A critical review of microplastic pollution in urban freshwater environments and legislative progress in China: recommendations and insights

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Freshwater systems are vitally important, supporting diversity and providing a range of ecosystem services. In China, rapid urbanization (over 800 million urban population) has led to multiple anthropogenic pressures that threaten urban freshwater environments. Microplastics (<5 mm) result from intensive production and use of plastic materials, but their effects in urban freshwater environments remain poorly understood. Rising concerns over the ecological effects of microplastics have resulted in increased attention being given to this contaminant in Chinese freshwater systems. Some studies provide quantitative data on contamination loads, but in general relevant knowledge in freshwater environment remains narrow in China, and lacking adequate understanding of threshold levels for detrimental effects. Notably, non-standardized sample collection and processing techniques for point and non-point sources have hindered comparisons of contamination loads and associated risk. Meanwhile, legislative frameworks for managing microplastics in China remain in their infancy. This manuscript critically reviews what is known of the nature and magnitude of microplastic pollution in Chinese freshwater environments, and summarises relevant Chinese legislation. It provides recommendations for improving the legislative framework in China and identifies research gaps that need to be addressed to improve management and regulatory strategies for dealing with microplastic pollution in Chinese urban freshwater environments.

Keywords: microplastics, urban freshwater environment, abundance, China, legislation, policy

Content

1. Introduction

Annual global plastic resin and fibre production accelerated from 2 million metric tonnes in 1950 to 3.81 billion tonnes in 2015, contributing to the 6.3 billion tonnes of global plastic waste produced by 2015 (Geyer *et al*., 2017). The ubiquity of plastics results in serious environmental problems worldwide, with over 99 million metric tonnes mismanaged yearly and approximately 79% of total plastic waste accumulating in landfills or in the natural environment (Geyer *et al.*, 2017; Lebreton and Andrady, 2019). Plastic pollution can be conveyed between different ecosystems, with for example around ten million metric tonnes of terrestrial-based plastic litter estimated to enter the oceans every year (Jambeck *et al.*, 2015). Freshwater systems are a major pathway for delivering plastic pollution to the marine environment (Crawford and Quinn, 2017b).

China is the largest plastic producer in the world, with monthly plastic production reaching at 5-12 million metric tonnes by 2019 (Garside, 2019). Since the early 1950s, the utilisation of plastic mulch in agriculture has become widespread across China, while plastic tableware and bags became prevalent in industrial and domestic sectors after the economic reforms in the late 1970s (Zhou *et al.*, 2016). The growth of E-Commerce further increased China's plastic consumption, especially the fast food delivery services which are part responsible for the approximately 60 million items of plastic tableware daily used in China, most of which is single-used (Industry, 2019). Thus, China plays an important role in global plastic production and consumption (Wang *et al.*, 2018). The Chinese plastic material market has resulted producing more than 8.82 million metric tonnes of mismanaged plastic waste annually, which ranked as the global highest (Jambeck *et al.*, 2015). Based on current trends, global mismanaged plastic waste is estimated to reach 155-265 million metric tonnes annually by 2060s, with China remaining as one of the major sources (Everaert *et al.*, 2018; Lebreton and Andrady, 2019; van Wijnen *et al.*, 2019).

"*Microplastics*", defined as plastic debris smaller than 5 mm in diameter, can be ingested by organisms, and abrade and clog breathing and feeding apparatus (Eerkes-Medrano *et al.*, 2015; Li *et al.*, 2018). Given the size of microplastics, they can be transported for long distances (i.e. more than thousands of km) and have been found in geographically remote regions (i.e. polar areas and waterbodies on undeveloped plateaus) (Lusher *et al.*, 2015; Horton *et al.*, 2017a; Baptista Neto *et al.*, 2019; C. Jiang *et al.*, 2019). Microplastics also have the potential to adsorb other contaminants (including hydrophobic persistent organic pollutants, pathogenic microorganisms and antibiotics) and transport these pollutants over a large spatial area (Lambert and Wagner, 2018; Arias-Andres *et al.*, 2019).

Microplastics encompass a highly diverse group of materials (e.g. Polyethylene Terephthalate (PET), Polystyrene (PS) and Polypropylene (PP)), morphologies (e.g. fragments, fibres and beads), colours and sizes (usually 1 μm to 5 mm). Microplastics are classified as being primary (manufactured at micro-size) or secondary (smaller fragments that have been eroded or weathered from the larger plastics) (Eerkes-Medrano *et al.*, 2015; Horton *et al.*, 2017b; Sharma and Chatterjee, 2017). Despite the potential significance of microplastic pollution, much remains unknown about its sources, pathways, fate and impacts on receptors. Major sources of plastic wastes and the burning and breakdown of those mismanaged larger plastic litter (e.g. via microbeads, fibres, etc.) is estimated to be the largest contributor of microplastics (Horton *et al.*, 2017b; Conley *et al.*, 2019), and is likely to be greater in urban areas. Urban freshwater environments may therefore be of great significance as a source of microplastics, rapidly conveyed from urban discharge into fluvial systems and eventually to marine systems via estuaries and deltas (Zhao *et al.*, 2014).

Zhao *et al.* (2014) were the first study to quantify microplastic pollution in freshwater environments in China, but there has been limited subsequent research. Some studies of Chinese freshwater bodies have reported higher microplastic concentrations than many other countries (Su *et al.*, 2016; Zhang *et al.*, 2018; X. Jiang *et al.*, 2019). Rivers in East Asia are predicted to carry the highest annual microplastic loads by 2050, approximately four times higher than the microplastic emission from other OECD (Organization for Economic Cooperation and Development) countries (van Wijnen *et al*., 2019). Because of its size and population, China plays the most important role in the East Asia region. Chinese cities have large populations and substantial plastic use, but often with poor disposal management and limited knowledge of microplastic concentrations in urban freshwater environment. China's current legal framework still does not specifically cover the management of microplastic (Zhang *et al.*, 2019). Legislation aimed at reducing microplastic pollution can have multiple positive effects in China's, but an essential prerequisite for this is awareness of contamination sources, pathways and levels.

Microplastic pollution has been reported worldwide and, according to the reviews of Eerkes-Medrano *et al.* (2015) and Horton *et al.* (2017b), is constantly increasing in freshwater environments. Zhang *et al.* (2018) were the first to review what is known of microplastic pollution in Chinese inland water systems; they also considered the State-of-the-Art approaches for sampling microplastics. Fu and Wang (2019) reviewed research approaches, characteristics, sources and fate of microplastics in the Chinese freshwater environments and provided recommendations for the Chinese Government and public to reduce freshwater microplastic pollution. Fok *et al.* (2020) studied the investigating approaches used in microplastic studies in China, while Fu *et al.* (2020) synthesised knowledge of microplastic pollution in various ecosystems and provided an overview of policies related to plastic and microplastic management in China. These reviews established a thoughtful basis for future development of microplastic controls in the Chinese freshwater environment, but understanding of microplastics in Chinese urban catchments still remains limited. However, available literatures are still general on the discussion of microplastic management and current legislation do not provide specific guidance on developing appropriate policies.

Given the circumstances above, this manuscript reviews microplastic pollution in urban freshwater catchments in China, with a particular focus on legal frameworks for managing the problem. The aim of the review is to identify major knowledge and policy gaps that need to be filled to improve understandings of the environmental risks of microplastics. Specific objectives are:

1) To review what is known of microplastic abundance and characteristics in China's freshwater environment and identify current knowledge gaps, especially related to urban catchments.

2) To review key existing legislation and policies related to microplastics worldwide and in China.

3) To provide recommendations for managing microplastic pollution in China's freshwater environments, and specifically for dealing with pollution of urban catchments.

2. Current knowledge of urban freshwater microplastics in China

2.1. The foci of China's microplastics research

Following the first use of the term '*Microplastics*' (Thompson *et al*., 2004), 1563 papers about microplastic pollution have been published (up an and including 2019; Web of Science). The trajectory during the last 16 years reflects a rapidly growing concern about microplastics worldwide (Fig. 1). The first data of microplastic loads in China were not published until 2014, when Zhao *et al*. (2014) reported on loads in both freshwater and seawater zones of the Yangtze River Estuary System. By the end of 2019, 255 papers concerning microplastics in China had been published, with these using a wide variety of sampling and sample processing approaches (Zhang *et al.*, 2018). Since then, China has become a significant contributor to the literatures, producing more than 16% (according to Web of Science) of the global microplastics research (China is ranked first, followed by USA, UK and Germany). This indicates that China is starting to play an important role in the understanding of microplastics, and consequently may influence future research directions. This section reviews Chinas 255 contributions to the global literature.

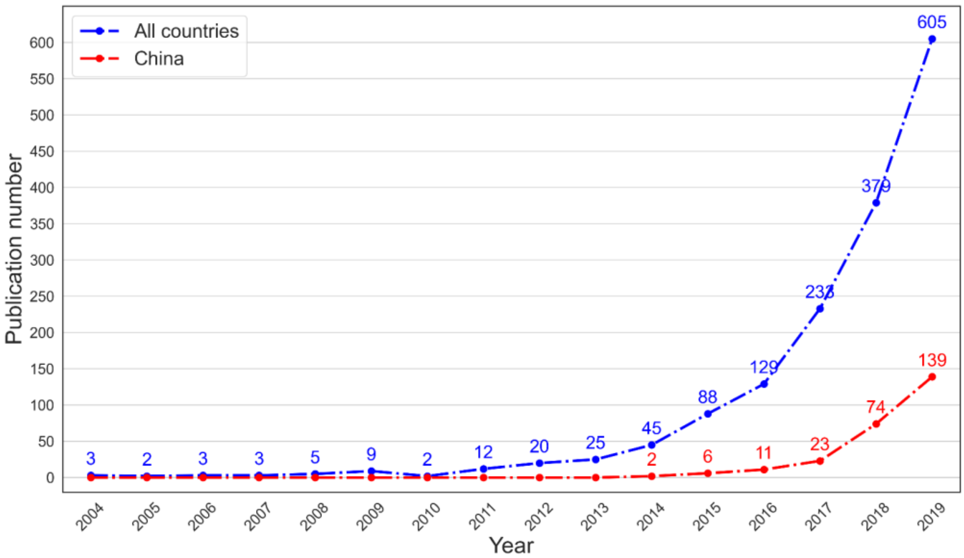

Figure 1. Number of academic publications about microplastics from 2004 to 2019 (data source: Web of Science). Blue bar represents global annual publication numbers and orange bars means yearly publication numbers from China.

The VOSviewer software (Leiden University, Netherlands) was used to provide an overview of current microplastics research in China (Figure 2). The academic terms repeatedly occurring in each paper were collected from the 255 publications and analysed in this software. The frequency of occurrence of each keyword and the co-occurrence of pairs of keywords were used to indicate the foci of published work; in the resulting schematic (Fig. 2), the foci of proximity between terms indicates the frequency of co-occurrence, the size of each term illustrating the occurrence frequency, and the colours indicate temporal patterns. This analysis demonstrates that the '*Marine Environment*' was a very common focus and was closest to '*Microplastics*' and '*Pollution*', indicating that a large proportion of microplastics research in China (and globally) has been conducted in marine environments. The red colour of

'*Freshwater*' indicates that this topic is relatively new in China. The direct links from '*Freshwater*' to topics such as '*Sediments*', '*Coastal*', '*Soil*', '*Marine-environment*' and '*Transport*' demonstrated that microplastic pollution in China's freshwater environments correlates with microplastics in other compartments of the environment. Nonetheless, the relatively great distance between '*Freshwater*' and '*Microplastics*' suggests that relevant work is still limited in China. Notably, the missing connections between several focal terms (such as '*Exposure*', '*Toxicity*', and '*Wastewater*') to '*Freshwater*' indicates that gaps remain in understanding links between these things. The terms '*Urban*' and '*City*' do not appear in the figure highlighting the lack urban freshwater microplastics research in China. This supports the contention that more studies are required in urban freshwaters to assess the potential significance of microplastics (Zhang *et al.*, 2018).

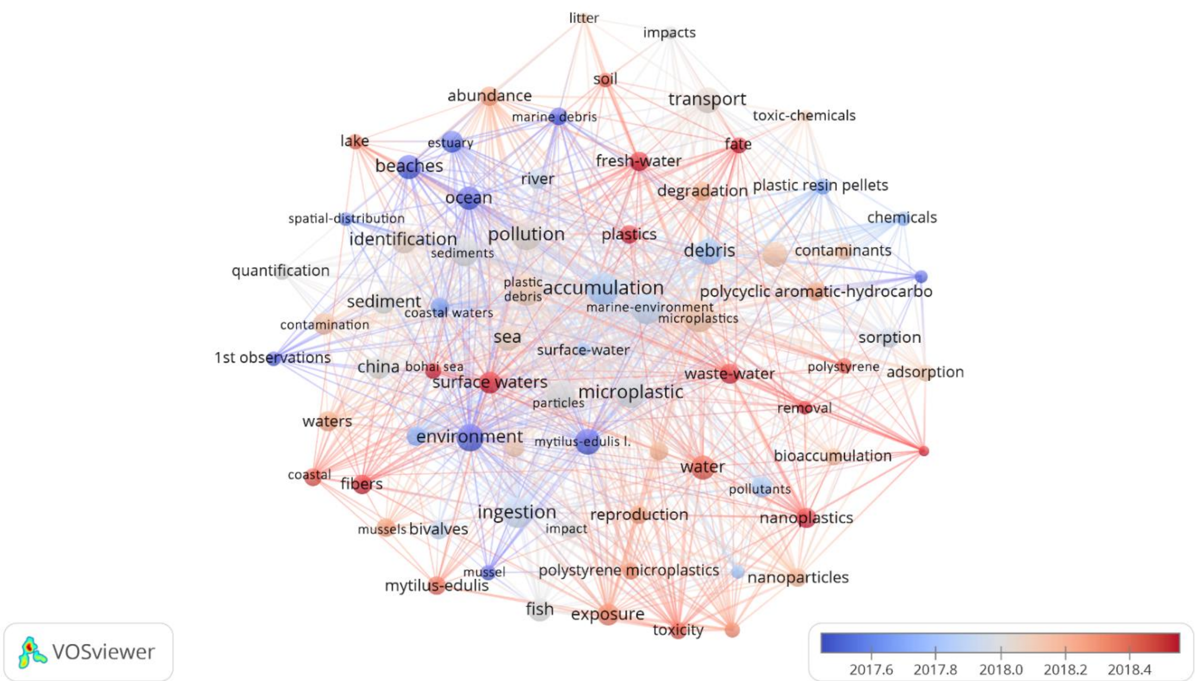

Figure 2. A visualization of the keywords co-occurrence in 255 publications of China's microplastics researches

(database: Web of Science) from 2014 to 2019, where colours represent the average publication time of each keyword (blue to red: early to current). Database: Web of Science from 2004 to 2019.

2.2. Microplastics in freshwaters in China

To further understand current progress in microplastics research in China's freshwater environments, twenty-one papers reporting microplastic loads in various types of Chinese freshwater environments were analysed in detail (Table 1).

Microplastic pollution has been investigated in freshwater systems including the Poyang Lake (the largest freshwater lake in China), Dongting Lake (the second largest freshwater lake in China), Qinghai lake (the largest inland lake in China), Yangtze River (the largest river catchment in China), Pearl River (the largest river catchment in Southern China), and other large waterbodies in the country (Zhao *et al.*, 2014; Lin *et al.*, 2018; Wang *et al.*, 2018; Xiong *et al.*, 2018; Zhou *et al.*, 2018; Yuan *et al.*, 2019). These studies provided quantitative evidence of microplastic pollution but so far none has investigated loads in any environments in an integrated way, so as to characterise contamination in waterbodies, sediments and biota; moreover, small- to medium-sized freshwater systems remain under-represented.

Table 1. Twenty-one publications involving investigations of microplastic abundances in freshwater environments in China

No.	Location	Sampling time	Abundances	Dominant types	Citations
1	The Yangtze Estuary System and East China Sea (involving urban catchment)	July-August, 2013	Freshwater (1 m depth surface water): 500-10200 n/m^3 (average: 4137.3 n/m^3) Marine water (333 μm mesh-size neuston net for surface layer water): 0.03-0.455 n/m^3 (average: 0.167 n/m^3)	Materials: N/A Colours: transparent in freshwater and coloured in marine water Shape: fibres Size: 0.5-2.5mm	(Zhao *et al.*, 2014)

2	Mingjiang, Jiaojiang and Oujiang estuaries (involving urban sections)	July, 2013	Surface water (30 cm depth): Minjiang-A: 1245.8±531.5 particles/m^3; Minjiang-B: 1170.8±953.1 particles/m^3; Jiaojiang: 955.6±848.7 particles/m^3; Oujiang: 680.0±284.6 particles/m^3	Materials: PP and PE Colour: coloured Shape: fibres and granules Size: <2mm	(Zhao *et al.*, 2015)
3	Beijiang River littoral zone, Qingyuan City (involving urban section)	March, 2015	Surface layer of sediments (top 2 cm): 178±69 items/kg to 544±107 items/kg	Materials: PE, PP, and copolymer Colour: blue Shape: particles Size: N/A	(J. Wang *et al.*, 2017)
4	Siling Co Basin, Tibet	May-June, 2015	Sediment (top 2 m): Siling Co: 4-1219 items/m^2; Geren Co: 42±47 items/m^2; Wuru Co: 117±126 items/m^2; Mujiu Co: 17±20 items/m^2	Materials: PE and PP Colours: N/A Shape: N/A Size: 1-5mm in the most sits excluding in Wuru Co.	(Zhang *et al.*, 2016)
5	The Taihu Lake (involving urban catchment)	Aug, 2015	Plank samples: 0.01x10^6-6.8x10^6 items/km^2 Surface water (less than 0.3 m deep): 3.4-25.8 items/L Sediments: 11.0-234.6 items/kg (dry weight) Clams: Summer (Aug.): 1.3-12.5 items/kg; Winter (Nov.): 0.2-9.6 items/kg	Materials: cellophane and PET Colours: blue in plank and water samples; white/transparent in sediments and organisms Shape: fibres Size: 0.1-1mm in water, sediment and organism samples; 0.333-5mm in plank samples	(Su *et al.*, 2016)
6	Xiangxi River, Yangtze River, TGR area, Hubei Province (involving county/town sections)	Apr, July and Oct 2015; Jan, 2016	Surface water: 0.55x10^5-3.42x10^5 items/km^2 Sediment: 80-864 items/m^2 Fish: none or 0.33-1.5 items in each fish	Materials: PP in water and sediments, PE in fish Colour: blue in sediments Shape: sheet and fragment in water, sheet in sediment Size: 1-5mm in water and sediment	(Zhang *et al.*, 2017)
7	Surface water of 20 major urban lakes and urban sections of Yangtze River and Hanjiang River in Wuhan city, China (urban catchments)	April 2016	Surface water (0-20 cm depth): From 1660.0±639.1 n/m^3 to 8925±1591 n/m^3 in different waterbodies	Materials: PET and PP Colours: coloured Shape: fibre Size: <2mm	(W. Wang *et al.*, 2017)
8	Qinghai Lake (inland waterbody)	July, 2016	Surface water (112μm mesh size net): 3090-757,500 particles/km^2 Sediment (top 2 cm): 50±50 to 1292±582 particles/m^2 Fish: 5.4±3.6 particles/individual	Materials: PP and PE Colour: coloured Shape: fibres Size: 0.1-0.5mm in surface water of lake; 1-5mm in river samples	(Xiong *et al.*, 2018)
9	Middle-	Aug-Oct,	Surface water (0-12cm depth): 0.5-3.1	Materials: PS	(Su *et al.*,

	lower Yangtze River Basin (involving urban sections)	2016	particles/L Sediment (top 10 cm): 15-160 particles/L Asian clam: 0.3-4.9 particles/g or 0.4-5.0 particles/individual	Colour: transparent and blue Shape: fibres Size: 0.25-1mm	2018)
10	Poyang Lake section of Le'an River (involving industrial and residential areas)	Dec, 2016	Sediment (5cm depth): Average: 1800 ind/kg; upper stream: 1121 ind/kg; branch stream: 2871 ind/kg; downstream: 1366 ind/kg	Materials: PE Colour: white Shape: fragment Size: <1mm	(Zhou *et al.*, 2018)
11	Mainstream Pearl River, its three major tributaries and Pearl River Estuary	March to May, July to August, November to January, 2016-2017	River water: 0.57±0.71 items/L Riverbed sediments: 685±342 items/kg (dry weight) Estuarine sediment: 258±133 items/kg (dry weight)	Materials: PP Colour: white and transparent Shape: sheet Size: <0.25mm	(Fan *et al.*, 2019)
12	Changjiang Estuary (CE) and the East China Sea (including urban sections)	Feb, May and July, 2017	Surface water (30 cm depth): Changjiang Estuary: 157.2±75.8 n/m^3; The East China Sea: 112.8±51.1 n/m^3	Materials: PE and PA Colour: N/A Shape: fibres Size: < 1000 μm	(Zhao *et al.*, 2019)
13	The urban section of the Pearl River along Guangzhou City (urban catchment)	July 2017	Surface water (50 cm depth): 379-7924 items/m^3 (average:2724 items/m^3) Sediment (top 5 cm): 80-9597 items/kg (average: 1669 items/kg) Influent of wastewater treatment plant: 0.5-4.2 items/L Effluent: 0.3-2.7 items/L	Materials: PP and PE in surface water and sediments Colours: white in surface water samples and yellow in sediments Shape: fibres in surface water, sediments and effluent samples Size: 0.02-1mm in surface water and sediment samples	(Lin *et al.*, 2018)
14	Dongting Lake and Hong Lake (involving urban catchments)	September 2017	Dongting Lake (0-20 cm depth surface water): 900-2800 n/m^3 (average: 1911.7 n/m^3) Hong Lake (0-20 cm depth surface water): 1250-4650 n/m^3 (mean: 2282.5 n/m^3)	Materials: PP and PE Colours: coloured Shape: fibres Size: 0.05-0.33mm	(Wang *et al.*, 2018)
15	Poyang Lake (involving urban sections)	Nov, 2017	Surface water (0-1 m depth): 5-34 items/L Sediment: 54-506 items/kg (dry weight) Fish: 0-18 items/fish	Materials: PP and PE Colours: coloured Shape: fibres Size: 0.1-0.5mm in water, 0.1-0.4mm in sediment and 0.5-1mm in fish	(Yuan *et al.*, 2019)
16	Wei River, Wushan County, Gansu Province (including county sections)	Winter of 2017	Surface water: 3.67-10.7 items/L Sediments: 360-1320 items/kg	Materials: PET Colour: N/A Shape: fibres Size: <0.5 mm	(Ding *et al.*, 2019)

17	Poyang Lake, Jiangxi Province (involving urban sections)	December 2016 and April, July, 2018	Sediments (top 2 cm): 11-3153 items/kg (dry weight); average: 1134 items/kg (dry weight)	Materials: N/A Colour: N/A Shape: fragments Size: <1mm	(Liu *et al.*, 2019)
18	Buqu River, Naqu River, Lhasa River, Brahmaputra River, and Nyang River in Tibet Plateau	July, 2018	Surface water: 483-967 items/m^3 Sediments (top 2 cm): 50-195 items/kg	Materials: PET Colour: transparent Shape: fibres Size: <1mm	(C. Jiang *et al.*, 2019)
19	Yangtze Delta area, Shanghai (urban sections)	April-September, 2018	Overall surface water: 0.08-7.4 items/L; Freshwater: 1.8-2.4 items/L Coastal and estuarine water: 0.9 items/L	Materials: Shape: fibres Colours: blue and red Size: 100-1000 µm	(Luo *et al.*, 2019)
20	Middle and lower reaches of Yangtze River (involving urban sections)	Aug-Sep, 2018	Surface water: 240 items/m^3 to 1800 items/m^3 Sediments: 90-580 items/m^3	Materials: PP Colour: blue Shape: fibres Size: <1mm	(Li *et al.*, 2019)
21	Urban lakes in Changsha (urban waterbodies)	N/A	Surface water: 2425±247.5 to 7050±1060.6 items/m^3	Materials: PP and PE Colour: transparent Shape: linear Size: <2mm	(Yin *et al.*, 2019)

The properties of microplastics are important indicators of sources. Microplastics detected in Chinese freshwaters consists of diverse materials including Polypropylene (PP), Polystyrene (PS), Polyethylene Terephthalate (PET (also abbreviated PETE)), Polyethylene (PE) and Polyvinyl Chloride (PVC). PP and PE were dominant in most investigated freshwater environments (PP in 12 waterbodies and PE in 11 waterbodies; Table 1). This condition fits with the current state of the Chinese plastics market, with the annual yields of PP and PE accounting for 27.21 and 30.04 million tonnes and representing more than 40% and 30% of global totals respectively by 2018 (Yin and Zhang, 2019; Zhang, 2019). Although published research used different sorting strategies, plastic fibres were dominant in 14 cases (Table 1). Size ranges of microplastics were also variable, with some suggesting smaller microplastics (e.g. < 1 mm) are disproportionately abundant (Su *et al.*, 2016; Yuan *et al.*, 2019).

Microplastic abundance also varied substantially between different geographic areas. For example, concentrations in surface water of rivers on the Tibet Plateau were 483 - 967 particles/m^3 compared to 4,137.3 particles/m^3 in the Yangtze Estuary (Table 1). Such cases also imply that densely populated areas (e.g. urban areas) have higher microplastic concentrations compared to remote areas. Concentrations are also variable over smaller geographic areas. For instance, within the same catchment, Lin *et al*. (2018) found that concentrations along the urban section (Guangzhou) of the Pearl River varied from 379 to 7,924 particles/m^3 in surface water (Table 1); a concentration of 0.167 particles/m^3 was recorded offshore from the Yangtze River in comparison to 4,137.3 particles/m^3 in the Yangtze estuary (Zhao *et al.*, 2014). The spatial variation in the Yangtze is likely due to dilution (Mendoza and Balcer, 2018; Wang *et al.*, 2018). No consistent relative patterns have been found in microplastic concentrations in water versus sediment in fluvial or limnetic environments (Zhou *et al.*, 2018; Ding *et al.*, 2019; Zhao *et al.*, 2019), which suggests complex sources and pathways and patterns of accumulation.

The properties of microplastics, hydrological conditions, surroundings and meteorological conditions have been investigated as the four major factors influencing microplastics' distribution patterns in waterbodies in China (W. Wang *et al.*, 2017). Unfortunately, no clear patterns or consensus has yet been reached. For example, recent studies indicated that the lower microplastic concentrations during the wet season (summer) in the Pearl River, China could be attributed to dilution by higher precipitation and river flows (Fan *et al.*, 2019). Conversely Zhao *et al*. (2019) found an increased concentration during wet periods, presumably due to more runoff washing plastic particles into waterbodies. As with suspended sediment, microplastic concentrations in recorded river water may be dictated by preceding conditions (e.g. whether a preceding flood has caused washout), such discharge-concentration relationships are not ways clear.

Sources differ greatly from place to place. For instance Peng *et al.* (2018) explained that polyester, rayon and other fibres detected in their samples were from clothes washing (based on the materials and shapes of microplastics), while Xiong *et al.* (2018) believed that the PE and PP microplastics detected in the Qinghai Lake, China originated from tourists, due to these types plastics being commonly used in packaging. Nevertheless, a problem that may contribute to different interpretations of sources and loads is the lack of consistent collection, identification and analytical approaches (Luo *et al.*, 2019). Zhao et al. (2015) used a 333 µm pore-size sieve to filter water samples from the Minjiang, Jiaojiang and Oujiang estuaries, while Wang *et al*. (2018) selected a 50 µm mesh-size steel sieve for the investigation in the Dongting Lake and the Hong Lake, China. In most microplastics studies in Chinese freshwater environments, smaller-sized microplastics (< 2 mm) are usually most abundant (see Table 1). Such differences cause large variation in reported concentrations.

2.3. Microplastic dynamics in Chinese freshwater environments

Rivers are often conceptualised as conveyor belts, transporting water, sediments and contaminants to the oceans. However, transport is not continuous, with material stored periodically (e.g. sediment deposited and stored for a period of time on the riverbed, before the next competent event leads to its onward conveyance). This and the different course areas – some of the, point sources and some of them diffuse - may underpin spatial variation reported to date. Wang et al. (2018) reported with high concentrations at the confluence between the Dongting Lake and Yangtze River. Based on work in the Pearl River, Lin et al. (2018) argued that tributaries transport microplastics to the mainstream and result in high concentration in confluence zones. Peng et al. (2018) observed that the microplastics transported by the Yangtze River and Huangpu River stagnated and accumulated at the plume front area formed between freshwater and seawater of the East China Sea. These findings not only indicate the significance of Chinese fluvial systems as a pathway, delivering microplastics towards trunk streams and marine environments, but also illustrate that confluence areas may be contamination 'hotspots'.

The transportation of microplastics may be critical to assessing and understanding health risks. Because of their lipophilic features and high surface area to volume ratio, which enable them to absorb chemical pollutants, including persistent organic pollutants (e.g. pesticides and antibiotics), as well as pathogenic bacteria, fungi and viruses (Zou *et al*., 2017), microplastics pose risks to ecosystems and human health. Additionally, toxic plastic additives, such as flame retardants, pigment and ultraviolet stabilizer can be release once plastics are in the freshwater environment (Gabriella, 2019). Risk partly depends storage dynamics. For instance, exposure of benthic organisms to microplastics depends how much material may be stored within the bed matrix, and the duration of residence here before being remobilised during high flows (van Cauwenberghe *et al*., 2015). Residence times are likely to be longer in stable sediments that are infrequently disturbed, so lentic environments can act as a longer term store for microplastics than fluvial environments (Eerkes-Medrano *et al*., 2015). Movement of microplastics can also be altered by absorption of other materials or colonisation by microbial communities, changing particle density and causing microplastics to settle more easily (Lin *et al.*, 2018; Wang *et al.*, 2018; Fan *et al.*, 2019). Research foci are now changing from simple assessment of loads to efforts understand pathways, including those in the subsurface (i.e. via hyporheic zone and groundwater), although such work still remains limited in China (Zhao *et al.*, 2015; Su *et al.*, 2016).

River Basin Management for navigation purposes, alongside with other factors such as, water supply, flood control and hydropower production alter flow regimes and flow hydraulics, and hence, may modify transport and storage dynamics of microplastics. Dams and reservoirs trap sediments, and therefore are likely to also trap microplastics (Crawford and Quinn, 2017b). Microplastics accumulated in stable freshwaters will not stop degrading, potentially generating and releasing smaller-sized, secondary microplastics that that may be more easily ingested by organisms.

Another issue relates to the temporal dimension. Most studies lack long-term, repeat sampling and measurement. This is important because, when studied, significant temporal differences in microplastic concentrations have been found to exist; this raises concerns over the representativeness of single date or spot sampling (Stanton *et al*. 2019). Such temporal differences may arise due to seasonal and/or weather-related factors, or dues to activities of organisms (Crawford and Quinn, 2017b). For example, in China cyclonic effects (i.e. typhoons) have been reported to increase microplastic loads in freshwaters and conveyance to the marine environment (e.g. especially along the Southern and Eastern coastline of China; Wang *et al.*, 2019). Studies are needed in China to elucidate the causes of temporal variation in microplastics and the implications of this for accurate assessment of loads and risk.

2.4. Sources of microplastics in urban freshwaters

Urban areas play a key role as sources of microplastics in China (Zhang *et al*., 2018; Fu and Wang, 2019). These sources are summarised in Figure 3. Primary microplastics are usually discharged from industrial areas associated with plastic production or residential areas through wastewater treatment plants (WWTPs) (Figure 3). Microplastics could be removed from sewage during the primary treatment and adsorbed by activated sludge during secondary treatment in WWTPs, but even if removal reached 95-99%, as recorded in some developed countries, the remaining material released to the environment could still be problematic (Talvitie *et al.*, 2015). Many WWTPs do not attain 99% removal efficiency of microplastics in China (Lin *et al.*, 2018); for example, a municipal WWTP equipped with activated sludge techniques in Wuhan only removed about 64.4% of microplastics (Liu *et al*. 2019). Another issue is that 60% of polluted sludge from WWTPs in China is disposed of in landfill sites (Sun *et al.*, 2019). Microplastics can leach from landfills and find routes through soils to contaminate freshwaters (He *et al.*, 2019). Thus, due to the relatively underdeveloped techniques and poor management of waste treatment, WWTPs play significant roles in Chinese urban microplastic pollution, as documented by W. Wang *et al.* (2017) and Lin *et al.* (2018), respectively.

Secondary microplastics usually reach freshwater environments through non-point sources. In Chinese urban areas, mismanaged plastics are the major terrestrial non-point source, which includes dumping and littering of solid wastes (W. Wang et al., 2017; Zhou et al., 2018; Fan et al., 2019). Fragmentation of large plastic waste generates secondary microplastics on land (Zhang *et al.*, 2015), while road dusts containing car tyre fragments contribute to loads entering freshwater systems as a result of runoff (Zhang *et al.*, 2018). Atmospheric dispersal of microplastic may also be important in urban areas (Dris *et al.*, 2016). For example, Zhou *et al.*

(2017) found microplastic fibres in atmospheric deposition in Yantai, China. Shipping and fishing in urban catchments can also release microplastics directly to aquatic environments, where fragments and fibres from fishing nets or gear have been observed in urban waterbodies in Changsha City (Yin *et al.*, 2019).

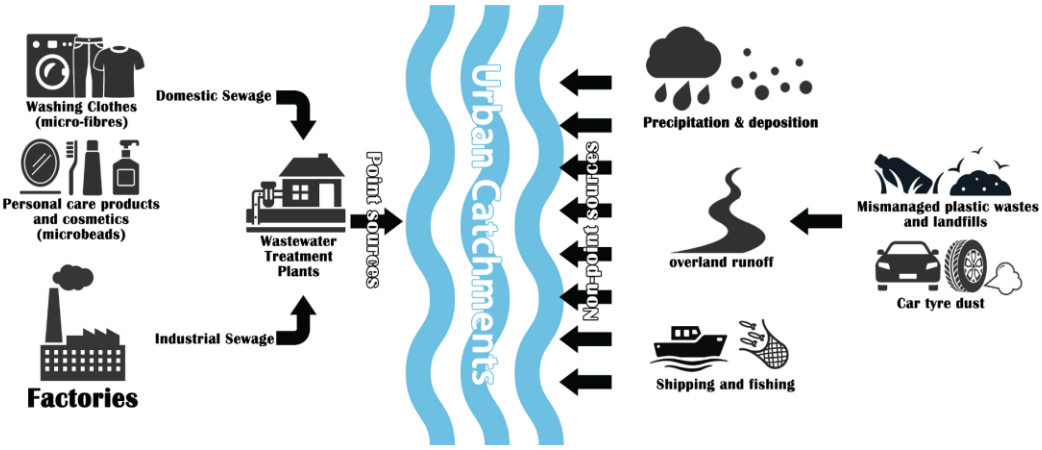

Figure 3. Potential microplastic sources towards urban catchment (source by Yuyao Xu)

Previous literature has assessed factors influencing microplastic pollution in Chinese urban catchments. Fan *et al*. (2019) found a direct linear relationship ($R^2 = 0.772$) between microplastic abundance in water samples and population density in the Pearl River catchment, where large population centres generated and released more microplastics. Similarly, Wang *et al*. (2017) found an inverse linear relationship ($p < 0.001$) between the distance from an urban centre and microplastic concentration in surface waters of the Yangtze River. Other investigations have, however, failed to find such relationships (e.g. Shanghai) (Peng *et al.*, 2018).

Zhao *et al*. (2015) suggested that different economic structures might lead to different microplastic sources and abundances; interestingly this hypothesis was supported by the Gross

Domestic Product (GDP) and microplastic data presented by Fan *et al*. (2019). Li (2020) reported microplastic concentrations in urban runoff from residential roads were significantly higher than from parking lots and cement pavements, which also indicates that local land-use conditions will affect microplastic pollution levels in urban areas.

Rapid urbanisation in China may increases pressures on urban freshwaters, including contamination by microplastics (Zhang *et al.*, 2018). Therefore, understanding the roles of land-use, population density and local economic structure in influencing microplastic distribution patterns in urban waterbodies is an important first step to developing policy measures designed to minimise risk. Taking a precautionary approach via implementation of legislative enactments and guidelines to control microplastics is a growing area of interest in China. This is the focus of the section that follows.

3. Management and Legislations on microplastics

3.1. General legislation

Plastic microbeads (10 – 500 µm in diameter), used in personal care products (PCPs) (Sharma and Chatterjee, 2017), are a type of primary microplastics. To help reduce risks posed by microbeads to wildlife, Five European countries (i.e. Netherlands, Austria, Luxembourg, Belgium and Sweden) issued a joint statement calling for banning the use of microbeads in PCPs (see Table 2). In 2014, the State Government of Illinois (USA) enacted the first prohibition of production and sales of PCPs that contain microbeads (see Table 2), which subsequently led to the US '*Microbead-Free Water Act of 2015*' (see Table 2). In 2015 Canada also limited the addition of microbeads in PCPs, by adding microbeads as a new toxic substance to the 1999 '*Environmental Protection Act*' (Table 2). European nations also expressed the concerns about Microbead pollution in cosmetics through the proposal ‘*Cosmetics Europe Recommendation on Solid Plastic Particles (Plastics Micro Particles)*’ (Table 2). This recommendation has implications for future legislation worldwide (i.e. Microbeads in Toiletries Regulations by Canada in 2017). Following these first pieces of legislation, more countries (including the UK, France, South Korea, Italy, New Zealand, India and South Africa) joined in this ‘*Microbead-free*’ action (see Table 2), which will make efforts to reduce the global release of microbeads. Nonetheless, microbeads are only a small part of the total microplastic load, approximately accounting for 0.1~ 4.1% (McDevitt *et al.*, 2017) of total global microplastic pollution in aquatic environments, so broader action is also needed.

In October 2019, the Chinese government officially issued the “Economic Structure Adjustment Guidance Catalogue”, which included the prohibition of light plastic bags (< 0.025mm thickness), disposable-foamed plastic tableware, disposable plastic swabs, daily chemical products containing microbeads and polyethylene agricultural films (< 0.01 mm thickness) (Table 2). This catalogue not only highlights microbeads problem in both PCPs and cosmetics, but also looks at other commonly used in China but potentially polluting plastic products (NDRC, 2019).

Table 2. Brief history of ‘microbeads-free’ activities worldwide (The word ‘Microbead-free’ was from the ‘Microbead-free Act’ in USA and used to represent the popularization of banning plastic microbeads in relevant products in different countries in this paper)

No.	Time	Laws/Policies	Legislator	Legislative aims	Comments	Citations
(1)	2013	Joint call to EU for banning of microbeads	Five European Countries, EU	Issuing the public concern about the risks of microbeads in PCPs	This call (by the Netherlands, Austria, Luxembourg, Belgium and Sweden) followed a green paper by	(Crawford and Quinn, 2017a)

					EC published in 2013. It led to the following legislative actions on microbeads in Europe and even worldwide.	
(2)	2014	Legislation of banning microbeads	Illinois, USA	Banning the manufacture (by 2017) and sale (by 2018) of PCPs containing microbeads	Illinois was the first state enacting bans of microbeads in America. The state government also left certain periods for industries and market to prepare.	(Chicago Tribune, 2014; McCormick *et al.*, 2014; McDevitt *et al.*, 2017)
(3)	2015	A proposal under the *Canadian Environmental Protection Act* (1999)	Canada	Adding microbeads into a list of toxic substances and intending to ban the use of microbeads in PCPs	Canada was the first country who regarded microbeads as toxicities in the world. It is an alternative way to ban microbeads, which avoids superabundant legislative processes of structuring a new policy/law.	(Canada, 1999, 2015)
(4)	2015	*Cosmetics Europe Recommendation on Solid Plastic Particles (Plastic Micro Particles)*	Cosmetics Europe, EU	Suggesting banning the use of microbeads in cosmetic products	This is the first official concern about the plastic microbeads in cosmetics. Then, the microbead-free activities started to take cosmetic products into considerations.	(Cosmetics Europe, 2015)
(5)	2015	*Microbead-Free Water Act of 2015 (H.R.1321)*	USA	Prohibiting the manufacture and preventing the inputs of rinse-off PCPs and cosmetics containing microbeads into interstate commerce	After ten states banned microbeads and 15 states introduced relevant plans, President Obama signed the microbead-free act. The microbead-free legislation was from state governments at beginning then to the federal government.	(Pallone, 2015; McDevitt *et al.*, 2017)

					The local-to-center legislation route is a good example for Chinese relevant legislation.	
(6)	2017	A unique commercial testing service to assess ecological impacts of microbeads environmental impact assessment	Intertek, EU	Providing an available technique to assess the environmental risks of microbeads in relevant products	This was the first and only commercial service that combined ecological impact assessment and multiple samples polymer testing for microbeads.	(Intertek, 2017)
(7)	2017	*Microbeads in Toiletries Regulations*	Canada	Prohibiting the manufacture, import and sale of toiletries used to exfoliate or cleanse that contain plastic microbeads, including non-proscription drugs and natural health products	It was another use of toxic substance list for banning microbeads in relevant products. This was also the first formal legislation about the microbeads in toiletries in the world.	(Canada.ca, 2017)
(8)	2017	EU Eco-label for detergent	EC, EU	Updating the standards of EU Eco-label for detergent products with the content of microbeads as a new indicator	The products awarded the ecolabel afterwards will not contain plastic microbeads after this updating.	(Zhang *et al.*, 2019)
(9)	2017	Prohibition of sales cosmetics containing microbeads	South Korea	Banning the using and selling of cosmetics containing plastic microbeads	South Korea was the first Asian country issuing microbead-free police.	(BeatTheMicrobead, 2020)
(10)	2017	Ban of microbeads	Taiwan, China	Banning the application of microbeads in all cosmetic products	Taiwan was first area of China promoting microbeads relevant legislation.	(BeatTheMicrobead, 2020)
(11)	2017	*The Environmental protection (Microbeads) (England) Regulations 2017*	UK	Banning the manufacture and sale of rinse-off PCPs containing microbeads	After England microbeads regulations, similar regulations also issued in Scotland and Wales in 2018.	(Newground LUS, 2018)
(12)	2018	*The Decree 2017-2019*	France	Banning the using of microbeads in PCPs and the producing of plastic cotton buds	France was the first country to pass a legislation about plastic cotton buds productions.	(Zhang *et al.*, 2019)

(13)	2018	Draft legislation to ban microbeads in rinse-off PCPs as well as cosmetics and plastic cotton buds	Italy	Banning the using of microbeads in PCPs and cosmetics and the producing of plastic cotton buds	The ban of plastic cotton buds will take into force on the first day of 2019, which made Italy the first country enforced plastic cotton bans.	(BIOPLASTICS NEWS, 2019)
(14)	2018	Ban of microbeads in rinse-off PCPs	New Zealand			(BeatTheMicrobead, 2020)
(15)	2018	Microbeads ban	India	Announcing microbead ban, which will enter force in 2020	India was the first developing country contributing to the microbead-free activities.	(BeatTheMicrobead, 2020)
(16)	2018	Proposal of microbeads ban	South Africa	Issuing the proposal for microbeads ban legislations	After finding microbeads occurrence in tap water, the government of South Africa claimed their concerns. This is also the first step of microbead-free activities in Africa.	(BeatTheMicrobead, 2020)
(17)	2019	*Industrial structure adjustment guidance catalogue (2019) (exposure draft)*	China	Listing light plastic bags (0.025mm), disposable foamed plastic tableware, microbeads toothpaste, rinse-off PCPs and cosmetics as the obsoleted products	This document is a suggestion file, but it represents the concerns from Chinese government.	(NDRC, 2019)

Note: (The word ‘microbead-free’ was from the ‘Microbead-free Act’ in USA and used to represent the popularization of banning plastic microbeads in relevant products across different countries in this paper)

As yet, ‘*Microplastics*’ have not been adopted as a formal legislative object in any national or international laws (Zhang *et al.*, 2019). Nevertheless, because of the concern about marine microplastic pollution, several international conventions take microplastics into account (Crawford and Quinn, 2017a). The ‘*Oslo-Paris Convention for protecting and conserving the North-East Atlantic and its resources (OSPAR)*’ uses microplastic abundance in seabird stomachs as one indicator of marine ecological quality (see Table 3). In 2014, the United Nations Environment Assembly (UNEA) also identified microplastics as an emerging marine pollutant, which has placed marine microplastic management on the agenda of many countries worldwide (see Table 3). China has enacted a national marine environmental legislative framework that addressed the issues of shared maritime rights and obligations in the East and South China Seas, and extends to the management of waste dumping, shipping waste, construction waste and landfills in territorial waters (see Table 3).

Even though microplastics are not mentioned explicitly in these regulations and laws, their legislative power to reduce solid waste pollution in marine systems covers should help reduce plastic pollution (Li, 2018; Zhang *et al*., 2019). Lessons learned from their enactment, combined with lessons learnt from international conventions, are important for developing policies related explicitly to microplastics in China.

Table 3. The international and Chinese legislation related to plastic and microplastics (mainly for marine environments)

No.	Time	Laws/Policies	Legislators	Legislative aims	Comments
(1)	1972	*Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (The London Convention; LC'72')*	United Nations Conference on the Human Environment (UNCHE); IMO	Controlling marine pollution led by dumping wastes	This convention took into force in 1975. Till 2016, 89 parties signed this convention including China. The London Convention is regarded as a legislative framework of international environmental legislations.
(2)	1973	*International Convention for the Prevention of Pollution form Ships (MARPOL)*	IMO	Limiting the dumping and emission of ship garbage, including plastic litters	The convention issued in 1973, the protocol launched in 1978 and this policy finally took into force in 1983. Sometimes, a relatively long period is required for legislations, especially the multilateral policies involving many countries.

(3)	1982	*United Nations Convention on the Law of the Sea (UNCLOS)*	United Nations	Defining the rights and responsibilities of nations with respect to their legal rights in world's oceans, establishing guidelines for businesses, the environments and the managements of marine natural resources.	China signed this convention in 1982.
(4)	1982	*Marine Environment Protection Law of People's Republic of China (Marine Law)*	China	Controlling the marine pollution and defining the rights/responsibilities of organizations or individuals to the behaviors within marine environments.	The marine environment law is a basic framework of marine environmental legislation in China. It updated four times in 1999, 2013, 2016 and 2017.
(5)	1985	*Regulations of the People's Republic of China on the Control over Dumping Wastes into the Sea Waters (Dumping Regulations) [Revised]*	China	Limiting the dumping of marine waste into sea waters in China.	The regulations updated once in 2017.
(6)	1988	*Regulations of the People's Republic of China on the prevention of environmental pollution by shipbreaking (Shipbreaking Regulation)*	China	Controlling the marine pollution led by ship garbage in China	The regulations were updated twice in 2016 and 2017.
(7)	1989	*The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (the Basel Convention)*	The Conference of Plenipotentiaries in Basel, Switzerland	Standardizing the transboundary transportation of solid wastes and prohibiting the illegal transportation of harmful wastes among countries.	Norway government suggested adding 'solid plastic wastes' into the special concern list of wastes in Annex II.
(8)	1990	*Regulations of the People's Republic of China on the prevention and control of pollution damage to the marine environment by land-based pollution*	China	Controlling the land-based pollutants from marine ecosystems in China.	Plastic litters were emphasized in this policy.
(9)	1992	*Oslo-Paris convention for the North-East Atlantic Marine Environment (OSPAR)*	15 countries of EU	Protect the ecosystem of west coastal of Europe as well as its catchment	Microplastic occurrence in seabird stomach was regarded as an indicator of EcoQO (marine ecological quality objective)
(10)	1996	*1996 Protocol to the Convention on the Prevention of Marine*	LC '72' contracting parties	Update and replace the London convention	The new London Convention (1996) took both marine dumping and

		Pollution Dumping of Wastes and Other Matter, 1972		according to the status at that time.	land-based solid litters into consideration. It also issued some basic environmental legislative principles, such as 'precautionary approach', 'polluter-pay principle' and 'reverse list'.
(11)	1999	*Elimination of backward production capacity, technology and product catalogue (Patch I)*	China	Suggest banning the using of disposable foamed plastic tableware	The enforcement of this policy led to some relevant industries or company (producing or selling such plastic products) went into liquidation.
(12)	2002	Irish plastic bag levy	Ireland	Collect tax form the using/consuming of plastic bags	In 2002, Ireland became the first country to impose a plastic bag levy and led to a 90% drop of plastic bag consumption. The plastic bags tax usually cost 5-15 cents each bag and it generate 9.6 million pounds as a green fund supporting environmental projects for Ireland.
(13)	2006	*Regulations on the administration of the prevention and control of pollution damage to the marine environment by marine engineering construction projects*	China	Control the pollutants leaked during marine engineering constructions.	This policy was established basing on the *'Regulations of the People's Republic of China on the prevention and control of pollution damage to the marine environment by land-based pollution'* and was updated in 2017 and 2018.
(14)	2007	The San Francisco Plastic Bag Ban	San Francisco, US	Limit the use and production of plastic bags	This is the first major law regulating carry-out bags in the US, which desires to reach zero waste by 2020.
(15)	2007	*The Notice of the General Office of State Council on Restricting the Production, Sale and Use of plastic Shopping Bags*	China	Limit the consumption of plastic bags	Ban the manufacture, sale and usage of plastic bags that are thinner than 0.025mm from 1st June 2008.
(16)	2011	*The Honolulu Strategy*	UNEP and NOAA	Establish a global framework for prevention and management of marine litters	This strategy could be regarded as an international legislative transition from the concern of general marine wastes into the concern of small marine litter debris.
(17)	2012	Global partnership on marine litter (GPML)	UNEP	Protect human health and the global environment by	The GPML provided a platform for international

				setting reduction and management of marine litter as its main goal with several specific objectives	collaboration on environmental projects in the future.
(18)	2013	*Industrial structure adjustment guidance catalogue (2013)*	China	Update and replace previous catalogues such as elimination catalogue of 1999.	Disposable foamed plastic tableware was not included in this new catalogue.
(19)	2014	*Regulations and decisions adopted by the United Nations Environment Assembly of the United Nations Environment Program at its first session on 27th June 2014*	UNEA-1	Basing on GPML, passed first decisions about marine litters and microplastics.	Since UNEA-1, 'microplastics' as an emerging environmental concern, was first took into international legislation.
(20)	2015	*Marine Wastes Monitoring and Evaluating Techniques Regulations (in Chinese)*	SOA, China	Standardize the classification of marine wastes according to size the materials and monitoring protocols of marine litters	It supplied a technique basis for further research and legislation about microplastic pollution in the future in China.
(21)	2016	*2/11 Marine plastic litter and micro-plastics*	UNEA-2	Encourage governments looking for substitutions for microbeads and the microplastic materials used in PCPs and cosmetics. Call for graduation management for wastes.	UNEA-2 took the microbeads problem into international arena.
(22)	2017	Set up Marine Waste and Microplastics Research Centre	China	Officially start a national level research of microplastics in China.	Marine Waste and Microplastics Research Centre issued 'Marine microplastic monitoring and evaluation techniques regulations.
(23)	2017	*Foreign Garbage Prohibition: implement of reforming the management system for the import of solid waste plan (in Chinese) (Foreign Garbage Prohibition)*	General Office of the State Council	Reduce the pollution led by importing foreign garbage as producers' good	Since 1980s, China have imported a huge amount of solid waste for satisfy the immediate requirement of producers' good. However, foreign garbage has polluted the environments in China. The policy issued for banning the importing of foreign garbage since 2017 and has international influences on global garbage disposal.
(24)	2017	*UNEP/EA.3/Res. 7 Marine litter and microplastics*	UNEA-3	Encourage parties to reduce the marine pollution (especially terrestrial source pollution) by 2015	

(25)	2018	Strategy on Zero Plastic Waste	Canada	Achieve zero waste object with the vision in a circular economy	It sets stage-targets to reduce the plastic waste per capita per year from 706kg to 490kg by 2030 and to 350kg by 2040. After China issued 'Foreign Garbage Prohibition', some developed countries started to establish zero-waste plan or similar plans to reduce the waste amount and encourage higher recycling rates.
(26)	2019	*UNEP/EA.4/L.7 Marine Plastic Litter and Microplastics*	UNEA-4	Pay attention to the impacts of microplastics on wildlife health, ecology, food chain and human health.	The UNEA-4 encouraged the global relevant researchers focusing more on the healthy issues led by microplastics. At the same, UNEA-4 also called for long-term management scheme for microplastics.

3.2. Legislation directly relevant to freshwaters in China

There are multiple legislative efforts to protect and manage freshwater environments in China (see Table 4). Four basic laws established a legislative framework for Chinese freshwater management ("*The Water Pollution Law*", "*The Water Law*", "*The Soil and Water Conservation Law*", and "*The Flood Prevention Law*"). Some pieces of legislation relate more specific watersheds or to detailed management plans than to the issue of plastics, while others dealt more with wider hydrological issues connected to economic development (such as flood control, soil erosion, water and soil conservation, and land use demands), rather than tackling the water quality. For example, of 51 rules that make up the "*River Courses Regulations*" only two are concerned with freshwater pollution and wastewater management.

Several laws and regulations, including "*the National Water Law", *have been amended several times in the past 20 years to meet the needs of China's current development (see Table 4). The "*Environmental Quality Standards for Surface Water (GB3838-2002)*", which was updated from the older version (*GB3838-1998)*, was issued in 2002. This provides an appraisal system to classify the quality of Chinese surface water, and has been applied to fluvial systems, groundwater, lakes, and irrigation water quality (Table 4). Other more recent frameworks that aim to improve water quality include the "*Water Pollution Action of 2015*", the "*Sponge City Program*" (Chan *et al*., 2018), and the "*River Chief System*', these latest developed blue-green infrastructure and urban water management systems are the initiative to further integrate with microplastics and plastics control, in prior to improving the urban freshwater quality (Table 4). Nevertheless, Artificial Polymers (including microplastics) are not considered to be contaminants in the national water quality standards. Recently, an official letter was issued by the Ministry of Ecology and Environment to suggest setting up a list of toxic and harmful water pollutants, which includes heavy metal compounds. This letter reflects an official desire to update existing freshwater quality standards in China; it may be a timely opportunity to include artificial polymers as indicators or parameters of water quality in standards.

Table 4. Legislation and progress for catchment management in China

No.	Time	Laws/Policies	Legislative aims	Comments	Citations
(1)	1984	*Law of the People's Republic of China on Prevention and control of water pollution (Water Pollution Law)*	Establishing a legislative framework of water pollution management	The water pollution law has been updated three times in 1996, 2008 and 2017. It involved the River Chief System in the version of 2017. The 37th rule prohibits discharging and dumping industrial garbage, urban litters and other types of wastes into Chinese waterbodies. In the 38th rule, any deposit of solid waste and other type pollutants under the highest water level line of rivers, lakes, channels or reservoirs are forbidden.	(NPC, 2008)
(2)	1988	*Regulations of the People's Republic of China on the administration of river courses (River Courses Regulations)*	Refining regulations for freshwater management	Two regulations of its 51 rules (34th and 35th) involved freshwater pollution and wastewater management. However, the rest rules are more about land-use issues and flood management. No punishment aiming	(GOSC, 1988)

				at polluting freshwater behaviors in this document.	
(3)	1988	*Water law of the People's Republic of China (Water Law)*	Establishing a rational legislative basis for developing, using and protecting water resources	The Water Law was updated in 2002 and 2016. In 2002, the concerns of flood, drought, water pollution and soil erosion were added into the new Water Law of 2002. Water Law of 2002 also emphasized the importance of scientific reasoning in management. Water Law of 2016 involves more rules about water pollution and wastewater discharge, where unauthorized wastewater discharge is regarded as illegal behaviors.	(NPC, 2000)
(4)	1988	*Provisions for the development and construction of water and soil conservation in the areas bordering Shanxi, Shaanxi and Inner Mongolia*	Solving the confliction between constructions and local water and soil conservation	This policy focuses on the provisional environmental damage led by constructions but pays more attentions to the water and soil conservation instead of pollution problem. This policy was updated once in 2011.	(GOSC and MWR, 2011)
(5)	1988	*Provisions for the administration of water conservation in cities*	Managing urban water consumptions	This policy is the first official concern of urban water resource from Chinese central government, where the major concern was about water shortage and water reusing.	(MOHURD, 2015)
(6)	1989	*Provisions for the prevention and control of pollution in water source protection areas for drinking water*	Protecting drinking water quality	This policy was updated once in 2010. It sets conservation areas for drinking water sources. It also stipulates that the water quality in the first level conservation area of drinking water, should achieve the Level I of both surface water environmental standards and drinking water quality standards. It forbids the dumping of industrial, urban-based in protected waterbodies. Any leaks of dangerous/risky pollutants into protected waterbodies were prohibited.	(MWR *et al.*, 2015)
(7)	1989	*Environmental Protection Law of the People's Republic of China (Environmental Protection Law)*	Improving ecosystem quality and preventing environmental hazards	Environmental Protection Law mentioned the management of marine environments in the 21st rule. It also stipulates the pollutants emission towards waterbodies should obey Water Pollution Law. Environment Protection Law was updated in 2014.	(NPC, 1989)
(8)	1991	*Law of the People's Republic of China on soil and water conservation (Soil and Water Conservation Law)*	Providing legislative basis for water and soil conservation in China	Soil and Water Conservation Law aims at protection water and soil resources and reducing hydrological hazards and drought events. This law was published in 1991 and updated in 2010.	(NPC, 2013)

(9)	1994	*Urban water supply ordinance of 1994*	Managing water supply system in urban area	This policy directly involved urban water supply system but focused on water supply techniques and the water price rather than the water quality in and after the treatment by the system.	(GOSC, 2015a)
(10)	1995	*Interim regulations on prevention and control of water pollution in the Huaihe River Basin*	Improving water quality in Huaihe River Basin	This policy was updated during 2010 and 2011. It standardized the industrial emission/discharge towards Huaihe River Basin by 1997 and pushed the river channel cleaning work by 2000. From 1998, any industrial waste emissions towards waterbodies were banned. Some types of industries such as paper mill, electroplate factory, printing and dyeing mill are forbidden nearby the protected waterbodies.	(GOSC, 2015b)
(11)	1997	*Law of the People's Republic of China on flood prevention (Flood Prevention Law)*	Establishing alegal basis for flood prevention work and projects in China	Due to China was in a fast but very beginning developing stage at that time, land-uses and flood/drought management is the major hydrological problems existing in China, especially in urban area. Flood Prevention Law as well as Soil and Water Conversation Law were designed for solving above problems.	(NPC, 2006)
(12)	1999	*Measures for the administration of the Pearl River Estuary*	Managing water resources in the Pearl River Estuary	This policy was established according to Flood Prevention Law and River Courses Regulations, while it did not involve water pollution considerations. There were also many other similar measures focusing on river- or catchment- scale hydrological environments without involving enough pollution concerns, which implies the first requirement of hydrological environments at that time in China.	(MWR, 2018)
(13)	2000	*Detailed rules for the implementation of the law of the People's Republic of China on prevention and control of water pollution (Detailed Rules of Water Pollution Law)*	Providing detailed stipulations for enforcing water pollution law	This policy was established according to Water Pollution Law. It stipulated the vessel shipping in river channel must be awarded pollution prevention certification and instructed with pollution prevention equipment. Port should have relevant equipment to deal with the wastes and ship garbage as well. It also sets four specific objects: 1) Achieving the requirement of environmental functions of waterbodies; 2) Setting staged due time and targets for law implementation; 3) Designing detailed measures for key water pollution prevention areas and pollution sources;	(GOSC, 2005)

				4) Improving urban planning with the considerations of drainage system in basin area and sewage treatment system.	
(14)	2002	*Environmental quality standards for surface water (GB 3838-2002)*	Standardizing the surface water quality assessment	To satisfy the requirement of Environmental Protection Law and Water Pollution Law, the GB 3838 was published in 1988 and updated in 1999. The GB3838-2002 (a new version) took into force from 1st Jun 2002 and replaced previous versions of GB3838. It classified the water quality into five levels according to a list of indicators: 1) Head of water and national natural conservation; 2) Level I conservation area of drinking water, distinct aqua ilia habitats, spawning habitat for fish and shrimps; 3) Level II conservation of drinking water source; 4) Normal industrial water and indirectly contacting entertainment water; 5) Agricultural water and landscape water. Artificial polymers (plastics or microplastic content) did not involve in this standard as an indicator.	(MEE and AQSIQ, 2002)
(15)	2002	*Measures for the demonstration and management of water resources for construction projects*	Setting a framework of scientific demonstration for relevant construction projects.	This policy was updated once in 2015. Water quality and hydrological environment are regarded as evaluation criterions in the measures.	(MWR and SDPC, 2018)
(16)	2004	*Measures for the supervision and control of sewage discharge outlets into river*	Controlling pollutants emission into river	According to Water Law, Flood Prevention Law and River Courses Regulations, this policy stipulated the files and information required for applying construction or reconstruction of sewage draining exit towards river. It is a concern of freshwater quality from another aspect. However, it did not involve a detailed demand of water quality.	(MWR, 2015a)
(17)	2004	*Measures for the administration of the Yellow River estuary*	Managing the water environment of the Yellow River estuary	It is similar with the '*Measures for the administration of the Pearl River Estuary*' and did not involve water pollution consideration.	(MWR, 2015b)
(18)	2005	*Standards for irrigation water quality (GB 5084-2005)*	Refining the water quality standards for irrigation water	This standard was established basing on GB3838 and replaced GB 5084-1992. As the same as GB3838, GB5084 did not considered artificial polymer content as a factor of water quality.	(AQSIQ, 2005)

(19)	2006	*Standards for drinking water quality (GB 5749-2006)*	Refining the water quality standards for drinking water	GB5749 also did not involve artificial polymer occurrences as a factor of water quality.	(MOH and AQSIQ, 2006)
(20)	2007	*Regulations of the People's Republic of China on hydrology (Hydrology Regulations)*	Standardizing the hydrological management and relevant projects	It was established according to the Water Law and Flood Prevention Law, and updated three times in 2013, 2016 and 2017. It provides a framework for the hydrological planning, construction, forecast, monitoring, data management, instruction protection and legal responsibilities.	(GOSC, 2017c)
(21)	2008	*Plans for the route to the sea for the operation of the three gorges reservoir and measures for the management of water resources and river courses in the reservoir area*	Managing the channels of Three Gorges Basin	It forbids dumping wastes and discharging sewage into the reservoir areas according to the Water Law and Flood Prevention Law.	(MWR, 2018)
(22)	2009	*Measures for the administration of the estuary of the New Yongding River, the Haihe River and the Duliujian River*	Channel management for estuary of three rivers	With Water Law, Flood Prevention Law and River Courses Regulations as the legislative basis, the waste dumping and deposal are not allowed in those managed catchment areas.	(MWR, 2015c)
(23)	2011	*Measures for the protection of hydrological monitoring environment and facilities*	Protecting hydrological monitoring area and facilities	It was updated once in 2015 and banned dumping wastes near to the monitoring area of hydrological conditions.	(MWR, 2015d)
(24)	2011	*Regulations on the administration of the Taihu Lake Basin (Taihu Regulations)*	Protect hydrological environment of the Taihu Lake Basin	Taihu Regulations make specific rules for the management of Taihu Lake catchment according to Water Law and Water Pollution Law. The dumping of any types wastes into the Taihu Lake is banned.	(GOSC, 2015c)
(25)	2015	*Action plan for prevention and control of water pollution (Water Pollution Action)*	Enhancing prevention of water pollution and strengthening national water security	Water Pollution Action, as known as 'Ten Measures of Water' in China, issued ten demands on water pollution prevention works nationwide: (1) Completely controlling pollutants discharge; (2) Transforming and upgrading the economic structures; (3) Conserving and protecting water resources; (4) Strengthening science and technology support; (5) Giving full play to the role of market mechanisms; (6) Intensifying environmental law enforcement and supervision; (7) Reinforcing management on water environments;	(MEE, 2016)

				(8) Ensuring ecological safety of water environments; (9) Clarifying and implementing the responsibilities of all parts in governments and organizations; (10) Strengthening public participation and oversight. It also requires that the water quality of over 70% of total water in the major seven basins (Yangtze River, Yellow River, Pearl River, Songhua River, Huaihe River, Haihe River and Liaohe River) reach Level III according to GB3838-2002 by 2020.	
(26)	2016	*Views on the full implementation of the River Chief System*	Popularizing the River Chief System scheme to national level	It stipulates to establish provincial, city, county and township level in the River Chief Systems by the end of 2018 nationwide in China. By June 2018, 31 provinces have established the River/Lake Chief System (RCS) and 300,000 river chiefs have been selected for the four levels. By the end of 2018, Beijing, Tianjin, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi and Hainan had established RCS completely.	(GOSC, 2016)
(27)	2017	*Standards for groundwater quality (GB/T 14848-2017)*	Refining the water quality standards for groundwater	It replaced GB/T 14848-1993 and added another 54 indicators for water quality evaluations but did not include any considerations of artificial polymers.	(AQSIQ, 2017)
(28)	2018	*Work Specification of the River Chief System (DB3306/T 015-2018); Work Specification of the Lake Chief System (DB3306/T 016-2018)*	Establishing the responsibility framework of RCS/LCS.	They are the first formal legislations for River Chief System scheme even if they were issued by local governments. The popularization of such work specification could be expected.	(Shaoxing City, 2018a, 2018b)
(29)	2018	*Implementation plan for urban black and smelly water treatment*	Completing the installation of and improving sewage treatment systems in cities and towns	Basing on Water Pollution Action, this policy aims at eliminating 90% black and smelly waterbodies (BSW) in urban built-up areas for major cities in China by the end of 2018, for prefecture cities by the end of 2020. RCS/LCS is required to play an important role in this implement.	(MOHURD, 2018)
(30)	2019	*Management of urban pipe networks and sewage treatment subsidy funds*	Standardizing the grants of subsidy funds for urban pipe networks and sewage treatment from 2018 to 2021	This subsidy funds will cover Sponge City project, underground pipe network establishment project, urban BSW treatment pilot project, and improvement of sewage systems in the cities and towns of central and western regions, with different specific plans.	(MOHURD and MOF, 2019)
(31)	2019	*The notice of the three ministries on organizing the application of pilot*	Standardizing the requirements of applying pilot cities	Basing on the official document 'Implement plan for urban black and smelly water treatment', this	(MOF, 2019)

		cities for the treatment of black and smelly waterbodies in urban areas in 2019	for treatment of black and smelly waterbodies	document clarifies the application approaches to becoming treatment urban BSW pilot cities. Sponge City theory and RCS/LCS was encouraged to combine with BSW treatment in this document.	
(32)	2019	*Three-year action plan for improving the quality and efficiency of urban sewage treatment (2019-2021)*	Completing the installation of and improving sewage treatment systems in cities and towns	This policy confirms the major objects on the improving sewage treatment systems in cities and towns, where Biochemical Oxygen Demand (BOD) was precisely issued as the indictor representing the quality of sewage treatment systems.	(MOHURD, 2019)
(33)	2019	*Letter soliciting opinions on 'the list of toxic and harmful water pollutants (Batch I) (exposure draft)'*	Suggesting establishing a professional list to clarify the types of water pollutants and collecting comments from relevant professional organization in China	By February 2019, nine pollutants were added into the list: dichloromethane, trichloroethane, trichloro ethylene, tetrachloroethylene, cadmium and cadmium compounds, mercury and mercury compounds, hexavalent chromium compounds, lea compounds, and arsenic and arsenic compounds.	(MEE, 2019)

4. Mitigation of microplastic pollutions in Chinese urban freshwater environment

The growing findings on microplastic pollution, especially in urban catchment (Figure 4), are likely to motivate legislative action in China (Yuan *et al*., 2019). However, there are major challenges to reducing plastic pollution in China, stemming from the many benefits of and society's reliance on plastics, and a lack of suitable alternatives for some applications. These challenges are summarised in Figure 5. Reflecting both current knowledge gaps and these challenges, we put forward a number of recommendations, as detailed in the remainder of this section.

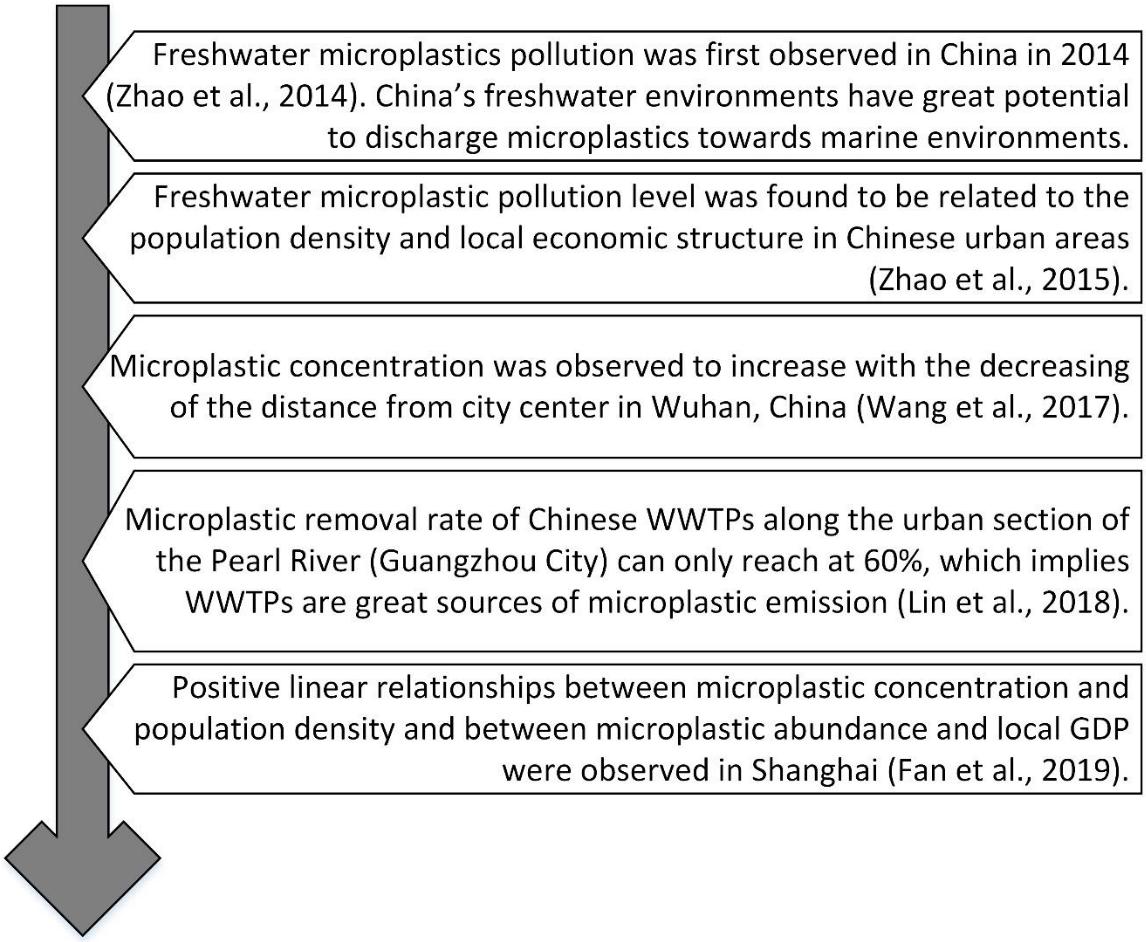

Figure 4. Key research progresses on microplastic pollution in Chinese urban catchments (Source: Yuyao Xu)

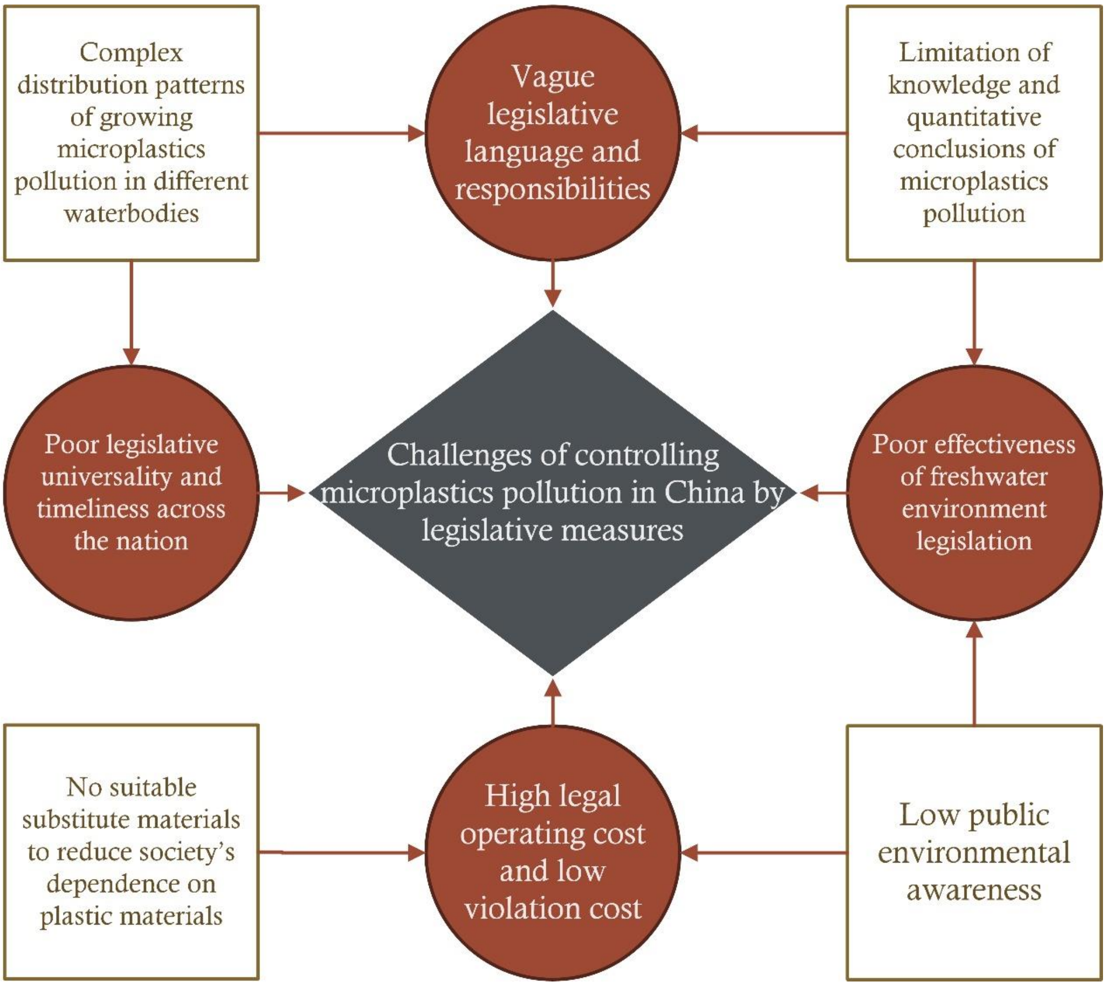

Figure 5. Reasons of legislative difficulties on microplastic pollution (Source: Yuyao Xu)

4.1. Toxicology.

China needs to build a toxicological (dose-based) or environmental (impact-based) microplastic pollution risk assessment system, and formulate reasonable treatment plans based on this quantitative basis. Although microplastics are categorised as toxic pollutants and banned in Canada (Canada, 2015; Canada.ca, 2017), there are some uncertainties remaining over direct toxicity to humans and wildlife. A common problem is that many toxicity tests have been based on doses much higher than found in the environment, so assessing the risks to human and ecological health from current levels of contamination remains problematic (X. Jiang *et al.*, 2019). Advanced toxicological studies may either provide the impetus for the Chinese government to list microplastics as toxic pollutants or allay concerns about current levels. Risk assessment systems should also consider the interactions between microplastics and other relevant pollutants (persistent organic matters, microorganisms and heavy metal).

4.2.Recognising different types of microplastics

China should apply specific management measures for different types of microplastics. Microplastic is actually a general term, encompassing plastic debris with a wide variety of characteristics. These characteristics (e.g. sizes, shapes, chemical composition) affect their distribution patterns and environmental impacts, and require different solutions to manage each type of them. '*Microbead-free*' action is a successful case for the management of a single group of microplastics, but micro-fibres are far more abundant in many freshwaters, especially in urban catchments (see Table 1). Domestic household discharge (e.g. via washing clothes on urban rivers) is one of the main sources of fibres in freshwater environments (see Figure 3). Yang *et al.* (2019) found that polyester fabric releases fewer fibres during laundry compared to polyamide fabric and acetate fabric and so developing textiles that do not as readily shed fibres would be beneficial. Also, improving laundry and fabric filter techniques of washing machines may reduce the amount of fibres from washing machines into sewage pipes in residential areas, is a way to cut the transportation of microplastics. Compared to platen laundry machines, fibres are easier to peel off in pulsator laundry machine (Yang *et al.*, 2019). Another way to cut the transportation of synthetic fibres is to improve the microplastic removal rate of WWTPs in China. Legislation aiming at those three points can effectively control the amount of synthetic fibre emitted in densely populated areas. This approach to controlling fibre pollution could also be extended to other types of microplastics.

4.3.Consumption rates

We recommend reducing the consumption of plastic products, such as plastic bags and single-use food containers. This will be a considerable challenge as the amount of plastic consumed from these sources is increasing every year in China. By 2017, over 20 million fast-food deliveries were produced per day, where daily plastic bag consumption was enough to cover 168 football fields in China (Xue, 2017). In early 2011, the Chinese Government had to spend about 18.5 million yuan per year to control macro-plastic pollution (Zhu, 2011). Promoting the use of recyclable packaging throughout China's e-commerce industry, or supplying recycling services for non-disposable food containers in food delivery businesses, are therefore measures with great potential within China (Hao, 2019). This alone will not be enough and such reductions should be coupled with investment and development of adequate recycling infrastructure. Developing alternative materials for plastics or controllable plastics degradation technology is also an approach to reducing the society's dependence on plastic products.

4.4. Management strategy

The fourth recommendation is the devolution of management responsibility for microplastic pollution to local governments after central government sets general targets and overarching legislation. As evident in Table 1, microplastic loads vary markedly across different waterbodies and, therefore, local governments are better placed to specify management strategies given their detailed local knowledge and prioritisation of local environmental threats and constraints. This may then inform national action, as was employed in the USA for the "*Microbeads-free Waters Act*" (McDevitt *et al.*, 2017), and a similar approach has been used to develop the "*Sponge City Program*" in China (Chan *et al.*, 2018). As part of a better management strategy, it is useful to consider microplastics and water quality more broadly, in longer-term land-use improvement projects in China. By combining the microplastic risk assessment system and the approach that manages different types of microplastics separately, the abundance of some groups of microplastics (such as PP or PE in particular size range) could be listed as a water quality index of the national freshwater quality standard (e.g. based on the *GB3838-2002 that published by the National Environmental Bureau from the Chinese Government).* The updated water quality standards will have a long-term impact on China's future hydrologic and environmental management, accomplished with current freshwater management strategies such as the "*River/Lake Chief System*" and "*Sponge City Project*".

Complex land-use patterns and a multitude of industrial and urban activities create substantial challenge for employing a unified approach to freshwater management in China. As microplastic pollution is related closely to land-use function and local economic structure in Chinese cities, the country's urban planning system is well placed as to help integrate considerations of land-use demand and microplastic pollution, as part of strategies to promote more sustainable development.

5. Conclusion

In this paper, we have reviewed microplastics in Chinese urban freshwater environments and relevant legislation that aims at managing microplastic pollution. Microplastic properties, hydrological, meteorological and geographical conditions, population size and local land-use functions are critical factors determining microplastic concentrations in urban waterbodies in China. With the growing loads of microplastics entering lakes, streams and rivers, improving management strategies and developing legislation is a significant challenge in Chin but one that needs to be addressed. Unfortunately, fundamental knowledge of loads, transport pathways and mechanisms, and of the toxicological effects of microplastic, remains limited in China, so there remains a need for more empirical research to help underpin evidence-based legislation.

The Chinese government has paid more attention to urban water quality over the last three years, but as yet there is no legislation that deals explicitly with microplastics. This is an important issue, given that China is known to release large quantities of microplastic particles into its freshwaters. The potential ecological and human health risks posed by microplastics, speak to the need for improving legislation and policy frameworks, to better manage current and deal with future threats of plastic waste.

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References

1992 OSPAR Convention (2007) *Convention for the protection of the marine environment of the north-east Atlantic*. March 19, 2020, from https://www.ospar.org/site/assets/files/1290/ospar_convention_e_updated_text_in_2007_no_revs.pdf

1Bag at a Time (2019) *The San Francisco Bag Ban*. 1 Bag at a Time. March 19, 2020, from https://1bagatatime.com/learn/guide-bag-bans/bag-ban-san-francisco/

AQSIQ (2005) *Standards for irrigation water quality (GB 5084-2005).* Book118. March 19, 2020, from https://max.book118.com/html/2019/0424/8050002055002020.shtm

AQSIQ (2017) *Standard for groundwater quality (GB/T 14848-2017)*. GB688. March 19, 2020, from http://www.gb688.cn/bzgk/gb/newGbInfo?hcno=F745E3023BD5B10B9FB5314E0FFB5523

Arias-Andres, M., Rojas-Jimenez, K. and Grossart, H. P. (2019) Collateral effects of microplastic pollution on aquatic microorganisms: An ecological perspective. *TrAC - Trends in Analytical Chemistry*. Elsevier Ltd, 112, pp. 234–240. 10.1016/j.trac.2018.11.041.

Baptista Neto, J. A., Gaylarde, C., Beech, I., Bastos, A. C., da Silva Quaresma, V. and de Carvalho, D. G. (2019) Microplastics and attached microorganisms in sediments of the Vitória bay estuarine system in SE Brazil. *Ocean and Coastal Management*. Elsevier, 169(January), 247–253. 10.1016/j.ocecoaman.2018.12.030.

Basel Convention (2019) *Basel Convention*. March 19, 2020, from http://www.basel.int/TheConvention/Overview/tabid/1271/Default.aspx

BeatTheMicrobead (2020) *Global Impact.* Beat the Microbead. March 19, 2020, from https://www.beatthemicrobead.org/impact/global-impact/

BIOPLASTICS NEWS (2019, January 12) *Plastic Microbeads Bans in 2018.* Bioplastics News. March 19, 2020, from https://bioplasticsnews.com/2019/01/12/plastic-microbeads-bans-in-2018/

Cai, P. (2012) The Implementation Dilemma and Perfect Path of River Chief System. *Journal of Social Science of Harbin Normal University*, pp. 4–8. 10.13727/j.cnki.53-1191/c.2012.04.009.

Canada (1999) *Canadian Environmental Protection Act, 1999*. Canada Justice Law Website. March 19, 2020, from https://laws-lois.justice.gc.ca/eng/acts/c-15.31/

Canada (2015) *Chemical substances glossary.* Canada.ca. March 19, 2020, from https://www.canada.ca/en/health-canada/services/chemical-substances/chemical-substances-glossary.html#s

Canada.ca (2017, June 14) Microbeads in Toiletries Regulations. *Canada Gazette Part II*, 151(12), 1349–1376. March 19, 2020, from http://www.gazette.gc.ca/rp-pr/p2/2017/2017-06-14/html/sor-dors111-eng.html

Carr, S. A. (2016) Transport and Fate of Microplastic Particles in Wastewater Treatment Plants. *Water Res.,* 15(91), 174-82. 10.1016/j.watres.2016.01.002

CCME (2018) *STRATEGY ON ZERO PLASTIC WASTE*. Canadian Council of Ministers of the Environment. March 19, 2020, from https://www.ccme.ca/files/Resources/waste/plastics/STRATEGY ON ZERO PLASTIC WASTE.pdf

Chan, F. K. S., Griffiths, J. A., Higgitt, D., Xu, S., Zhu, F., Tang, Y., Xu, Y. and Thorne, C. R. (2018) "Sponge City" in China—A breakthrough of planning and flood risk management in the urban context. *Land Use Policy*, 76(March), 772–778. 10.1016/j.landusepol.2018.03.005.

Chicago Tribune (2014, June 8) *Governor signs bill making Illinois first state to ban microbeads.* Chicago Tribune. March 19, 2020 from https://www.chicagotribune.com/news/ct-xpm-2014-06-08-chi-governor-signs-bill-making-illinois-first-state-to-ban-microbeads-20140608-story.html

Conley, K., Clum, A., Deepe, J., Lane, H., and Beckingham, B. (2019) Wastewater treatment plants as a source of microplastics to an urban estuary: Removal efficiencies and loading per capita over one year. *Water Research X*. Elsevier, 3(April). 10.1016/j.wroa.2019.100030.

Cosmetics Europe (2015, October 21) *Cosmetics Europe Recommendation on Solid Plastic Particles (Plastic Micro Particles)*. Cosmetics Europe. March 19, 2020, from https://www.cosmeticseurope.eu/files/3714/7636/5652/Recommendation_on_Solid_Plastic_Particles.pdf

Crawford, C. B. and Quinn, B. (2017a) 3 - Plastic production, waste and legislation. in Crawford, C. B. and Quinn, B. B. T.-M. P. (eds), Microplastic Pollution (pp. 39-56). *Elsevier*. https://doi.org/10.1016/B978-0-12-809406-8.00003-7.

Crawford, C. B. and Quinn, B. (2017b) 5 - Microplastics, standardisation and spatial distribution. in Crawford, C. B. and Quinn, B. B. T.-M. P. (eds), Microplastic Pollution (pp. 101-130). *Elsevier*. https://doi.org/10.1016/B978-0-12-809406-8.00005-0.

Dikareva, N. and Simon, K. S. (2019) Microplastic pollution in streams spanning an urbanisation gradient. *Environmental Pollution*. Elsevier Ltd, 250, pp. 292–299. 10.1016/j.envpol.2019.03.105.

Ding, L., Mao, R. f., Guo, X., Yang, X., Zhang, Q. and Yang, C. (2019) Microplastics in surface waters and sediments of the Wei River, in the northwest of China. *Science of the Total Environment*. Elsevier B.V., 667, pp. 427–434. 10.1016/j.scitotenv.2019.02.332.

Dris, R., Gasperi, J., Mirande, C., Mandin, C., Guerrouache, M., Langlois, V. and Tassin, B. (2017) A first overview of textile fibers, including microplastics, in indoor and outdoor environments. Environmental Pollution, 221, pp. 453-458. https://doi.org/10.1016/j.envpol.2016.12.013

Eerkes-Medrano, D., Thompson, R. C. and Aldridge, D. C. (2015) Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Water Research*. Elsevier Ltd, 75, pp. 63–82. 10.1016/j.watres.2015.02.012.

Everaert, G., van Cauwenberghe, L., De Rijcke, M., Koelmans, A. A., Mees, J., Vandegehuchte, M. and Janssen, C. R.(2018) Risk assessment of microplastics in the ocean: Modelling approach and first conclusions. *Environmental Pollution*, 242, pp. 1930–1938. 10.1016/j.envpol.2018.07.069.

Fan, Y., Zheng, K., Zhu, Z., Chen, G. and Peng, X. (2019) Distribution, sedimentary record, and persistence of microplastics in the Pearl River catchment, China. *Environmental Pollution*. Elsevier Ltd, 251, pp. 862–870. 10.1016/j.envpol.2019.05.056.

Fok, L., Lam, T. W. L., Li, H. and Xu, X. (2020) A meta-analysis of methodologies adopted by microplastic studies in China. Science of the Total Environment, Elsevier Ltd, 718, pp: 1-10. https://doi.org/10.1016/j.scitotenv.2019.135371

Fu, D., Chen, C. M., Qi, H., Fan, Z., Wang, Z., Peng, L. and Li, B. (2020) Occurrences and distribution of microplastic pollution and the control measures in China. Marine Pollution Bulletin, Elsevier Ltd, 153, pp. 1-14. https://doi.org/10.1016/j.marpolbul.2020.110963

Fu, Z. and Wang, J. (2019) Current practices and future perspectives of microplastics pollution in freshwater ecosystems in China. *Science of the Total Environment*. Elsevier B.V., 619, pp: 697-712. https://doi.org/10.1016/j.scitotenv.2019.07.167

Garside, M. (2019, December 4) *Plastic materials production worldwide by region 2018.* Statista. March 19, 2020, from https://www.statista.com/statistics/281126/global-plastics-production-share-of-various-countries-and-regions/

Geyer, R., Jambeck, J. and Law, K. (2017) 'Production, Use, And Fate of All Plastics Ever Made', *Science Advances*, 3(7), pp. 25–29. 10.1126/sciadv.1700782

GOSC (1985, June 3) *Regulations of the People's Republic of China on the Control over Dumping Wastes into the Sea Waters [Revised]*. March 19, 2020, from http://www.lawinfochina.com/display.aspx?lib=law&id=1255&CGid=

GOSC (1988) *Regulations of the People's Republic of China on the administration of river courses.* March 19, 2020, from http://www.gov.cn/flfg/2005-08/06/content_21041.htm

GOSC (1990, June 22) *Regulations of the People's Republic of China on the prevention and control of pollution damage to the marine environment by land-based pollution.* March 19, 2020, from http://www.chinalawedu.com/falvfagui/fg22016/971.shtml

GOSC (2005, August 6) *Detailed rules for the implementation of the law of the People's Republic of China on prevention and control of water pollution.* March 19, 2020, from http://www.gov.cn/ziliao/flfg/2005-08/06/content_21045.htm

GOSC (2008, January 8) *The Notice of the General Office of State Council on Restricting the Production, Sale and Use of Plastic Shopping Bags*. March 19, 2020, from http://www.gov.cn/zwgk/2008-01/08/content_852879.htm

GOSC (2015a, June 2) *Urban water supply ordinance of 1994*. March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/xzfghfgxwj/201707/t20170713_955714.html

GOSC (2015b, June 2) *Interim regulations on prevention and control of water pollution in the Huaihe River Basin*. March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/xzfghfgxwj/201707/t20170713_955715.html

GOSC (2015c, October 11) *Regulations on the administration of the Taihu Lake basin.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/xzfghfgxwj/201707/t20170713_955727.html

GOSC (2016, December 12) 'Views on the full implementation of the River Chief System'. March 19, 2020, from http://www.scio.gov.cn/34473/34515/Document/1535410/1535410.htm

GOSC (2017a, July 18) *Foreign Garbage Prohibition.* March 19, 2020, from http://www.gov.cn/zhengce/content/2017-07/27/content_5213738.htm

GOSC (2017b) *Regulations of the People's Republic of China on the Prevention of environmental pollution by shipbreaking.* March 19, 2020, from http://www.gov.cn/gongbao/content/2017/content_5219150.htm

GOSC (2017c, March 22) *Regulations of the People's Republic of China on hydrology.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/xzfghfgxwj/201707/t20170713_955725.html

GOSC (2018, October 10) *Regulations on the administration of the prevention and control of pollution damage to the Marine environment by Marine engineering construction projects.* March 19, 2020, from http://sthj.ln.gov.cn/xxgk/flfg/xzfg/201810/t20181010_106616.html

GOSC and MWR (2011, January) *Provisions for the development and construction of water and soil conservation in the areas bordering Shanxi, Shaanxi and Inner Mongolia.* March 19, 2020, from http://www.gov.cn/gongbao/content/2011/content_1860824.htm

Hao, D. (2019) "Recycle of takeout containers" requires the joint efforts of all parties (in Chinese). *Journal of Chinese population*, 3. March 19, 2020, from https://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CCND&dbname=CCNDLAST2019&filename=CRCB201906120032&v=MTQ0MzE4VG5qcXF4ZEVlTU9VS3JpZlplWnZGU2p0VTczTUlGMGRKai9JYkxHNEg5ak1xWTVIWk9zTURoTkt1aGRobmo5

He, P., Chen, L., Shao, L., Zhang, H. and Lü, F. (2019) Municipal solid waste (MSW) landfill: A source of microplastics? -Evidence of microplastics in landfill leachate. *Water Research*, 159, pp. 38–45. 10.1016/j.watres.2019.04.060.

Horton, A. A., Svendsen, C., Williams, R. J., Spurgeon D. J. and Lahive, E. (2017a) Large microplastic particles in sediments of tributaries of the River Thames, UK – Abundance, sources and methods for effective quantification. *Marine Pollution Bulletin*. Elsevier B.V., 114(1), pp. 218–226. 10.1016/j.marpolbul.2016.09.004.

Horton, A. A., Walton, A., Spurgeon, D. J., Lahive, E. and Svendsen, C. (2017b) Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of the Total Environment*. Elsevier B.V., 586, pp. 127–141. 10.1016/j.scitotenv.2017.01.190.

IMO (1996) *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972*. Available at: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/Pages/1996-Protocol-to-the-Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter,-1972.aspx (Accessed: 11 April 2019).

IMO (1997) *International Convention for the Prevention of Pollution from Ships (MARPOL)*. March 19, 2020, from http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

IMO (2014, June 8) *Climate Change and the London Convention and Protocol.* March 19, 2020, from http://www.imo.org/en/KnowledgeCentre/ReferencesAndArchives/IMO_Conferences_and_Meetings/London_Convention/Pages/default.aspx

Industry, C. P. (2019) ‘More than 60 million plastic tablewares are consumed every day in China (in Chinese)’, *China Plastics Industry*, 47(6), p. 154. March 19, 2020, from https://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CJFQ&dbname=CJFDLAST2019&filename=SLGY201906037&v=MTQ5NjlEaDFUM3FUcldNMUZyQ1VSN3FmWk9kbUZ5M2xVN3JMTmlITWQ3RzRIOWpNcVk5R1k0UjhlWDFMdXhZUzc=

Intertek (2017, January 19) *Intertek launches unique testing service for microbeads environmental impact assessment.* March 19, 2020, from http://www.intertek.com/news/2017/01-19-unique-testing-service-microbeads-environmental-impact-assessment/

Irish environment (2015, October 1) *Plastic Bag Levy*. March 19, 2020, from http://www.irishenvironment.com/iepedia/plastic-bag-levy/

Jambeck, J., Geyer, R., Wilcox C., Siegler T. R., Perryman, M., Andrady, A., Narayan, R., and Law, K. L. (2015) Plastic waste inputs from land into the ocean. *Science (New York, N.Y.). American Association for the Advancement of Science,* 347(6223), pp. 768–71. 10.1126/science.1260352.

Jiang, C., Yin, L., Li, Z., Wen, X., Luo, X., Hu, S., Yang, H., Long, Y., Deng, B., Huang, L. and Liu, Y. (2019) Microplastic pollution in the rivers of the Tibet Plateau. *Environmental Pollution*, 249, pp. 91–98. 10.1016/j.envpol.2019.03.022.

Jiang, X., Chen, H., Liao, Y., Ye, Z., Li, M. and Klobučar, G. (2019) Ecotoxicity and genotoxicity of polystyrene microplastics on higher plant Vicia faba. *Environmental Pollution*. Elsevier. 10.1016/j.envpol.2019.04.055.

Lambert, S. and Wagner, M. (2018) *Freshwater Microplastics, Freshwater Microplastics The Handbook of Environmental Chemistry*. 10.1007/978-3-319-61615-5.

Lebreton, L. and Andrady, A. (2019) Future scenarios of global plastic waste generation and disposal. *Palgrave Communications*, 5(1). 10.1057/s41599-018-0212-7.

Li, J., Liu, H. and Paul Chen, J. (2018) Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection. *Water Research*. Elsevier Ltd, 137(May), pp. 362–374. 10.1016/j.watres.2017.12.056.

Li, L., Geng, S., Wu, C., Song, K., Sun, F., Visvanathan, C., Xie, F. and Wang, Q. (2019) Microplastics contamination in different trophic state lakes along the middle and lower reaches of Yangtze River Basin. *Environmental Pollution*. Elsevier, 254, p. 112951. 10.1016/J.ENVPOL.2019.07.119.

Li, W. (2020) Occurrence of Characteristics of Microplastics Pollution in Different Types of Urban Runoff. BARCELONE 21st Int'l Conference on Chemical, Biological & Environmental Science (BCBES-20), 2020, Barcelona, Spain. https://doi.org/10.17758/URUAE10.AE0220204

Li, Y. (2018) Legislation Issues on Marine Pollution of Microplastics. *Journal of Xidian University (Social Science Edition)*, 28(1), pp. 70–76. 10.16348/j.cnki.cn61-1336/c.2018.01.009.

Lin, L., Zuo, L., Peng, J., Cai, L., Fok, L., Yan, Y., Li, H. and Xu, X. (2018) Occurrence and distribution of microplastics in an urban river: A case study in the Pearl River along Guangzhou City, China. *Science of the Total Environment*. Elsevier B.V., 644, pp. 375–381. 10.1016/j.scitotenv.2018.06.327.

Liu, S., Jian, M., Zhou, L. and Li, W. (2019) Distribution and characteristics of microplastics in the sediments of Poyang Lake, China. *Water Science and Technology*, 79(10), pp. 1868–1877. 10.2166/wst.2019.185.

Luo, W., Su, L., Craig, N. J., Du, F., Wu, C. and Shi, H. (2019) Comparison of microplastic pollution in different water bodies from urban creeks to coastal waters. *Environmental Pollution*, 246, pp. 174–182. 10.1016/j.envpol.2018.11.081.

Lusher, A. L., Tirelli, V., O'Connor, I. and Officer, R. (2015) Microplastics in Arctic polar waters: The first reported values of particles in surface and sub-surface samples. *Scientific Reports*. Nature Publishing Group, 5(June), pp. 1–9. 10.1038/srep14947.

Ma, J. and Wang, W. (2017, September 1) *The establishment of Marine waste and microplastic research center*. March 19, 2020, from http://www.oceanol.com/content/201709/01/c67977.html

McCormick, A., Hoellein, T., Mason, S., Schluep, J. and Kelly, J. J. (2014) Microplastic is an abundant and distinct microbial habitat in an urban river. *Environmental Science and Technology*, 48(20), pp. 11863–11871. 10.1021/es503610r.

McDevitt, J. P., Criddle, C. S., Morse, M., Hale, R. C., Bott, C. B. and Rochman, C. M. (2017) Addressing the Issue of Microplastics in the Wake of the Microbead-Free Waters Act - A New Standard Can Facilitate Improved Policy. *Environmental Science and Technology*, 51(12), pp. 6611–6617. 10.1021/acs.est.6b05812.

MEE (2016, Dec 16) Notice of the State Council on Issuing the *Action Plan for Prevention and Control of Water Pollution (in Chinese)*. Douban. March 19, 2020, from https://www.douban.com/group/topic/94622772/

MEE (2019, January 25) *Letter soliciting opinions on 'the list of toxic and harmful water pollutants (Batch I) (exposure draft)*. March 19, 2020, from http://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/201902/t20190201_691863.html

MEE and AQSIQ (2002) *Environmental quality standards for surface water (GB 3838-2002)*. March 19, 2020, from http://img.jingbian.gov.cn/upload/CMSjingbian/201806/201806210945047.pdf

MOF (2019, May 14) *The notice of the three ministries on organizing the application of pilot cities for the treatment of black and smelly waterbodies in urban areas in 2019*. March 19, 2020, from http://www.sohu.com/a/313880298_532149

MOH and AQSIQ (2006) *Standards for drinking water quality (GB 5749-2006)*. March 19, 2020, from http://www.steriq.cn/pdf/34.pdf

MOHURD (2015, June 2) *Provisions for the administration of water conservation in cities.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/xzfghfgxwj/201707/t20170713_955710.html

MOHURD (2018, October 15) *Notice on printing and distributing the implementation plan for urban black and smelly water treatment (in Chinese)*. March 19, 2020 from http://www.mohurd.gov.cn/wjfb/201810/t20181015_237912.html

MOHURD (2019, April 29) *Notice on the issuance of the three-year action plan for improving the quality and efficiency of urban sewage treatment.* March 19, 2020, from http://www.mohurd.gov.cn/wjfb/201905/t20190509_240490.html

MOHURD and MOF (2019) *Notice on printing and distributing measures for management of urban pipe networks and sewage treatment subsidy funds.* March 19, 2020, from http://www.chinairn.com/news/20190703/115043236.shtml

MWR (2015a, December 17) *Measures for the supervision and control of sewage discharge outlets into river*. March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960245.html

MWR (2015b, June 9) *Measures for the administration of the Yellow River estuary.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960244.html

MWR (2015c, June 9) *Measures for the administration of the estuaries of the New Yongding River, the Haihe River and the Duliujian River.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960259.html

MWR (2015d, December 17) *Measures for the protection of hydrological monitoring environment and facilities.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960262.html

MWR (2018, January 15) *Measures for the administration of the pearl river estuary.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960229.html

MWR (2018, January 15) *Plans for the route to the sea for the operation of the three gorges reservoir and measures for the management of water resources and river courses in the reservoir area.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960257.html

MWR and SDPC (2018, January 15) *Measures for the demonstration and management of water resources for construction projects.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960236.html

MWR, MOHURD, MOH, MLR, MEE (2015, June 2) *Provisions for the prevention and control of pollution in water source protection areas for drinking water.* March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/bmgz/201707/t20170714_960211.html

NDRC (2019) *Industrial structure adjustment guidance catalogue of 2019.* March 19, 2020, from http://www.gov.cn/xinwen/2019-11/06/5449193/files/26c9d25f713f4ed5b8dc51ae40ef37af.pdf

Newground LUS (2018, June) *Plastic microbeads ban enters force in England, Scotland & Wales - Legislation Update Service.* March 19, 2020, from https://legislationupdateservice.co.uk/news/plastic-microbeads-ban-enters-force-uk/

NOAA and UNEP (2011) *The Honolulu Strategy - A Global Framework for Prevention and Management of Marine Debris*. March 19, 2020, from http://wedocs.unep.org/bitstream/handle/20.500.11822/10670/Honolulu strategy.pdf?sequence=1&isAllowed=y

NPC (1982, August 23) *Marine Environment Protection Law of People's Republic of China*. March 19, 2020 from http://www.jincao.com/fa/05/law05.15.htm

NPC (1989, December 26) *Environmental Protection Law of the People's Republic of China*. March 19, 2020, from http://www.npc.gov.cn/wxzl/gongbao/1989-12/26/content_1481137.htm

NPC (2000, December 6) *Water Law of the People's Republic of China.* March 19, 2020, from http://www.npc.gov.cn/wxzl/wxzl/2000-12/06/content_4493.htm

NPC (2006, July 27) *Law of the People's Republic of China on flood prevention*. March 19, 2020, from http://www.gov.cn/ztzl/2006-07/27/content_347485.htm

NPC (2008, February 28) *Law of the People's Republic of China on Prevention and control of water pollution*. March 19, 2020, from http://www.mwr.gov.cn/zw/zcfg/fl/201612/t20161222_775485.html

NPC (2013, December 4) *Law of the People's Republic of China on soil and water conservation*. March 19, 2020, from http://www.npc.gov.cn/npc/sjxflfg/201906/3939e6d8953841ebbde5bb008be676e1.shtml

Pallone, F. J. (2015) *H.R.1321 - 114th Congress (2015-2016)*: *Microbead-Free Waters Act of 2015*. Gongress.gov. March 19, 2020, from https://www.congress.gov/bill/114th-congress/house-bill/1321

Peng, G., Xu, P., Zhu, B., Bai, M. and Li, D. (2018) Microplastics in freshwater river sediments in Shanghai, China: A case study of risk assessment in mega-cities. *Environmental Pollution*. Elsevier Ltd, 234, pp. 448–456. 10.1016/j.envpol.2017.11.034.

Rios Mendoza, L. M. and Balcer, M. (2018) Microplastics in freshwater environments: A review of quantification assessment. *TrAC - Trends in Analytical Chemistry*. 10.1016/j.trac.2018.10.020.

Shaoxing City (2018a) *Work Specifications of the Lake Chief System (DB3306/T 016-2018)*. March 19, 2020, from http://www.doc88.com/p-6751710080146.html

Shaoxing City (2018b) *Work Specifications of the River Chief System (DB3306/T 015-2018)*. March 19, 2020, from https://wenku.baidu.com/view/a770edd58662caaedd3383c4bb4cf7ec4bfeb61d.html

Sharma, S. and Chatterjee, S. (2017) Microplastic pollution, a threat to marine ecosystem and human health: a short review. *Environmental Science and Pollution Research*, 24(27), pp. 21530–21547. 10.1007/s11356-017-9910-8.

SOA (2015, December 18) *Marine wastes monitoring and evaluating techniques regulations (in Chinese)*. March 19, 2020, from http://gc.mnr.gov.cn/201807/t20180710_2079008.html

Stanton, T., Johnson, M., Nathanail, P., MacNaughtan, W. and Gomes, R. L. (2019) Freshwater and airborne textile fibre populations are dominated by “natural”, not microplastic, fibres. *Science of the Total Environment*. Elsevier B.V., 666, pp. 377–389. 10.1016/j.scitotenv.2019.02.278.

Su, L., Cai, H., Kolandhasamy, P., Wu, C., Rochman, C. M. and Shi, H. (2018) Using the Asian clam as an indicator of microplastic pollution in freshwater ecosystems. *Environmental Pollution*, 234, pp. 347–355. 10.1016/j.envpol.2017.11.075.

Su, L., Xue, Y., Li, L., Yang, D., Kolandhasamy, P., Li, D. and Shi, H. (2016) Microplastics in Taihu Lake, China. *Environmental Pollution*. Elsevier Ltd, 216(July), pp. 711–719. 10.1016/j.envpol.2016.06.036.

Sun, S., Zhao, Z., Li, B., Ma, L., Fu, D., Sun, X., Thapa, S., Shen, J., Qi, H. and Wu, Y. (2019) Occurrence, composition profiles and risk assessment of polycyclic aromatic hydrocarbons in municipal sewage sludge in China. *Environmental Pollution*, 245, pp. 764–770. 10.1016/j.envpol.2018.11.067.

Talvitie, J., Heinonen, M., Pääkkönen, J., Vahtera, E., Mikola, A., Setälä, O. and Vahala, R. (2015) Do wastewater treatment plants act as a potential point source of microplastics? Preliminary study in the coastal Gulf of Finland, Baltic Sea. *Water Science and Technology*, 72(9), pp. 1495–1504. 10.2166/wst.2015.360.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis., Rowland, S. J., John, A. W. G., McGonigle, D. and Russell, A. E. (2004) Lost at Sea: Where Is All the Plastic?. *Science*, 304(5672), p. 838. 10.1126/science.1094559.

UN environment (2019) *Global partnership on marine litter | UN Environment*. March 19, 2020, from https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/addressing-land-based-pollution/global-partnership-marine

UNEA-1 (2014) *Resolutions and decisions adopted by the United Nations Environment Assembly of the United Nations Environment Programme at its first session on 27 June 2014 Contents.* March 19, 2020, from https://wedocs.unep.org/bitstream/handle/20.500.11822/17285/K1402364.pdf?sequence=3&isAllowed=y

UNEA-2 (2016) *Resolutions and Decisions: UNEA 2 | UN Environment Assembly.* March 19, 2020, from http://web.unep.org/environmentassembly/resolutions-and-decisions-unea-2

UNEA-3 (2017) *United Nations Environment Assembly of the United Nations Environment Programme 3/7. Marine litter and microplastics.* March 19, 2020, from https://papersmart.unon.org/resolution/uploads/k1800210.english.pdf

UNEA-4 (2019) *Marine plastic litter and microplastics**. March 19, 2020, from https://papersmart.unon.org/resolution/uploads/k1900897.pdf

United Nations (n. d.) *United Nations Convention on the Law of the Sea*. March 19, 2020, from https://www.un.org/Depts/los/convention_agreements/texts/unclos/unclos_e.pdf

van Cauwenberghe, L., Devriese, L., Galgani, F., Robbens, J. and Janssen, C. R. (2015) Microplastics in sediments: A review of techniques, occurrence and effects. *Marine Environmental Research*. Elsevier Ltd, 111, pp. 5–17. 10.1016/j.marenvres.2015.06.007.

van Wijnen, J., Ragas, A. M. J. and Kroeze, C. (2019) Modelling global river export of microplastics to the marine environment: Sources and future trends. *Science of The Total Environment*. Elsevier, 673, pp. 392–401. 10.1016/j.scitotenv.2019.04.078.

Wang, J., Lu. L., Wang M., Jiang, T., Liu, X. and Ru, S. (2019) Typhoons increase the abundance of microplastics in the marine environment and cultured organisms: A case study in Sanggou Bay, China. *Science of the Total Environment*. Elsevier B.V., 667, pp. 1–8. 10.1016/j.scitotenv.2019.02.367.

Wang, J., Peng, J., Tan, Z., Gao, Y., Zhan, Z., Chen, Q. and Cai, L. (2017) Microplastics in the surface sediments from the Beijiang River littoral zone: Composition, abundance, surface textures and interaction with heavy metals. *Chemosphere*, 171, pp. 248–258. 10.1016/j.chemosphere.2016.12.074.

Wang, W., Ndungu, A. W., Li, Z. and Wang, J. (2017) Microplastics pollution in inland freshwaters of China : A case study in urban surface waters of Wuhan , China. Science of the Total Environment, 575, pp. 1369–1374. 10.1016/j.scitotenv.2016.09.213.

Wang, W., Yuan, W., Chen, Y. and Wang, J. (2018) Microplastics in surface waters of Dongting Lake and Hong Lake, China. *Science of the Total Environment*. Elsevier B.V., 633, pp. 539–545. 10.1016/j.scitotenv.2018.03.211.

World Health Organization (WHO) (2019) *Microplastics in drinking-water*. ISBN: 978-92-4-151619-8

Xiong, X., Zhang, K., Chen, X., Shi, H., Luo, Z. and Wu, C. (2018) Sources and distribution of microplastics in China's largest inland lake – Qinghai Lake. *Environmental Pollution*, 235, pp. 899–906. 10.1016/j.envpol.2017.12.081.

Xu, X., Hou, Q., Xue, Y., Jian, Y. and Wang. L. (2018) Research progress on the transference and pollution characteristics of microplastics in wastewater treatment plants. Ch*ina Environmental Science*, 38(11), pp. 4393–4400. 10.19674/j.cnki.issn1000-6923.2018.0490

Xue, T. (2017) *Chinese order over 20 million take-out each day (in Chinese)*. March 19, 2020, from http://www.xinhuanet.com//politics/2017-09/20/c_1121696014.htm

Yang, L., Qiao, F., Lei, K., Li, H., Kang, Y., Cui, S. and An, L. (2019) Microfiber release form different fabrics during washing. Environmental Pollutant. 249, pp. 136-143. doi.org/10.1016/J.ENVPOL.2019.03.011

Yin, L., Jiang, C., Wen, X., Du, C., Zhong, W., Feng, Z., Long, Y. and Ma, Y. (2019) Microplastic pollution in surface water of urban lakes in changsha, china. *International Journal of Environmental Research and Public Health*, 16(9). 10.3390/ijerph16091650.

Yin, Q. and Zhang, N. (2019) Supply and demand analysis of China's polypropylene market in 2018. *Petrochemical Technology & Application*, 37(5), pp. 297-300.

Yuan, W., Liu, X., Wang, W., Di, M. and Wang, J. (2019) Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. *Ecotoxicology and Environmental Safety*. Elsevier Inc., 170(October 2018), pp. 180–187. 10.1016/j.ecoenv.2018.11.126.

Zhang, J., Qing, L., Zhang, C., Deng, Y. and An, L. (2019) Study on the legislation of the marine plastic and microplastic management. *Marine Environmental Science*, 38(2), pp. 167–177. 10.13634/j.cnki.mes.2019.02.002.

Zhang, K., Shi. H., Peng, J., Wang, Y., Xiong, X., Wu, C., and Lam, P. K. S. (2018) Microplastic pollution in China's inland water systems: A review of findings, methods, characteristics, effects, and management. *Science of the Total Environment.* Elsevier, pp. 1641–1653. 10.1016/j.scitotenv.2018.02.300.

Zhang, K., Su, J., Xiong, X., Wu, X., Wu, C. and Liu, J. (2016) Microplastic pollution of lakeshore sediments from remote lakes in Tibet plateau, China. *Environmental Pollution*. Elsevier Ltd, 219, pp. 450–455. 10.1016/j.envpol.2016.05.048.

Zhang, K., Xiong, X., Hu, H., Wu, C., Bi, Y., Wu, Y., Zhou, B., Lam, P. K. S. and Liu, J. (2017) Occurrence and Characteristics of Microplastic Pollution in Xiangxi Bay of Three Gorges Reservoir, China. *Environmental Science and Technology*, 51(7), pp. 3794–3801. 10.1021/acs.est.7b00369.

Zhang, W. (2019) Supply and demand analysis of China's polyethylene market in 2018. *Petrochemical Technology & Application*, 37(4), pp. 230-232

Zhao, S., Wang, T., Zhu, L., Xu, P., Wang, X., Gao, L. and Li, D. (2019) Analysis of suspended microplastics in the Changjiang Estuary: Implications for riverine plastic load to the ocean. *Water Research*. Elsevier Ltd, 161, pp. 560–569. 10.1016/j.watres.2019.06.019.

Zhao, S., Zhu, L. and Li, D. (2015) Microplastic in three urban estuaries, China. *Environmental Pollution*. Elsevier Ltd, 206, pp. 597–604. 10.1016/j.envpol.2015.08.027.

Zhao, S., Zhu, L., Wang, T. and Li, D. (2014) Suspended microplastics in the surface water of the Yangtze Estuary System, China: First observations on occurrence, distribution. *Marine Pollution Bulletin*. Elsevier Ltd, 86(1–2), pp. 562–568. 10.1016/j.marpolbul.2014.06.032.

Zhou, L., Jian, M., Yu, H., Li, W. and Liu, S. (2018) Distribution of Microplastics in Its Source in the Sediments of the Le' an River in Poyang Lake. *ACTA PEDOLOGICA SINICA*, 55(5), pp. 1222–1232. 10.11766/trxb201803010115

Zhou, Q., Tian, C. and Luo, Y. (2017) Various forms and deposition fluxes of microplastics identified in the coastal urban atmosphere. *Science China Press*, 62(33), pp. 3902-3909. 10.1360/N972017-00956

Zhou, Q., Zhang, H., Zhou, Y., Li, Y., Xue, Y., Fu, C., Tu, C. and Luo, Y. (2016) Separation of microplastics from a coastal soil and their surface microscopic features. *Chinese Science Bulletin*, 61, pp. 1604–1611. 10.1360/N972015-01098.

Zhu, Q. (2011) An appraisal and analysis of the law of "Plastic-Bag Ban". *Energy Procedia*, 5, pp. 2516–2521. 10.1016/j.egypro.2011.03.432.

Zou, Y., Xu, Q., Zhang, G., Wang, Y., Liu, C., Zheng, H. and Li, M. (2017) Review on the Joint Toxicity of Microplastics and Pesticide Pollution. *Asian Journal of Ecotoxicology*, 12(4), pp. 25–33. 10.7524/AJE.1673.

Appendix: Abbreviation of organization names

AQSIQ: Administration of Quality Supervision Inspection and Quarantine (中华人民共和国国家质量监督检验检疫总局)

GOSC: General Office of the State Council of the People’s Republic of China (中华人民共和国国务院办公厅)

IMO: International Maritime Organization

MEE: Ministry of Ecology and Environment of the People’s Republic of China (中华人民共和国生态环境部)

MLR: Ministry of Land and Resources of the People’s Republic of China (中华人民共和国国土资源部)

MOF: Ministry of Finance of the People’s Republic of China (中华人民共和国财政部)

MOH: Ministry of Health of the People’s Republic of China (中华人民共和国卫生部)

MOHURD: Ministry of Housing and Urban-Rural Development of the People’s Republic of China (中华人民共和国住房和城乡建设部)

MWR: Ministry of Water Resources of the People’s Republic of China (中华人民共和国水利部)

NDRC: National Development and Reform Commission of the People’s Republic of China (中华人民共和国国家发展和改革委员会)

NPC: The National People’s Congress of the People’s Republic of China (中华人民共和国全国人民代表大会)

UNEA: United Nations Environment Assembly

WHO: World Health Organization

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