing has taken great efforts in wastewater treatment. With the improvement of urban wastewater treatment technology, the utilization amount of reclaimed water has been continuously increased. According to the Beijing Environment Statement of 2012, the wastewater treatment rate in Beijing was 83%, and reclaimed water consumption reached 750 million m^3, accounting for 20% of total water consumption [1].

On the other hand, Beijing is still facing a water shortage. For example, the city has been experiencing a decrease in per capita water resources from 127.8 m^3 in 2003 down to 124.3 m^3 in 2010, which is just one eighth of the national average decrease [2]. However, the annual water consumption almost remains increasing due to population rise and industrial development in Beijing. It is necessary that effective and efficient wastewater reclamation and reuse will be a water resource conservation strategies.

For many developed urban areas in the world, the problems of water shortage are urgent too. Therefore, the gov-

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Table 1. Typical wastewater advanced treatment projects in Beijing.

No.	WWTPs	Capacity (10^4 m^3/d)	Original treatment process	Advanced treatment process
1	Gaobeidian	100	CAS	Sand filtration+O_3+BAF
2	Jiuxianqiao	20	OD	Coagulation+Sedimentation+Disinfection
3	Fangzhuang	0.3	CAS	Coagulation+Sedimentation+Disinfection
4	Qinghe	55	CAS	MBR/UF+O_3
5	Beixiaohe	10	CAS	MBR+O_3
6	Wujiacun	8	CASS	BAF+O_3
7	Xiaohongmen	60	CAS	BAF+UF+O_3
8	Lugouqiao	10	CAS	BAF+O_3

ernments usually resort to wastewater reclamation and reuse. In the case of Greece, wastewater within the allowable limit of wastewater's quality and toxicity was used for agricultural and landscape irrigation [3]. In Australia, the membrane bioreactor (MBR) treatment with nanofiltration (NF) or reverse osmosis (RO) membrane filtration were applied for the removal of trace organic contaminants for indirect potable water recycling applications [4]. In addition to being a means of wastewater treatment, the recycling of treated wastewater is a serious point of peer considering the water shortages that have occurred in Beijing. Treated municipal wastewater can be reused as domestic miscellaneous water (toilet-flushing water), greening water, ecological water compensation for urban rivers and lakes, and agricultural irrigation [5].

The most mainstream wastewater treatment methods in Beijing are aerobic biological proceses.

The reclaimed and reused water standards are much more stringent than the wastewater discharge standards. In view of this, in recent years Beijing has implemented renovation projects on existing wastewater treatment plants (WWTPs). The renovation projects mainly consist of various forms of advanced treatment processes, including membrane bioreactor (MBR), biological aerated filter (BAF), and chemical oxidation [6].

While the existing conventional and advanced treatment processes are mainly evaluated by the indexes, such as remediation of COD, ammonia nitrogen, total nitrogen, total phosphorus and other conventional organic pollutants, micro pollutants, such as persistent organic pollutants (POPs), are not considered in the design of WWTPs. Therefore, the existing wastewater treatment facilities must be strengthened and improved. In terms of the above, this paper provides a description of past and future trends of wastewater treatment in Beijing.

Characteristics of Wastewater Treatment in the Past

Generally, wastewater treatment processing in Beijing can be classified into two types. The first is urban centralized wastewater treatment, which is responsible for the treatment of domestic wastewater and industrial wastewater to meet the discharge or reuse standards. The second is on-site pre-treatment within the enterprises generating industrial wastewater, where the treated wastewater may reach or slightly exceed the pre-treatment standards before discharging into the centralized WWTPs.

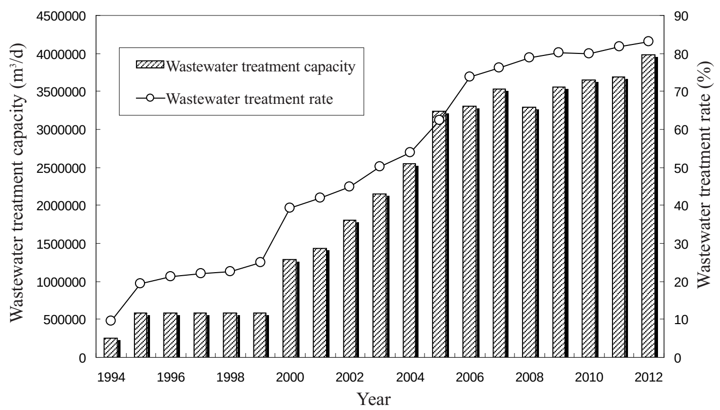

Fig. 1. Wastewater treatment capacity and rate in Beijing.

Urban centralized wastewater treatment capacity has been increased steadily in recent years. Fig. 1 shows the wastewater treatment capacity and rate from 1994 to 2012 in Beijing.

It can be seen from Fig. 1 that the wastewater treatment rate in Beijing has increased rapidly from 1994 to 2005. After 2005, because the total volume of water and wastewater changed little, the wastewater treatment rate in Beijing grew slowly. In 1994, only less than 10% of the total wastewater was treated. By 2012, more than 80% of the wastewater was treated in Beijing. In 2015 Beijing's wastewater treatment rate will reach above 90%, and the wastewater treatment rate will reach 100% in urban areas [7].

Considering the scale and the distribution area, the wastewater treatment plants in Beijing can be graded into four classifications: large-scale urban centralized WWTPs, large-scale suburb or satellite city centralized WWTPs, medium-scale town centralized WWTPs, and decentralized rural wastewater treatment stations.

At the end of 2012, the total number of large-scale urban centralized WWTPs whose treatment capacity ≥1000 m^3/d in Beijing reached 41. The centralized WWTPs in Beijing have different wastewater treatments, but they are all based on a combination of traditional mechanical and biological treatment. Large-scale urban centralized WWTPs mainly employ the conventional activated sludge (CAS) process, anaerobic-anoxic-oxic (AAO) process, anaerobic/anoxic-oxic (AO) process, oxidation ditch (OD), sequencing batch reactor (SBR), biofilm reactor, lagoon, etc. For example, the Gaobeidian WWTP in Beijing has been the largest WWTP in China since 1961. Its treatment capacity was extended to 1,000,000 m^3/d. The Gaobeidian WWTP was divided into four series with each treatment capacity of 250,000 m^3/d. A two-stage CAS process is used in Gaobeidian WWTP. Primary treatment includes grid, pump house, aerated grit chamber, and horizontal sedimentation tank. The secondary treatment uses aerated activated sludge processing, and the effluent is discharged into the Tonghui River. The sludge enters the medium-temperature secondary digestion treatment system after gravitational thickening. The dehydrated mud cake can be used for fertilizer. The biogas generated during the digestion process can be used for inner-plant electric power generation [8].

In remote suburban districts and counties surrounding Beijing, large-scale suburb or satellite city centralized WWTPs were built in downtowns. The treatment capacity is generally ranged from 10,000 m^3/d to 100,000 m^3/d, and the treatment processes are similar with the large-scale urban centralized WWTPs. For instance, the treatment capacity of Miyun Tanzhou WWTP is 45,000 m^3/d, and the scheme diagram of its treatment process is shown in Fig. 2.

As for the towns in suburban districts and counties, WWTPs are constructed with treatment capacity of hundreds to thousands of tons per day. The SBR and contact aerobic biological oxidation processes are the most popular treatment processes for their high removal efficiencies, and low construction and maintenance costs [9].

There are many villages with small populations in Beijing. The CAS process that is widely used in urban areas is a stable system, but is not suitable for a small-scale treatment system. It is difficult to treat the wastewater in these villages and towns in concentrated WWTPs. So other treatment systems are being selected. The treatment scales of these systems are between ten and several hundreds of tons per day, and the employed techniques usually are constructed wetlands, land infiltration, and unpowered anaerobic treatment [10]. However, on one hand, there are some restrictions on the construction cost and operation management cost of treatment facilities in rural areas. On the other hand, the wastewater discharge or reuse standards are very strict in the Beijing area. Generally, the treatment processes mentioned above cannot meet the discharge or reuse standards. So, treatment technology combined with conventional secondary treatment process requiring inexpensive construction and maintenance costs, like the tricking filter or the constructed wetland process, is actively being developed [11].

As the wastewater treatment capacity grew, more and more industrial and domestic waters in Beijing were being treated. In recent years, Beijing has taken great efforts in reclaiming municipal wastewater and promoting water reclamation and reuse to mitigate the shortage of water [12]. So far it has achieved substantial development in Beijing, utilizing 780 million m^3 reclaimed wastewater, which accounts for 20% of annual water consumption in 2012. Reclaimed water has advantages in being unaffected by climate, being concentrated conveniently, and discharging water with stable quality. In 2010, 47% of the reclaimed water was used for agricultural irrigation, and about 30% and 20% of the reclaimed water was used for environmental reuse and industrial reuse, respectively. Facing a water shortage, Beijing began to utilize reclaimed wastewater to replenish droughted rivers and lakes. Wastewater reclamation as a means for the conservation of water resources has been proved to be successful in Beijing. The reclaimed wastewater reuse rate has increased steadily since 2005 (Fig. 3) [13].

Since the reuse standards are much more stringent than emission standards. The design, construction, and operation of WWTPs have been greatly improved in Beijing, the transformations of the existing WWTPs which focus on the advanced treatment have been constructed widely in

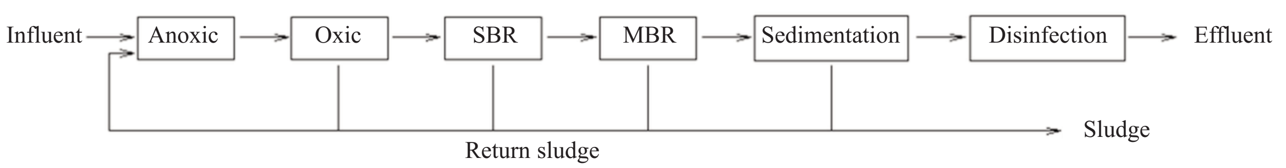

Fig. 2. Scheme diagram of treatment process in WWTP of Miyun County, Beijing.

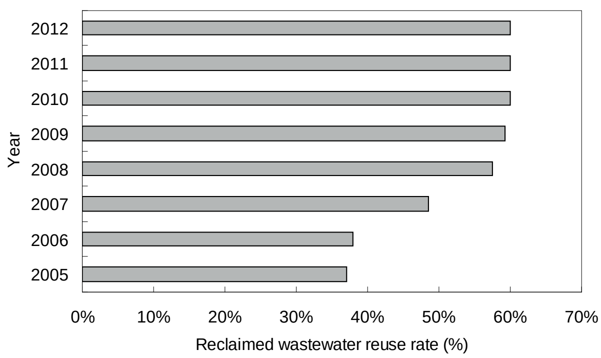

Fig. 3. The reclaimed wastewater reuse rate in Beijing.

Beijing. The typical wastewater advanced treatment projects are shown in Table 1 [14]. With the rapid increase of wastewater treatment capacity, the increasing volume of sludge produced in WWTPs has been one of a prime environmental issue in Beijing. Approximately 1,000,000 tons (moisture content 80%) of sludge were produced in 2008. About 2,400 t/d sludge came from urban areas and 400 t/d sludge came from suburban areas. It is predicted that the sludge production will rise to 5,000 t/d (annual output 1,830,000 t/a) by 2015, including 3,300 t/d from urban areas and 1,700 t/d from suburban areas [15].

At present, there are only five sludge disposal plants in Beijing, including Panggezhuang Sludge Disposal Plant, Changping Sludge Disposal Plant, Fangzhuang Sludge Disposal Plant, Qinghe Sludge Disposal Plant, and Beijing Cement Plant. The disposal scales are 110,000 t/a, 29,000 t/a, 11,000 t/a, 146,000 t/a, and 184,000 t/a separately, and the total disposal scale is 480,000 t/a (moisture content 80%), which is less than 50% of the total sludge production in Beijing. Only Gaobeidian WWTP and Xiaohongmen WWTP have facilities for anaerobic sludge digestion. However, these two facilities cannot operate steadily due to inadequate management. Other WWTPs use the concentrating-dewatering process, the moisture content can reach 80%, cannot meet final disposal requirements. The technological cost of deep dehydration (moisture content 80%-60%) is too high to afford [16].

There are different disposal methods for the sludge in WWTPs. The disposed sludge was mainly landfilled or used as soil fertilizer and building materials in Beijing. However, any form of disposal needs to be controlled in order to protect human health and the environment, considering that sewage sludge potentially carries relatively high levels of bacteria, ascarid eggs, and a certain amount of heavy metal ions, poisonous and harmful organic pollutants, nitrogen, phosphorus, and other elements [17, 18]. For example, it was found that the concentration of Zn in Wujiacun WWTP was higher than the Chinese regulation limit of pollutants for sludge to be used for agriculture in China [19].

However, most WWTPs were not designed for final disposal of sludge in Beijing. Sludge was mainly disposed of in landfills or directly used in agriculture as fertilizer. Compared with the significant increase in wastewater treatment processes, the sludge treatment and disposal technologies and projects lagged far behind wastewater treatment. This indicates that wastewater and sludge have not formed a complete technology chain. The sludge treatment and disposal issue has become an important issue for Beijing's municipal government [20]. It is urgent for Beijing to support the new sludge treatment and disposal technology and industrial policies.

Future Trends of Wastewater Treatment in Beijing

Wastewater Treatment Technologies

In the future, the priority technologies for wastewater treatment in Beijing should have the features of high efficiency and stability, and lower energy consumption and operational costs. Suitable technologies for wastewater handling in rural areas are necessary for a scattering population [21]. Reclaimed wastewater contains a variety of micro-pollutants, especially persistent organic pollutants (POPs), which has a negative impact on the environment and human health. The existing conventional and advanced treatment processes mainly focus on remediation of COD, ammonia nitrogen, total nitrogen, total phosphorus, and other conventional organic pollutants. Micro pollutants such as POPs are not considered in the design of WWTPs. Therefore, the existing wastewater treatment facilities for wastewater treatment facilities must be strengthened and improved. Existing advanced treatment technologies such as membrane and advanced oxidation are too expensive [22]. So developing high-performance, low-cost advanced treatment technologies, reducing recycling costs, and increasing operational stability are the goals in the near future.

Suitable Sludge Treatment and Disposal Technologies

Increasing wastewater treatment capacity and enhanced treatment processes will produce a huge quantity of sludge. Owing to the high water content of dewatered sludge, the sludge has too poor strength to be accepted by landfills. Suitable sludge treatment and disposal technologies should be developed urgently. Relevant preferential policies should be provided for businesses and individuals who participate in sludge treatment and disposal. The establishment of a technical standard system for sludge treatment and disposal should be accelerated.

Conclusions

1. The wastewater treatment capacity has been increased greatly with the newly construction of WWTPs in Beijing. Generally, there are four classes of WWTPs in Beijing: large-scale urban-centralized WWTPs, large-

scale suburban or satellite city-centralized WWTPs, medium-scale town-centralized WWTPs, and decentralized rural wastewater treatment stations.

2. To solve the problem of water shortage, Beijing has taken great efforts in reclaiming municipal wastewater and promoting water reclamation and reuse. The advanced treatment processes in WWTPs have been constructed widely to meet the strict reuse standards. The typical wastewater advanced treatment methods include MBR, BAF, O_3 oxidation, coagulation, and disinfection, etc.
3. With the rapid increase of wastewater treatment capacity, the increasing amounts of sludge produced in WWTPs have been a prime environmental issue in Beijing. The sludge treatment and disposal issue has become an important issue for Beijing's municipal government.
4. The priority technologies for wastewater treatment in Beijing should have the features of high efficiency and stability, lower energy consumption and operational costs. Suitable technologies for wastewater handling in rural areas are necessary for a scattering population. To remediate the micro-pollutants in wastewater, the existing wastewater treatment facilities for wastewater treatment facilities must be strengthened and improved.

Acknowledgements

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