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Evaluation of textile industry wastewater treatment and reuse in China

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ABSTRACT

Textile industry is a significant water consumer and wastewater discharger. China has been the largest textile producer in the world over the years. Textile wastewater has become an important source of pollution that affects the water environments in China. This paper mainly discusses the current status and challenges of the water pollution control in Chinese textile industry, including wastewater discharge, wastewater characteristics, discharge standards, wastewater treatment and reuse technologies, costs, and emerging contaminants. The wastewater treatment and reuse technologies in Chinese textile industry have been developed significantly, but the wastewater management has been imprudent. With the consumers' growing demands for novel textile products and the stricter environmental protection requirements, Chinese textile water pollution control needs a systematic solution. To effectively improve pollution control and environmental sustainability, it is necessary to change the end-of-pipe control to the whole process design and control.

Keywords: Environmental management; Industrial wastewater treatment; Discharge standards; Water quality requirements; Cost of construction and operation

1. Textile production in China

Chinese textile industry occupies an essential position in global textile trading [1]. At present, China is the world's largest producer of fabrics such as cotton yarn, cotton cloth, woolen fabric, silk fabric, chemical fiber, and clothing [2,3]. Textile industry is the pillar industry of China [4]. In 2015, the total output of printed and dyed fabrics in China was 50.953 billion meters, while the five provinces Zhejiang, Jiangsu, Fujian, Guangdong, and Shandong in eastern coastal area accounted for 95.79% of the total output of the country [5].

According to *Environmental Statistics Annual Reports* issued by the Chinese Ministry of Environmental Protection (MEP) from 2006 to 2015, the total amount of wastewater and pollutants discharged by Chinese textile industry was huge, as shown in Fig. 1. The discharge volume of textile wastewater reached the peak in 2010, and the average annual increase during 2006–2010 was 5.54%. Since 2011, the discharge volume of wastewater decreased yearly, with an average annual decline of 6.52% during 2011–2015. Meanwhile, discharge of chemical oxygen demand (COD), (COD values throughout the whole text were tested using dichromate as oxidants) and NH_3–N also decreased annually. Since the output of textiles is increasing yearly, pollutants per unit textile produced exhibit even faster declines. This can be attributed to the stricter national energy-saving and waste-reduction requirements. However, according to the annual report in 2014, among the 41 main industrial sectors of China, the textile industry still ranked the third place for wastewater discharge, the fourth place for COD discharge, and the third place for NH_3–N discharge.

The dyeing and printing factories in China mainly adopt wet processing method, including pretreatment, dyeing, and finishing processes [6]. According to the census data of 3,821 textile mills from Chinese MEP, in 2013, textile wet processing contributed to nearly 70% of the total textile wastewater discharge in China. Compared with the figure 80% in 2004, it implied that water-saving measures in textile production had achieved notable results. However, textile wet processing is still the main source of wastewater discharge in the industry

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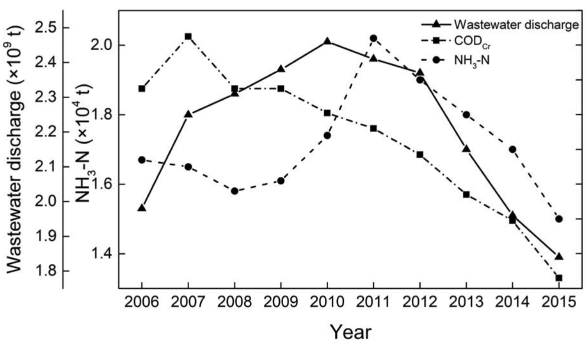

Fig. 1. Discharge of wastewater, COD, and NH_3–N from Chinese textile industry during 2006–2015 according to Environmental Statistics Annual Report by Chinese MEP.

and also the focus of pollution control in the future, according to *the Action Plan for Prevention and Treatment of Water Pollution* issued by Chinese government in 2015.

2. Characteristics of textile wastewater

Textile wet processing consumes enormous amounts of freshwater, producing large volumes of textile wastewater [7]. The pollutants in textile wastewater are mainly attributed to the fiber materials, dyes, and chemicals added during the production processes. The fiber materials involved in textile industry are mainly cotton, wool, linen, silk, and chemical fibers [8]. Due to the exposure to chemicals such as surfactants and concentrated alkaline, these fibers can be structurally damaged and shed into effluents by mechanical actions, leading to increase of suspended solids (SS) in the wastewater. Common dyes include direct dyes, reactive dyes, vat dyes, sulfur dyes, acid dyes, disperse dyes, azo dyes, and cationic dyes [9]. Residual dyes in the effluents result in significant increase of COD and color. Especially, some of them such as azo dyes are highly toxic and carcinogenic [10]. Meanwhile, in order to improve dye uptake, large amounts of inorganic salts are added as accelerants in the dyeing processes, most of which are discharged in rinsing process, resulting in high total dissolved solids (TDS) in the effluents [9,11]. The main sources and pollutants of wastewater from different textile productions are shown in Table 1.

According to the census data of 3,821 mills from Chinese MEP in 2013, typical characteristics of wastewater from different textile productions are shown in Table 2. Generally, with the renewal of dyeing technology and equipment, and the enhancement of Chinese environmental protection requirements, water-saving measures are promoted in textile production, leading to significant increase of the concentration of these pollutants [12].

3. Discharge standards of textile wastewater in China and problems

Since January 1st, 2013, China started to implement the *Discharge Standard of Water Pollutants for Dyeing and Finishing in Textile Industries* [13]. The standard (Table 3) specified two discharge limits, i.e., indirect limits and direct limits. Indirect limits refer to the discharge limits of textile mills to public or centralized wastewater treatment plants (WWTPs). Direct limits are the discharge limits of textile mills directly to the environment. The standard sets stricter requirements for the final effluents than before and also stricter discharge limits of COD, biochemical oxygen demand (BOD_5), SS, and NH_3–N. It added requirements that sulfides, anilines, and Cr(VI) should not be detected. Absorbable organic halogen (AOX) limit was added in order to enhance the control of toxic and hazardous pollutants. In addition, total nitrogen (TN) and total phosphorus (TP) discharge limits were implemented to alleviate water eutrophication.

Fig. 2 shows a comparison of COD discharge limits for textile wastewater in different countries/areas. The above Chinese standard was almost the most stringent standard for textile wastewater worldwide.

Sources:

- Japan: National Effluent Standards, http://www.env.go.jp/en/water/wq/nes.html;
- Germany: Ordinance on Requirements for the Discharge of Waste Water into Waters, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Appendix 38 and Appendix 57;
- Europe: Council Directive of 21 May 1991, concerning urban waste water treatment, 91/271/EEC, Reference document on Best Available Techniques for the manufacture of Organic Fine Chemicals, European Commission, Integrated Pollution Prevention and Control;
- USA: Part 410-Textile Mills Point Source Category, COD of Federal Regulations.

Table 1
Main sources and pollutants of wastewater from different textile productions

Textile products	Main sources	Main pollutants
Cotton, chemical fiber, and their blended fabric	Desizing, scouring, bleaching, mercerizing, dyeing, printing, finishing	Pulp, dyes, additives, fiber wax, pectin, heavy metals, oil, chemical fiber degradation products
Knitting	Alkali shrinkage, scouring, bleaching, dyeing, finishing	Wax, dyes, additives, oil
Woolen	Scouring, shredding, dyeing, finishing	Lanolin, dyes, additives, fibers
Linen	Degumming, dyeing, finishing	Lignin, pectin and other ramie gum, dyes, additives
Silk	Silk, scouring (degumming), dyeing, finishing	Sericin, dyes, additives

Table 2
Characteristics of textile wastewater from different textile productions

	Product types	pH	Colority * (multiple)	BOD_5 (mg/L)	COD (mg/L)	SS (mg/L)
Woven cotton and cotton blend fabrics	Cotton dyeing and printing	10.0–12.0	400–800	300–500	1,500–3,000	200–500
	Blended cotton dyeing and printing	9.5–12.0	400–800	300–500	1,500–3,000	200–500
	Cotton bleaching and dyeing	10.0–12.0	300–500	200–300	800–1,200	200–400
	Blended cotton bleaching and dyeing	10.0–12.0	200–300	200–300	1,000–1,500	100–400
Knitted cotton and cotton blend fabrics	Cotton garment	9.0–11.5	200–500	200–350	500–1,000	150–300
	Polyester-cotton garment	8.5–10.5	200–500	200–450	500–1,000	150–300
	Main cotton, less acrylic	9.0–11.0	200–400	150–300	400–950	150–300
	Stretch sock	7.0–8.5	200–200	100–200	400–700	100–300
Wool fabrics	Scouring	10.0–12.0	–	6,000–12,000	15,000–30,000	8,000–12,000
	Neutralization after carbonization	5.0–6.0	–	80–150	300–500	1,250–4,800
	Carded wool	6.0–7.0	100–200	150–300	500–1,000	200–500
	Worsted wool	6.0–7.0	50–80	80–180	350–600	80–300
	Knitting wool	6.0–7.0	100–200	70–120	300–450	100–300
Silks fabrics	Silk dyeing	7.5–8.0	100–200	250–350	500–1,000	100–150
	Silk printing	6.0–7.5	50–250	200–300	500–1,000	100–150
	Blended silk printing	6.5–7.5	200–500	100–200	500–800	100–150
	Blended silk dyeing	7.0–8.5	300–400	90–180	500–750	100–150
	Silk scouring	7.5–8.0	–	200–300	500–1,000	100–180
Chemical fabrics	Dacron (with alkali minimization)	10.0–13.0	100–200	350–750	1,500–3,000	100–300
	Dacron (without alkali minimization)	8.0–10.0	100–200	250–350	800–1,200	50–100
	Acrylic	5.0–6.0	–	240–260	1,000–1,200	–

*Colority is the indication of color in Chinese standards. Dilute the sample with optically pure water until the color is barely visible compared with optically pure water. The value of colority is the dilution multiple. The unit of colority is multiple.

The strict discharge standard showed a strong determination of Chinese government to control environmental pollution. However, this standard caused problems in its implementation, mainly in the following aspects:

- indirect discharge limits

The standard set a stricter indirect discharge limit for each parameter, leading to lower concentrations of pollutants in the influents of existing public or centralized WWTPs. It also changed the composition of wastewater. As a result, (1) textile mill owners must upgrade existing treatment facilities to meet the indirect discharge limits and (2) it might cause many facilities and equipment of public or centralized WWTPs to be unemployed, resulting in serious waste of facilities and equipment. In addition, existing facilities might not be able to achieve the desired treatment efficiency due to the change of wastewater composition. In order to meet the new standard, most mills need large-scale reconstruction of water treatment facilities; however, the land for reconstruction is often too difficult to acquire in China.

- “not detected” requirements

The standards set “not detected” requirements for Cr(VI), aniline, and sulfide, which resulted in inconsistencies with other standards. The detection of Cr(VI) is according to the standard method *Water Quality—Determination of Chromium(VI)—Flow Injection Analysis(FIA) and Diphenylcarbazide Spectrometric Method* [14], but the minimum detectable level by this method is 0.004 mg/L. Moreover, since the allowable limit of Cr(VI) in the *Standards for Drinking Water Quality* is 0.05 mg/L [15], the “not detected” requirements for Cr(VI) lacked a reasonable basis.

The standard also required that aniline should not be detected. Aniline is used to synthesize azo dyes by coupling with other components after aniline diazotization or directly through its amino activity [16]. Therefore, free aniline compounds are present in azo dye products and may end up in textile wastewater when azo dyes are used in dyeing processes. In addition, biodegradation of unfixed azo dyes during wastewater treatment can lead to an increase of aniline in the effluents [17,18]. Similarly, the sulfide in wastewater mainly comes from sulfur dyes, sulfates, and sulfonates used in dyeing and finishing [19]. In other industrial wastewater discharge standards in China, though, there is no such requirement as “not detected” for the above pollutants. For instance, as stated in the *Emission Standard of Pollutants for Petroleum Chemistry Industry* [20], the special direct discharge limits of Cr(VI), anilines, and sulfides in the treated petrochemical industrial wastewater are 0.5 mg/L.

In response to these problems in the implementation of the discharge standard, MEP successively promulgated in 2015 the *Amendment to the Discharge Standard of Water*

Table 3
The discharge standard for textile wastewater in China announced on January 1st, 2013 (units: mg/L, except pH and colority)

	Parameters	Indirect discharge		Direct discharge	
		Limits	Special limits*	Limits	Special limits
1	pH	6–9	6–9	6–9	6–9
2	COD	200	80	80	60
3	BOD_5	50	20	20	15
4	SS	100	50	50	20
5	Colority	80	50	50	30
6	NH_3–N	20	10	10	8
7	TN	30	15	15	12
8	TP	1.5	0.5	0.5	0.5
9	ClO_2	0.5	0.5	0.5	0.5
10	AOX	12	8	12	8
11	Sulfide	0.5	ND**	0.5	ND
12	Anilines	ND	ND	ND	ND
13	Cr(VI)	ND	ND	ND	ND

*Special discharge limits are implemented in regions where the land is over developed, the environmental carrying capacity begins to decrease, or regions where the environment capacity is small the ecological environment is fragile and severe environmental pollution problems are inclined to occur.
**ND: not detected.

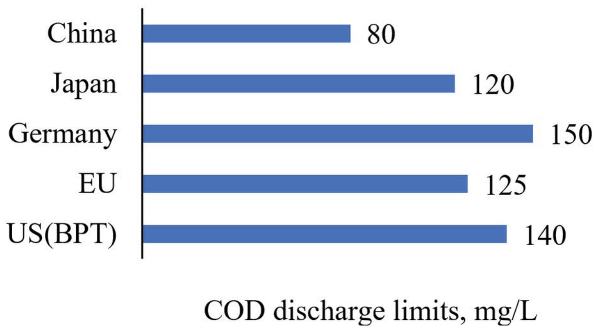

Fig. 2. COD discharge limit of textile wastewater worldwide.

Pollutants for Dyeing and Finishing in Textile Industries [21] and the *Announcements on Adjusting the Implementation Requirements of Some Indicators of Discharge Standard of Water Pollutants for Dyeing and Finishing in Textile Industries* [22]. The former adjusted the indirect discharge limit of COD to 500 mg/L and BOD_5 to 150 mg/L and also added the control of total antimony with its direct and indirect discharge limits both set at 0.1 mg/L. The latter announcement proposed to suspend the discharge requirements for aniline and Cr(VI).

Consequently, it is suggested that in the establishment of textile discharge standards, the characteristics of production, the environmental impact of pollutants discharged, the demand of water environmental protection, the technical and economic feasibility, and also the harmonious development of various industries should all be considered. Otherwise, the effective implementation of the standards will be affected.

4. Textile wastewater treatment

4.1. Typical technologies

Production of different textile orders often adopts different production processes, dyes, and auxiliaries, leading to drastic changes in wastewater characteristics. Therefore, most textile mills in China collect and treat wastewater with different characteristics separately. Lightly polluted wastewater is mainly rinsing wastewater, accounting for 25%–30% of the total wastewater volume [23]. Wastewater containing highly concentrated pollutants or special pollutants needs pretreatment to meet the corresponding water quality requirements before the wastewater is discharged into the following treatment units [24]. Fig. 3 exhibits a general textile wastewater treatment process. Physicochemical treatments are mainly coagulation and flotation. They are largely applied in primary treatment because of their cost effectiveness in decolorization [25]. Improvements for these two technologies have been reported in laboratory scale. Ke et al. used foam separation method to treat actual textile wastewater. The color removal efficiency reached 88.9%, and the residual dye concentration met the national discharge standard [26]. Electrocoagulation was applied to treat textile wastewater collected from singeing to finishing processes and removed 75.45% COD and 84.62% color after 25 min [27]. Wu et al. combined coagulation and flotation to treat wastewater from textile production and removed 68% COD [28].

Many mills tend to adopt anaerobic hydrolysis acidification as pretreatment to improve the efficiency of subsequent aerobic treatment [29,30]. Anaerobic baffled reactor (ABR) was reported to be an efficient hydrolysis technique for textile wastewater [31]. When treating highly concentrated scouring wastewater, silk scouring wastewater, and hemp degumming wastewater, ABR could remove over 50% of the organic pollutants [32]. Aerobic treatments are generally activated sludge and biofilm. When denitrification was needed, denitrification and nitrification processes (for instance, anoxic/oxic (A/O) process), sequencing batch reactor (SBR), and oxidation ditch technology could be applied [33]. Biological treatment was rarely reported individually in textile wastewater treatment but in conjunction with other technologies because individual technology is inefficient in decolorization. It was reported that coagulation and sedimentation + cyclic activated sludge system + sand filtration processes were stable and cost effective for treating bleaching and dyeing wastewater [34]. In pilot scale, other combinations such as membrane bioreactor (MBR) + nanofiltration (NF) [35], moving bed biofilm reactors + ozonation [36], biological contact + ozonation [37], A/O MBR [38], coagulation + hydrolysis

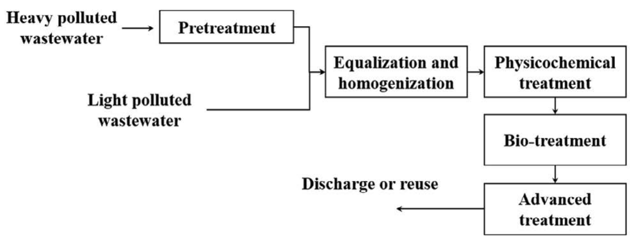

Fig. 3. General textile wastewater treatment process in China.

acidification + multilevel contact oxidation [39], and biological aerated filter + ozonation have been reported to achieve efficient removal to meet the discharge limits [40]. Membrane technology is largely applied in China. It was reported that by 2015, the total capacity of the membrane technology in dyeing wastewater treatment in China was about 662,000 m/d and the number of applications was 128 [41]. Ultrafiltration (UF) + reverse osmosis (RO) was the most commonly applied membrane technology in textile wastewater treatment [41].

4.2. Water reuse and requirements

In recent years, water reuse in textile production has developed rapidly to reduce the water overconsumption [42]. Water reuse requirements are generally promoted based on water usage. In the standard *Wastewater Treatment Project Technical Specification for Dyeing and Finishing of Textile Industry* issued by Chinese MEP, the reclaimed water can be used as process water, rinse water, dyeing water, and also for flushing, vehicle washing, and greening lands based on different water quality requirements. For example, Table 4 displays the reuse water quality for rinse suggested in the standard.

To improve reuse efficiency and save costs, water reuse requirements are also promoted based on water source. Lightly polluted wastewater is previous water source for water reuse. Consequently, source-separated reuse systems are largely developed. Rui et al. established a multilevel reuse system with source separation process for textile wastewater treatment. The evaluation system was based on 6 water quality parameters including COD, BOD_5, color, TDS, TP, and TN. It was reported that the water reuse ratio using the multilevel reuse system increased to 62% in a case study where freshwater consumption was 3,000 m/d [43]. For lightly polluted wastewater treatment, a simple combination of coagulation and ozonation could reach 71% COD removal and 98% color removal [23]. Our previous study also established a scheduling system with a database coupling with dynamic genetic algorithm to optimize the water reuse based on separated system [24]. Jin et al. promoted a mathematical programming model for water integration in the dyeing and finishing industrial park (DFIP) based on water separation and achieved 73% water recovery in the DFIP network [44].

In order to meet the water quality requirements for reuse, advanced treatment is required to ensure the reliability of the reclaimed water quality. Currently in China, advanced catalytic oxidation [45,46], ozonation combined with biological aerated filter [47,48], electrochemical oxidation, and membrane filtration [49] are common advanced technologies for textile wastewater reuse [50]. Biological activated carbon could stably treat the secondary effluents of textile wastewater during a 6-month continuous operation, and the effluents met the requirements to be reused in degumming, desizing, mercerizing, and bleaching [51]. A combination of MBR and NF was reported to provide efficient removal of COD, total organic carbon, color, and turbidity with high water recovery [35]. Other membrane technologies included UF + RO, UF + electrodialysis, or UF + RO + mixed ion exchange bed [52–54]. Using membrane technology in a pilot scale of 600 m/d, the treated effluent quality satisfied the water quality requirement for dyeing process [55].

Table 4
Reuse water quality requirements for rinse

Parameters	Value	Parameters	Value
Colority	25	Transparency (cm)	≥30
Total hardness (as $CaCO_3$, mg/L)	450	SS (mg/L)	≤30
pH	6.0–9.0	COD (mg/L)	≤50
Fe (mg/L)	0.2–0.3	Conductivity (μs/cm)	≤1,500
Mn (mg/L)	≤0.2		

4.3. Sludge treatment and disposal

The purpose of sludge treatment and disposal is reduction, stabilization, harmlessness, and comprehensive utilization of the sludge. In order to reduce sludge volume and subsequent treatment difficulties, sludge thickening is generally required. Thermal alkaline and micro-electrolysis were applied in sludge pretreatment to improve the dewaterability [56,57]. The sludge should be further dewatered to meet the requirements of subsequent sludge disposal. Liu et al. made a comparison of sludge dewatering processes in terms of environmental and economic factors. Broken cell composite reagent was reported to be more cost efficient than lime-ferric iron reagent and ultrahigh-pressure elastic press in the engineering practices [58]. Ultrasound-assisted Fenton-treated sludge was advantageous in sludge disintegration under conditions when the ultrasonic density was 0.12–0.16 W/mL and pH ≤ 3 [59]. The major phase for sludge treatment is anaerobic digestion. Xiang et al. compared alkaline, acid, thermal, and thermal alkaline pretreatment for anaerobic digestion. Thermal alkaline pretreated textile dyeing sludge performed best in solubilization, and thermal pretreated sludge showed highest total methane production [57].

Pyrolysis of textile dyeing sludge to produce fuels is a potential method for sludge utilization. Hedong et al. investigated an auger pyrolyzer under microwave irradiation for pyrolysis of textile dyeing sludge and produced various products including gas, oil, and sludge carbon using different additives [60,61]. The sludge disposal in China is mainly by incineration and landfill [61]. It was reported that aluminum could be recovered from textile sludge incineration residues after acidification [62].

In addition, some hazardous pollutants have caught attention in textile dyeing sludge such as aniline and polycyclic aromatic hydrocarbons (PAHs) [63,64]. Wang et al. reported that sigma PAH concentration in the dry textile sludge was 2,996.10 ± 151.0 ng/g and the landfill and agricultural reuse of the textile dyeing sludge might cause potential risk to ecosystem [63]. Ultrasound-Fenton could degrade 70%–80% PAHs in textile dyeing sludge [65,66]. For aniline, ultrasound-Mn(VI) was reported to successfully remove 85.5% aniline in the sludge [64].

4.4. Cost of construction and operation

The authors surveyed typical textile wastewater treatment facilities in China that were built in the recent five years and calculated the referable range of construction costs and operational costs by the cost estimation method in literature [67]. The construction and operational costs of textile wastewater treatment facilities are varied with textile production scale, different treatment processes, and effluent quality requirements, as shown in Table 5. The construction costs include civil construction, equipment supply and installation, auxiliary buildings, contractors' overhead, and profits. The operational costs include personnel, maintenance (repairs on mechanical, electrical, electronic, and civil parts and minor or major replacements like small or large parts for pumps, blowers, motors etc.), energy consumption, chemicals and materials, disposal (the costs for disposal consist of the disposal of screenings, sand, and waste), and miscellaneous (internal laboratory services, pollution charges, administrative cost, etc.).

5. Emerging chemical contaminants and removal

Hazardous contaminants can be introduced into textile wastewater during production processes, such as perfluorinated and polyfluorinated chemicals, PAHs, and heavy metals [68–70]. However, the textile wastewater management of China is not developed enough to include most of them. Nonylphenol (NP), aniline, and antimony are three hazardous contaminants that are largely used in Chinese textile industry. They have caused a wide range of social concerns in China and are gradually being incorporated into the wastewater quality management systems.

5.1. NP Ethoxylates and NP

NP ethoxylates (NPEOs) and its degradation products NPs are often found in textile wastewater, threatening public health [71,72]. Surfactants account for 80% of the ingredients of auxiliaries used in textile processes. Textile production is significantly dependent on the properties of surfactant, requiring its excellent wetting, emulsification, infiltration, dispersion performance, solubilization and washing abilities, and cost effectiveness. NPEOs are widely used in Chinese textile industry due to these properties [73].

Toxic and hazardous chemicals present in textile auxiliaries are banned or restricted by the regulations in many countries and areas. For example, the EU REACH regulation, which has been officially implemented for many years, restricted the use of NPEOs in 2003, namely, the 2003/53/EG law. In the EU, NPEOs were substituted by other environmental friendly surfactants (mainly alcohol ethoxylates) [74]. However, at present, there are few available replacements for NPEOs in developing countries such as China because these developed substitutes for NPEOs are too costly to be completely applied in Chinese textile mills. Many countries in the world have so far not completely stopped using NPEOs, and their traces in water can still be found [75,76]. Based on current researches, the removal efficiency of NPEOs and NPs can reach above 90% using biological treatment technologies combined with anaerobic and aerobic units [77]. Complete degradation of NPEOs and NPs can be achieved with further advanced oxidation technologies [78,79].

5.2. Aniline

The aniline in wastewater comes from dyes. Commonly used aniline dyes include acid dyes, direct dyes, reactive dyes, vat dyes, paints, and fluorescent brighteners. Reactive dyes synthesized through para-esters can produce anilines from residual dyes in the subsequent treatment processes [80]. Aniline in textile wastewater will not exceed the standards as long as the dye production factories do not produce aniline dyes and textile mills do not use aniline dyes.

Aniline with biological toxicity is difficult to be completely removed by biological treatments. To remove aniline, powdered activated carbon adsorption in the UF section could be employed after biological treatments [81]. The activated carbon could be pumped into the primary sedimentation tank to be mixed with the chemical sludge to further enhance the adsorption effect, which could not only remove COD, color, and aniline, but also improve the primary sedimentation efficiency [82].

5.3. Antimony

Chinese regulation stipulates that the maximum allowable concentration of antimony in surface water is 0.005 mg/L. Antimony in textile wastewater is unrelated to the

Table 5
Cost summary of construction and operation for textile treatment

Influent COD (mg/L)	Effluent COD (mg/L)	Descriptions*	Land occupied (m/m·d)	Construction cost (USD**/m·d)	Operational cost (USD/m·d)
2,000–3,000	500	Discharged into public or centralized WWTP	0.5–0.7	221.3–295.0	0.15–0.22
2,000–3,000	200	Indirect discharge, discharged into public or centralized WWTP	1.0–1.5	368.8–442.5	0.30–0.37
2,000–3,000	80	Indirect discharge under special limits, advanced treatment required (filtration, aeration biofilter, MBR, or ultralow-load operation)	2.0–3.0	590.0–737.5	0.59–0.74
2,000–3,000	60	Direct discharge under special limits, advanced treatment followed by activated carbon adsorption, catalytic oxidation, or membrane technology (UF, RO)	3.0–3.5	881.3–958.8	0.89–1.18

*Capacity of the cases: 3,000 m/d, being averaged scale in textile mills.
**The exchange rate on July 25, 2018: 1 YuanRMB ≈ 0.1475 USD.

production processes in textile mills, while it mainly comes from polyester in the greiges which are not yet dyed [83]. In the production of polyester, the synthesis of terephthalic acid and ethylene glycol requires antimony-containing catalysts, such as antimony acetate and ethylene glycol antimony, which are currently the most efficient and economical catalysts with nearly 100% conversion rate [84]. In the process of synthesis, free antimony is evenly dispersed in the polyester fiber. It enters into wastewater when these polyester fibers are used in textile desizing and alkali-reduction processes.

Using 1.5‰–2‰ ferric sulfate and polyacrylamide as flocculants in the primary sedimentation with pH in the influents adjusted to 9.5–10, 8.5 in the effluents, and later 7 in the distribution tank could reduce total antimony by generating antimony sulfate precipitates [85]. This method can also enhance the flocculation efficiency and reduce Fe(III)concentration in the effluents. Technically, antimony-based catalysts can be replaced by titanium-based catalysts, which have been started to be applied in China [83].

6. Conclusions

In the past 40 years, Chinese textile industry has got rapid development and became the largest textile producer in the world. Meanwhile, the textile industry discharges enormous amounts of wastewater which has complicated constituents. Textile wastewater treatment and reuse technologies have been rapidly developed, especially membrane technologies and advanced oxidation, but the costs of meeting discharge standards are also high. The environmental management of Chinese textile industry has received insufficient attention, and the wastewater management has been imprudent. As emerging hazardous contaminants are drawing social attention and environmental protection standards become more stringent, the textile industry in China will be greatly affected. For sustainable industrial development, from the perspective of environmental management, it is necessary to soon incorporate emerging pollutants into the control system. From the perspective of the textile enterprises, it is necessary to change from the end-of-pipe treatment to the source control, controlling the access of chemical pollutants throughout the production processes and using green substitutes and water-saving technologies.

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