Environment International 92–93 (2016) 11–22

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Review Article

Current status of urban wastewater treatment plants in China

Q.H. Zhang [a,b,*], W.N. Yang [b], H.H. Ngo [c,**], W.S. Guo [c], P.K. Jin [b], Mawuli Dzakpasu [b], S.J. Yang [a], Q. Wang [a], X.C. Wang [a], D. Ao [a]

[a] Key Lab of Northwest Water Resource, Environment and Ecology, Ministry of Education, Xi'an University of Architecture and Technology, Xi'an 710055, China
[b] School of Environmental and Municipal Engineering, Xi'an University of Architecture and Technology, Xi'an 710055, China
[c] Centre for Technology in Water and Wastewater, School of Civil and Environmental Engineering, University of Technology, Sydney, PO Box 123, NSW 2007, Australia

ARTICLE INFO

Article history:
Received 6 December 2015
Received in revised form 17 February 2016
Accepted 19 March 2016
Available online xxxx

Keywords:
Wastewater treatment plants (WWTPs)
Regional sewage treatment
Discharge standard and upgrading
Sludge disposal
Energy consumption
Wastewater reclamation and reuse

ABSTRACT

The study reported and analyzed the current state of wastewater treatment plants (WWTPs) in urban China from the perspective of treatment technologies, pollutant removals, operating load and effluent discharge standards. By the end of 2013, 3508 WWTPs have been built in 31 provinces and cities in China with a total treatment capacity of 1.48×10^8 m^3/d. The uneven population distribution between China's east and west regions has resulted in notably different economic development outcomes. The technologies mostly used in WWTPs are AAO and oxidation ditch, which account for over 50% of the existing WWTPs. According to statistics, the efficiencies of COD and NH_3–N removal are good in 656 WWTPs in 70 cities. The overall average COD removal is over 88% with few regional differences. The average removal efficiency of NH_3–N is up to 80%. Large differences exist between the operating loads applied in different WWTPs. The average operating loading rate is approximately 83%, and 52% of WWTPs operate at loadings of <80%, treating up to 40% of the wastewater generated. The implementation of discharge standards has been low. Approximately 28% of WWTPs that achieved the Grade I-A Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB 18918–2002) were constructed after 2010. The sludge treatment and recycling rates are only 25%, and approximately 15% of wastewater is inefficiently treated. Approximately 60% of WWTPs have capacities of 1×10^4 m^3/d–5×10^4 m^3/d. Relatively high energy consumption is required for small-scale processing, and the utilization rate of recycled wastewater is low. The challenges of WWTPs are discussed with the aim of developing rational criteria and appropriate technologies for water recycling. Suggestions regarding potential technical and administrative measures are provided.

Contents

* Correspondence to: Q.H. Zhang, Key Lab of Northwest Water Resource, Environment and Ecology, Ministry of Education, Xi'an University of Architecture and Technology, Xi'an 710055, China.
** Corresponding author.
E-mail addresses: qionghuazhang@126.com (Q.H. Zhang), h.ngo@uts.edu.au (H.H. Ngo).

http://dx.doi.org/10.1016/j.envint.2016.03.024

1. Introduction

Water scarcity poses a serious threat to the development of human societies. Wastewater reclamation and reuse is considered to be the best strategy for meeting current and future water needs. On the other hand, water pollution represents an especially dangerous problem in developing countries, such as China. In 2012, the total national wastewater discharge in China was 68.5 billion tons, which represented a 3.7% increase over the previous year. In 2013, 23.5 and 2.5 million tons of chemical oxygen demand (COD) and ammonia nitrogen, respectively, were discharged (China Environmental Status Bulletin, 2013). Thus, the need to analyze the achievements and future challenges of wastewater treatment in China cannot be overemphasized.

In recent years, as economic development has accelerated and public and governmental consciousness of environmental protection has grown, China's capacity to treat sewage has rapidly expanded. This capacity was established in a relatively short period, within which the treatment efficiencies were also significantly improved. The capacity and efficiency of wastewater treatment plants (WWTPs) have increased from 0.4×10^6 m^3 and 14.9%, respectively, in 1991 to 3.8×10^6 m^3 and 89.3% in 2013, indicating rapid development of sewage treatment. Although China has established the second largest sewage treatment capacity in the world (after the United States), regional developments are largely imbalanced. For example, the sewage treatment efficiencies in Heilongjiang (60.8%), Qinhai (60.4%) and Tibet (0.06%) are significantly less than the national average.

Wastewater treatment consists of primary, secondary, and sometimes advanced treatment processes, with different biological, physical, and chemical technologies. At present, many sewage treatment processes are used in WWTPs in China, including conventional activated sludge treatment, anaerobic-anoxic-oxic (A2/O), anaerobic-oxic (A/O), sequencing batch reactor (SBR), and oxidation ditch. The treatment efficiency of a WWTP is related to the process and also depends on the scale of the WWTP.

As of 2012, the six provinces or municipalities with per capita urban sewage discharges >45 m^3 were Shanghai, Beijing, Tianjin, Guangdong, Liaoning province, and Ningxia, in decreasing order. Shanghai, which had the highest per capita urban sewage discharge, ranked seventh for treatment efficiency, whereas Liaoning, which had the fifth highest per capita urban sewage discharge, ranked 22nd for treatment efficiency. Thus, the rankings of discharge and treatment efficiency of sewage and wastewater treatment facilities vary between regions. This variability depends on many factors, including the huge amount of the population (1.3 billion) in China, rapid economic growth, industrialization, urbanization and inadequate investment in infrastructure.

According to Yang et al. (2011), the construction of WWTPs and China's improved treatment capacity showed apparent geographical distribution, except in the northwest region, where capacity and GDP demonstrated good colinearity. A report by Yang et al. (2012) on the different treatment technologies for the utilization of sewage sludge showed an increasing trend in China. Due to the heterogeneous character of economic development, the eastern part of China showed higher increases, especially in Zhejiang and Jiangsu. Wang (2013) analyzed the investment, maintenance and annual operation costs of urban WWTPs; as an example, aeration equipment demonstrated a reasonable update lifetime of six years. However, it is difficult to maintain this frequency of updating equipment, which may explain why energy consumption is higher than that in developed countries. For this reason, Qu (2007) proposed the application of Public-Industry-Private-Partner (PIPP) investment and financing in WWTPs. However, governmental investment primarily funds the construction and operation of WWTPs, which has many disadvantages, such as construction delays, high expenses, and high energy consumption. These disadvantages consequently mean that WWTPs cannot achieve the required discharge standard.

Thus, the geographical distribution of WWTPs needs to be carefully and strategically considered, given that the rapid expansion of WWTP construction in China is almost complete. As such, there is a need to summarize and analyze the current situation in a focused document. Research on the state of sewage treatment in China is rarely reported. Therefore, this article reviews the current state of regional wastewater treatment in China. We focus on the treatment technologies, pollutants removals, operating load and effluent discharge standards. Furthermore, we provide an analysis of discharge standard and upgrading, sludge disposal, energy consumption, wastewater reclamation and reuse. The results of this review will provide effective technical support for the construction and operation of WWTPs.

2. Construction of WWTPs in China

2.1. Number and distribution of WWTPs

By the end of 2013, 3508 WWTPS had been built in 31 provinces. However, the distribution of WWTPS is dramatically uneven throughout China (Fig. 1). Of the 3508 WWTPs, 383 are located in Guangdong province, and 366 are in Jiangsu province, which are at the top of the list. Furthermore, 221 WWTPs are situated in Shandong province. In 19 provinces, the number of WWTPs is over 100, accounting for 61.3% of the total, with 118 in Liaoning, 114 in Guangxi, 111 in Shaanxi, 109 in Anhui, 108 in Inner Mongolia, 106 in Xinjiang, 101 in Jiangxi and Guizhou and 99 in Fujian. For the remaining 12 provinces, the number of WWTPs is <100. Of these, Xizang, Qinghai and Tianjin are at the bottom, with 2, 18 and 24, respectively.