Research on standards and regulations of the operation of wastewater treatment plants

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Abstract. This paper summarizes the regulations related to operation of wastewater treatment plant at home and abroad, analyses the system, quantity and type distribution of the standards related to operation of wastewater treatment plant (WWTP) at home and abroad, and provides the theoretical basis for research and development of operation effect evaluation criteria for Chinese WWTP by studying the contents and demands of standards related to operation effect evaluation of WWTP at home and abroad.

1. Standards and Regulations Related to Wastewater Treatment Plant Abroad

The wastewater treatment plant (WWTP) has gained more mature experience in developed countries. European countries such as UK, Germany, Finland and Netherlands have focused on the treatment of urban water pollution due to economic development [1]. Other countries such as Japan, Singapore, US, and Australia have also made a large investment in this area. Developed countries attached great importance to the mechanism establishment of the operation and management of WWTP [2]. The performance of WWTP is stabilized by the advanced modern scientific technology, such as high-level automation control technology, which provides predominant support for the development of wastewater treatment industry [3].

The laws about water pollution control in US have been developed for more than 100 years [4]. Under the force of serious water pollution problem during the 1960s and 1970s, the federal government formulated a series of laws and regulations such as Federal Water Pollution Control Act in 1972 to control the problem through laws and their implementation. From then on, the laws have been revised for several times, and the federal government established a variety of balanced management modes for mutual complement and restriction of water pollution control system. The current Federal Water Pollution Control Act adopts a multilevel management mode [5], thus forming a regulatory mechanism that is dominated by "command and control", assisted by "economic stimulus" and "public participation".

Germany implemented the Water Resources Management Act, emphasized on the principle of prevention, carried out the water control strictly follow the laws, and developed national laws of wastewater treatment technology criteria [6]. In 1998, Germany wastewater treatment rate has reached 99%, which was closely related to its rich management experience. German wastewater management took full advantage of wastewater industry association and intermediary organization, and played a role in assisting, supplementing and coordinating the macro management of the government. The quality of
Effluent from wastewater treatment plant was regularly issued on public network, and supervised by the whole society on the quality of water environment [7].

As early as 100 years ago, the Japanese government had developed, issued and implemented the laws about water resources protection in imitation of the legal systems of European and American countries. Those laws have also been constantly improved in practice. After World War II, Japan gradually stepped into a period of rapid economic growth. In order to prevent invasion of industrial wastewater into groundwater, the Japanese government rapidly introduced relevant laws to control water pollution. The Japanese government has made strict and explicit provisions on the protection of the water quality of rivers and lakes for domestic and industrial purpose [8]. In Japan, there is a clear division of responsibilities for the central and local governments on water resource management. The construction and management of wastewater facilities was undertaken by the Ministry of Land, and supervised by the Japan water resource agency [9]. In 2008, the industrial wastewater and domestic wastewater treatment rate in Japan exceeded 98% owing to the implementation of strict wastewater discharge standards and legal control [10].

Since developed countries proposed the concept of clean production for municipal wastewater treatment industry relatively early, there are many studies on related standards. There are about 51 standards related to wastewater treatment developed by these countries, including 2 general terminology standards, 23 technical specifications and standards, 13 equipment and device standards, 4 detection analysis method standards, and 9 management and evaluation standards, whilst evaluation standard for the operation performance of WWTP was not developed (see Table 1).

| No. | Standard No. | Standard Name (English) | Classification |
|-----|-------------|------------------------|----------------|
| 1   | DIN EN 1085 | Wastewater treatment - Vocabulary; Trilingual version | General terminology |
| 2   | DIN EN 16323| Glossary of wastewater engineering terms; Trilingual version | General terminology |
| 3   | BS 6297-2007| Code of practice for the design and installation of drainage fields for use in wastewater treatment | Technical specification |
| 4   | DIN EN 12255-1| Wastewater treatment plants - Part 1: general construction principles | Technical specification |
| 5   | DIN EN 12255-3| Wastewater treatment plants - Part 3: preliminary treatment | Technical specification |
| 6   | DIN EN 12255-4| Wastewater treatment plants - Part 4: primary settlement | Technical specification |
| 7   | DIN EN 12255-5| Wastewater treatment plants - Part 5: Lagooning processes | Technical specification |
| 8   | DIN EN 12255-6| Wastewater treatment plants - Part 6: Activated sludge process; | Technical specification |
| 9  | DIN EN 12255-7 | Wastewater treatment plants - Part 7: Biological fixed-film reactors | Technical specification |
|----|----------------|-------------------------------------------------|------------------------|
| 10 | DIN EN 12255-8 | Wastewater treatment plants - Part 8: sludge treatment and storage | Technical specification |
| 11 | DIN EN 12255-9 | Wastewater treatment plants - Part 9: odour control and ventilation | Technical specification |
| 12 | DIN EN 12255-1 | Wastewater treatment plants - Part 10: safety principles | Technical specification |
| 13 | DIN EN 12255-11 | Wastewater treatment plants - Part 11: general data required | Technical specification |
| 14 | DIN EN 12255-12 | Wastewater treatment plants - Part 12: Control and automation | Technical specification |
| 15 | DIN EN 12255-13 | Wastewater treatment plants - Part 13: Chemical treatment; Treatment of wastewater by precipitation/flocculation | Technical specification |
| 16 | DIN EN 12255-14 | Wastewater treatment plants - Part 14: Disinfection | Technical specification |
| 17 | DIN EN 12255-15 | Wastewater treatment plants - Part 15: Measurement of the oxygen transfer in clean water in aeration tanks of activated sludge plants | Technical specification |
| 18 | DIN EN 12255-16 | Wastewater treatment plants - Part 16: Physical (mechanical) filtration | Technical specification |
| 19 | BS EN ISO 28765-2011 | Vitreous and porcelain enamels—Design of bolted steel tanks for the storage or treatment of water or municipal or industrial effluents and sludges | Technical specification |
| 20 | ISO 16075-1:2016 | Guidelines for treated wastewater use for irrigation projects- Part 1:The basis of a reuse project for irrigation | Technical specification |
| 21 | ISO 16075-2:2016 | Guidelines for treated wastewater use for irrigation projects- Part 2:Development of the project | Technical specification |
| 22 | ISO 16075-3:2016 | Guidelines for treated wastewater use for irrigation projects- Part 3:Components of a reuse project for | Technical specification |
| No. | Standard | Description | Type |
|-----|----------|-------------|------|
| 23  | ISO 16075-4:2016 | Guidelines for treated wastewater use for irrigation projects- Part 4:Monitoring | Technical specification |
| 24  | ISO/AWI TS 24522 | Water quality event detection process: Guidelines for water and wastewater utilities | Technical specification |
| 25  | AC P16-635:2011 | Diagnosis repository for small wastewater treatment systems | Technical specification |
| 26  | DIN EN 12566-1 | Small wastewater treatment systems for up to 50 PT - Part 1: Prefabricated septic tanks | Equipment and device |
| 27  | DIN EN 12566-3 | Small wastewater treatment systems for up to 50 PT - Part 3: Packaged and/or site assembled domestic wastewater treatment plants | Equipment and device |
| 28  | DIN EN 12566-4 | Small wastewater treatment systems for up to 50 PT - Part 4: Septic tanks assembled in situ from prefabricated kits | Equipment and device |
| 28  | DIN-Fachbericht CEN/TR 12566-5-2009 | Small wastewater treatment plant systems for up to 50 PT - Part 5: pre-treated effluent filtration systems | Equipment and device |
| 30  | DIN EN 12566-6 | Small wastewater treatment systems for up to 50 PT - Part 6: Prefabricated treatment units for septic tank effluent | Equipment and device |
| 31  | DIN EN 12050- | Wastewater lifting plants for buildings and sites - Part 1: Lifting plants for wastewater containing faecal matter | Equipment and device |
| 32  | DIN EN 12050- | Wastewater lifting plants for buildings and sites - Part 2: Lifting plants for faecal-free wastewater | Equipment and device |
| 33  | DIN EN 12050- | Wastewater lifting plants for buildings and sites - Principles of construction and testing - Part 3: Lifting plants for wastewater containing faecal matter for limited applications; English version of DIN EN 12050-3 | Equipment and device |
| 34  | DIN EN 12050- | Wastewater lifting plants for buildings and sites - Part 4: Non-return valves for faecal-free wastewater and wastewater containing faecal matter | Equipment and device |
| No. | Standard Code | Description |
|-----|---------------|-------------|
| 35  | DIN EN 14801  | Conditions for pressure classification of products for water and wastewater pipelines |
| 36  | DIN EN 1124-4 | Pipes and fittings of longitudinally welded stainless steel pipes with spigot and socket for wastewater systems - Part 4: Components for vacuum drainage systems and for drainage systems on ships |
| 37  | ISO 21630:2007| Pumps — Testing — Submersible mixers for wastewater and similar applications |
| 38  | ISO 559:1991  | Steel tubes for water and sewage |
| 39  | FD T90-523-2:2008 | Water quality - Sampling guide for monitoring quality of waters in the environment - Part 2: sampling of wastewater |
| 40  | DIN EN ISO 18635:2017 | Water quality - Determination of short-chain polychlorinated alkanes (SCCPs) in sediment, sewage sludge and suspended (particulate) matter - Method using gas chromatography-mass spectrometry (GC-MS) and electron capture negative ionization (ECNI) |
| 41  | DIN 38414-13 | German standard methods for the examination of water, waste water and sludge; sludge and sediments (group S); detection of salmonellae in disinfected sewage sludge (S 13) |
| 42  | DIN EN ISO 22032 | Water quality - Determination of selected polybrominated diphenyl ethers in sediment and sewage sludge - Method using extraction and gas chromatography/mass spectrometry (ISO 22032:2006) |
| 43  | ISO 24521     | Activities relating to drinking water and wastewater services - Guidelines for the management of basic onsite domestic wastewater services |
| 44  | ISO 24523:2017| Service activities relating to drinking water supply systems and wastewater systems - Guidelines for benchmarking of water utilities |
| 45  | ISO 24511:2007| Activities relating to drinking water and wastewater services — Guidelines for the management of wastewater utilities and for the assessment of wastewater services |
| 46  | ISO 24512:2007| Activities relating to drinking water and wastewater services — Guidelines for the |
management of drinking water utilities and for the assessment of drinking water services

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|---|---|---|
| 47 | ISO 24510:2007 | Activities relating to drinking water and wastewater services — Guidelines for the assessment and for the improvement of the service to users | Management and evaluation |
| 48 | ISO 24518:2015 | Activities relating to drinking water and wastewater services - Crisis management of water utilities | Management and evaluation |
| 49 | ISO 24516-1:2016 | Guidelines for the management of assets of water supply and wastewater systems- Part 1: Drinking water distribution networks | Management and evaluation |
| 50 | ISO 24516-3:2017 | Guidelines for the management of assets of water supply and wastewater systems- Part 3: Wastewater collection networks | Management and evaluation |
| 51 | ISO/DIS 24516-4 | Guidelines for the management of assets of water supply and wastewater systems- Part 4: Wastewater treatment plants (including pumping and sludge treatment) | Management and evaluation |

Among them, the requirements for the process technology of activated sludge are mentioned in DIN EN 12255-6 [11]. According to ISO 24511:2007, the management evaluation of wastewater utilities and service include four types of indexes: public health and safety, occupational health and safety, environmental protection and sustainable development. However, no further refinement was made for these four types of indexes, and no specific requirement is made for the calculation and evaluation methods of relevant indexes [12].

2. Standards and Regulations Related to Operation of Wastewater Treatment Plant in China

During the 13th Five-Year Plan period, the Chinese government successively issued various of policies such as the "Water Pollution Prevention Action Plan", the "13th Five-Year Plan for Energy Conservation and Emission Reduction", the "13th Five-Year Plan for Energy Conservation and Environmental Protection Industry Development", and the "13th Five-Year Plan for National Municipal Wastewater Treatment and Recycling Facilities Construction, and "Opinions on Comprehensively Strengthening Ecological Environment Protection and Pollution Prevention and Control". These policies have emphasized on comprehensive control of pollutant emissions, with the goal of national chemical oxygen demand, the total emissions of ammonia nitrogen, sulfur dioxide and nitrogen oxides will be controlled at 2001 million tons, 2.07 million tons, 15.8 million tons and 15.74 million tons respectively by the end of 2020, reduce 10%, 10%, 15% and 15% respectively compared with the data in 2015. In the meantime, the government will also strengthen the comprehensive improvement of domestic pollution sources, upgrade the wastewater treatment facilities, improve the pipe network system, and improve the sewage collection and treatment capacity. Furthermore, it will also be of significance to develop the national sewage discharge standards, strengthen the operation supervision, and realize the comprehensive discharge of the sewage treatment plant. The safe treatment and disposal of sludge from sewage treatment plants will also be focused to prevent secondary pollution. By 2020, all counties and key towns in China will have sewage treatment capacity and the sewage treatment rates of cities and rural areas will reach 95% and 85% respectively.

In recent years, China has increased the control degree of water pollution, and organized various comprehensive management of water pollution with the construction of large-scale wastewater treatment projects. The Public-Private Partnership (PPP) model of the sewage treatment industry has
begun to appear, and the infrastructure of the sewage treatment facilities by government and companies has gradually increased since 2014. From 2011 to 2015, industrial wastewater discharge in China continuously decreased, while domestic sewage discharge increased year by year. In 2015, the total sewage treatment capacity was 42.9 billion cubic meters, the urban sewage treatment rate reached 91.9%. With the construction and operation of several large-scale WWTPs, such as Hangzhou Sibao Wastewater Treatment Plant, Beijing Gaobeidian Wastewater Treatment Plant and Shenyang North Wastewater Treatment Plant, China's sewage treatment enterprises have begun to comprehensively improve the operational efficiency integrating with the advanced world level. Among the WWTPs that has been put into use in China, WWTPs which satisfied requirements of first-class standard, accounting for 56% of the total treatment capacity, including 12% of the first-class A emission standard that has the function of nitrogen and phosphorus removal and 44% of the first-class B emission standard. Meanwhile there are 35% of the WWTPs satisfied requirements of secondary-class emission standard. However, these WWTPs do not have the function of nitrogen and phosphorus removal. As the national standards for the water quality is becoming more and more stringent, WWTPs in China must enhance the removal rate of the pollutants. Some WWTPs designed according to the first-class B emission standard must increase to A level while WWTPs constructed according to the secondary-class emission standard must upgrade to first-class A or B level. At present, many cities, such as Beijing, are implementing the effect and efficiency improvement. In addition, based on the need for sustainable recycling of water resources, in some water-deficient areas, such as the Northwest of China, the existing sewage treatment enterprises are also in urgent need of upgrading.

According to the policy requirements, combined with the development trend of the wastewater treatment industry, the framework of standard system for wastewater treatment is primarily established in order to solve the long-standing problems such as standard deficiency, and to effectively reflect the real demand of environmental protection industry.

As shown in Figure 1, the first level of the current standard system for WWTPs is consisted of six aspects, including discharge standard sub-systems, engineering standard sub-systems, monitoring and analysis standard sub-systems, equipment and product standard sub-systems, resource recycling standard sub-systems and evaluation management standard sub-systems. The second level includes a total of 30 existing national standards for municipal wastewater treatment which are demonstrated in Table 2 and Figure 2 illustrated the standard type distribution.
## Table 2 List of relevant national standards for wastewater treatment in China

| No. | Standard No. | Standard Name | Classification |
|-----|--------------|---------------|----------------|
| 1   | GB 18918-2002| Discharge standard of pollutants for municipal wastewater treatment plant | Discharge |
| 2   | GB 8978-1996 | Integrated wastewater discharge standard | Discharge |
| 3   | GB/T 31962-2015| Wastewater quality standards for discharge to municipal sewers | Discharge |
| 4   | GB/T 24188-2009| Quality of sludge from municipal wastewater treatment plant | Discharge |
| 5   | GB/T 18919-2002| The reuse of urban recycling water--Classified standard | Wastewater recycling |
| 6   | GB/T 18920-2002| The reuse of urban recycling water--Water quality standard for urban miscellaneous water consumption | Wastewater recycling |
| 7   | GB/T 18921-2002| The reuse of urban recycling water--Water quality standard for scenic environment use | Wastewater recycling |
| 8   | GB/T 19772-2005| The reuse of urban recycling water--Water quality standard for groundwater recharge | Wastewater recycling |
| 9   | GB/T 19923-2005| The reuse of urban recycling water--Water quality standard for industrial use | Wastewater recycling |
| 10  | GB 20922-2007| The reuse of urban recycling water--Quality of farmland irrigation water | Wastewater recycling |
| 11  | GB/T 25499-2010| The reuse of urban recycling water--Water quality standard for green space irrigation | Wastewater recycling |
| 12  | GB/T 19570-2004| Engineering technical specification for wastewater pipeline discharging into the sea | Technical specification |
| 13  | GB/T 21795-2008| Testing of chemicals - Simulation test Aerobic sewage treatment - Biofilms | Technical specification |
| 14  | GB/T 21829-2008| Chemicals--Simulation Test--Aerobic Wastewater Treatment--Activated Sludge Units | Technical specification |
| 15  | GB/T 21873-2008| Rubber seals--Joint rings for water supply, drainage and sewerage pipelines--Specification for materials | Technical specification |
| 16  | GB/T 22103-2008| Technology code for municipal wastewater reuse in agriculture | Technical specification |
| 17  | GB/T 28742-2012| Wastewater treatment equipment for prevention and treatment of water pollution | Technical specification |
| 18  | GB/T 28743-2012| Wastewater treatment vessel equipment--General technical requirements | Technical specification |
| 19  | GB 50335-2002| Code for design of municipal wastewater reclamation and reuse | Technical specification |
20. GB/T 23484-2009: The disposal of sludge from municipal wastewater treatment plant -- The classification (Sludge disposal)

21. GB/T 23485-2009: The disposal of sludge from municipal wastewater treatment plant -- Quality of sludge for co-landfilling (Sludge disposal)

22. GB/T 23486-2009: The disposal of sludge from municipal wastewater treatment plant -- Quality of sludge used in gardens or parks (Sludge disposal)

23. GB 24188-2009: Quality of sludge from municipal wastewater treatment plant (Sludge disposal)

24. GB/T 24600-2009: The disposal of sludge from municipal wastewater treatment plant -- Quality of sludge used in land improvement (Sludge disposal)

25. GB/T 24602-2009: The disposal of sludge from municipal wastewater treatment plant -- Quality of sludge used in separate incineration (Sludge disposal)

26. GB/T 25031-2010: The disposal of sludge from municipal wastewater treatment plant -- Quality of sludge used in making brick (Sludge disposal)

27. GB/T 26081-2010: Ductile iron pipes, fittings and accessories for sewage applications (Equipment and device standard)

28. GB/T 24674-2009: Waste submersible motor-pumps (Equipment and device standard)

29. GB/T 28743-2012: Sewage treatment vessel equipment -- General technical requirements (Equipment and device standard)

30. GB 32031-2015: Minimum allowable values of energy efficiency and energy efficiency grades for waste submersible motor-pumps (Equipment and device standard)

**Figure 2 Standard Type Distribution of Relevant National Standards for Wastewater Treatment**
As shown in Table 2 and Figure 2, at present, China has 30 national standards related to wastewater treatment, including 4 discharge standards, 8 technical specifications standards, 4 equipment and device standards, 7 wastewater recycling standards, and 7 sludge disposal standards. Standard quantity is less and unevenly distributed; evaluation management standard sub-systems are blank.

In terms of the operation performance evaluation of WWTP, the drainage professional committee of China Urban Water Association conducted investigation and assessment on the operation of WWTPs in 2008. WWTPs in China were divided into large, medium and small scales, and evaluations were carried out from the aspects of wastewater treatment capacity, sludge treatment condition, operational cost, safety management, etc. However, as the evaluation index system for the operation performance of WWTPs has not been established, the operational performance of municipal WWTPs are difficult to evaluate scientifically, and the operation efficiency is difficult to guarantee as a result.

In summary, among the current national standard system of municipal wastewater treatment system, discharge standard sub-systems, engineering standard sub-systems, equipment and device standard sub-systems and resource recycling standard sub-systems in the standard system are unevenly distributed; monitoring and analysis standard sub-systems and evaluation management standard sub-systems are blank, and there is no relevant national standard. The standard does not play a significant role to regulate and lead the development of the industry. Therefore, attentions need to be paid on improvement of the systemativeness and manageability of the entire national standard system. For the operation performance evaluation of the municipal WWTPs, a scientific performance evaluation standard system has not been established. With the development of economic development and public awareness of energy conservation and environmental protection, it is urgent to have a set of national standards that are scientific and reasonable and operable to fill in the gaps in the evaluation standards for the operation performance of municipal WWTPs, improve the municipal wastewater treatment standard systems, summarize and establish an objective and relatively quantitative method for evaluating the operation of wastewater treatment plants, and propose improvement measures for WWTPs with unsatisfactory operational performance and efficiency.

3. Conclusion
1. There are about 51 standards related to wastewater treatment developed by these countries, including 2 general terminology standards, 23 technical specifications and standards, 13 equipment and device standards, 4 detection analysis method standards, and 9 management and evaluation standards, and there is no standard for the operation performance evaluation of WWTP. Some standards have suggested that the management and service evaluation of wastewater treatment utilities should include four indexes of public health and safety, occupational health and safety, environmental protection and sustainable development, but no further refinement was made for the four types of indexes, and no specific requirement was made for the calculation and evaluation methods of relevant indexes.
2. China has 30 national standards related to wastewater treatment, including 4 discharge standards, 8 technical specifications standards, 4 equipment and device standards, 7 wastewater recycling standards, and 7 sludge treatment standards. Standard quantity is less and unevenly distributed; evaluation management standard sub-systems are blank, and there is no relevant national standard.
3. The standard does not play a significant role to regulate and lead the development of the industry. Therefore, attentions need to be paid on improvement of the systemativeness and manageability of the entire national standard system. There is an urgent need to have a set of national standards to fill in the gaps in the evaluation standards for the operation performance of WWTPs and to improve their operational performance and efficiency.

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