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Xu, Y, Chan, FKS, He, J et al. (10 more authors) (2020) A critical review of microplastic pollution in urban freshwater environments and legislative progress in China: Recommendations and insights. *Critical Reviews in Environmental Science and Technology*. pp. 1-44. ISSN 1064-3389

<https://doi.org/10.1080/10643389.2020.1801308>

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

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

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

44 **Keywords:** microplastics, urban freshwater environment, abundance, China,
45 legislation, policy

46

47

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73 **1. Introduction**

74 Annual global plastic resin and fibre production accelerated from 2 million metric tonnes in
75 1950 to 3.81 billion tonnes in 2015, contributing to the 6.3 billion tonnes of global plastic
76 waste produced by 2015 (Geyer *et al.*, 2017). The ubiquity of plastics results in serious
77 environmental problems worldwide, with over 99 million metric tonnes mismanaged yearly
78 and approximately 79% of total plastic waste accumulating in landfills or in the natural
79 environment (Geyer *et al.*, 2017; Lebreton and Andrady, 2019). Plastic pollution can be
80 conveyed between different ecosystems, with for example around ten million metric tonnes of
81 terrestrial-based plastic litter estimated to enter the oceans every year (Jambeck *et al.*, 2015).
82 Freshwater systems are a major pathway for delivering plastic pollution to the marine
83 environment (Crawford and Quinn, 2017b).

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

96 by 2060s, with China remaining as one of the major sources (Everaert *et al.*, 2018; Lebreton
97 and Andrady, 2019; van Wijnen *et al.*, 2019).

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

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

118 microplastics, rapidly conveyed from urban discharge into fluvial systems and eventually to
119 marine systems via estuaries and deltas (Zhao *et al.*, 2014).

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

134 Microplastic pollution has been reported worldwide and, according to the reviews of
135 Eerkes-Medrano *et al.* (2015) and Horton *et al.* (2017b), is constantly increasing in freshwater
136 environments. Zhang *et al.* (2018) were the first to review what is known of microplastic
137 pollution in Chinese inland water systems; they also considered the State-of-the-Art
138 approaches for sampling microplastics. Fu and Wang (2019) reviewed research approaches,
139 characteristics, sources and fate of microplastics in the Chinese freshwater environments and
140 provided recommendations for the Chinese Government and public to reduce freshwater

141 microplastic pollution. Fok *et al.* (2020) studied the investigating approaches used in
142 microplastic studies in China, while Fu *et al.* (2020) synthesised knowledge of microplastic
143 pollution in various ecosystems and provided an overview of policies related to plastic and
144 microplastic management in China. These reviews established a thoughtful basis for future
145 development of microplastic controls in the Chinese freshwater environment, but
146 understanding of microplastics in Chinese urban catchments still remains limited. However,
147 available literatures are still general on the discussion of microplastic management and
148 current legislation do not provide specific guidance on developing appropriate policies.

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

- 154 1) To review what is known of microplastic abundance and characteristics in China's
155 freshwater environment and identify current knowledge gaps, especially related to
156 urban catchments.
- 157 2) To review key existing legislation and policies related to microplastics worldwide
158 and in China.
- 159 3) To provide recommendations for managing microplastic pollution in China's
160 freshwater environments, and specifically for dealing with pollution of urban
161 catchments.

162 **2. Current knowledge of urban freshwater microplastics in China**

163 **2.1. The foci of China's microplastics research**

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

177

178 ***Figure 1 is about here***

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

182

183 The VOSviewer software (Leiden University, Netherlands) was used to provide an
184 overview of current microplastics research in China (Figure 2). The academic terms

185 repeatedly occurring in each paper were collected from the 255 publications and analysed in
186 this software. The frequency of occurrence of each keyword and the co-occurrence of pairs of
187 keywords were used to indicate the foci of published work; in the resulting schematic (Fig.
188 2), the foci of proximity between terms indicates the frequency of co-occurrence, the size of
189 each term illustrating the occurrence frequency, and the colours indicate temporal patterns.
190 This analysis demonstrates that the '*Marine Environment*' was a very common focus and was
191 closest to '*Microplastics*' and '*Pollution*', indicating that a large proportion of microplastics
192 research in China (and globally) has been conducted in marine environments. The red colour
193 of '*Freshwater*' indicates that this topic is relatively new in China. The direct links from
194 '*Freshwater*' to topics such as '*Sediments*', '*Coastal*', '*Soil*', '*Marine-environment*' and
195 '*Transport*' demonstrated that microplastic pollution in China's freshwater environments
196 correlates with microplastics in other compartments of the environment. Nonetheless, the
197 relatively great distance between '*Freshwater*' and '*Microplastics*' suggests that relevant
198 work is still limited in China. Notably, the missing connections between several focal terms
199 (such as '*Exposure*', '*Toxicity*', and '*Wastewater*') to '*Freshwater*' indicates that gaps remain
200 in understanding links between these things. The terms '*Urban*' and '*City*' do not appear in
201 the figure highlighting the lack urban freshwater microplastics research in China. This
202 supports the contention that more studies are required in urban freshwaters to assess the
203 potential significance of microplastics (Zhang *et al.*, 2018).

204

205 ***Figure 2 is about here***

206 *Figure 2. A visualization of the keywords co-occurrence in 255 publications of China's microplastics researches*
207 *(database: Web of Science) from 2014 to 2019, where colours represent the average publication time of each*
208 *keyword (blue to red: early to current). Database: Web of Science from 2004 to 2019.*

209 **2.2. Microplastics in freshwaters in China**

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

213 Microplastic pollution has been investigated in freshwater systems including the
214 Poyang Lake (the largest freshwater lake in China), Dongting Lake (the second largest
215 freshwater lake in China), Qinghai lake (the largest inland lake in China), Yangtze River (the
216 largest river catchment in China), Pearl River (the largest river catchment in Southern China),
217 and other large waterbodies in the country (Zhao *et al.*, 2014; Lin *et al.*, 2018; Wang *et al.*,
218 2018; Xiong *et al.*, 2018; Zhou *et al.*, 2018; Yuan *et al.*, 2019). These studies provided
219 quantitative evidence of microplastic pollution but so far none has investigated loads in any
220 environments in an integrated way, so as to characterise contamination in waterbodies,
221 sediments and biota; moreover, small- to medium-sized freshwater systems remain
222 under-represented.

223

224 ***Table 1 is about here***

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

227

228 The properties of microplastics are important indicators of sources. Microplastics
229 detected in Chinese freshwaters consists of diverse materials including Polypropylene (PP),
230 Polystyrene (PS), Polyethylene Terephthalate (PET (also abbreviated PETE)), Polyethylene
231 (PE) and Polyvinyl Chloride (PVC). PP and PE were dominant in most investigated

232 freshwater environments (PP in 12 waterbodies and PE in 11 waterbodies; Table 1). This
233 condition fits with the current state of the Chinese plastics market, with the annual yields of
234 PP and PE accounting for 27.21 and 30.04 million tonnes and representing more than 40%
235 and 30% of global totals respectively by 2018 (Yin and Zhang, 2019; Zhang, 2019). Although
236 published research used different sorting strategies, plastic fibres were dominant in 14 cases
237 (Table 1). Size ranges of microplastics were also variable, with some suggesting smaller
238 microplastics (e.g. < 1 mm) are disproportionately abundant (Su *et al.*, 2016; Yuan *et al.*,
239 2019).

240

241 Microplastic abundance also varied substantially between different geographic areas.
242 For example, concentrations in surface water of rivers on the Tibet Plateau were 483 - 967
243 particles/m³ compared to 4,137.3 particles/m³ in the Yangtze Estuary (Table 1). Such cases
244 also imply that densely populated areas (e.g. urban areas) have higher microplastic
245 concentrations compared to remote areas. Concentrations are also variable over smaller
246 geographic areas. For instance, within the same catchment, Lin *et al.* (2018) found that
247 concentrations along the urban section (Guangzhou) of the Pearl River varied from 379 to
248 7,924 particles/m³ in surface water (Table 1); a concentration of 0.167 particles/m³ was
249 recorded offshore from the Yangtze River in comparison to 4,137.3 particles/m³ in the
250 Yangtze estuary (Zhao *et al.*, 2014). The spatial variation in the Yangtze is likely due to
251 dilution (Mendoza and Balcer, 2018; Wang *et al.*, 2018). No consistent relative patterns have
252 been found in microplastic concentrations in water versus sediment in fluvial or limnetic
253 environments (Zhou *et al.*, 2018; Ding *et al.*, 2019; Zhao *et al.*, 2019), which suggests
254 complex sources and pathways and patterns of accumulation.

255

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

267

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

280 **2.3. Microplastic dynamics in Chinese freshwater environments**

281 Rivers are often conceptualised as conveyor belts, transporting water, sediments and
282 contaminants to the oceans. However, transport is not continuous, with material stored
283 periodically (e.g. sediment deposited and stored for a period of time on the riverbed, before
284 the next competent event leads to its onward conveyance). This and the different course areas
285 – some of the, point sources and some of them diffuse - may underpin spatial variation
286 reported to date. Wang et al. (2018) reported with high concentrations at the confluence
287 between the Dongting Lake and Yangtze River. Based on work in the Pearl River, Lin et al.
288 (2018) argued that tributaries transport microplastics to the mainstream and result in high
289 concentration in confluence zones. Peng et al. (2018) observed that the microplastics
290 transported by the Yangtze River and Huangpu River stagnated and accumulated at the plume
291 front area formed between freshwater and seawater of the East China Sea. These findings not
292 only indicate the significance of Chinese fluvial systems as a pathway, delivering
293 microplastics towards trunk streams and marine environments, but also illustrate that
294 confluence areas may be contamination ‘hotspots’.

295

296 The transportation of microplastics may be critical to assessing and understanding
297 health risks. Because of their lipophilic features and high surface area to volume ratio, which
298 enable them to absorb chemical pollutants, including persistent organic pollutants (e.g.
299 pesticides and antibiotics), as well as pathogenic bacteria, fungi and viruses (Zou *et al.*, 2017),
300 microplastics pose risks to ecosystems and human health. Additionally, toxic plastic additives,
301 such as flame retardants, pigment and ultraviolet stabilizer can be release once plastics are in
302 the freshwater environment (Gabiella, 2019). Risk partly depends storage dynamics. For
303 instance, exposure of benthic organisms to microplastics depends how much material may be

304 stored within the bed matrix, and the duration of residence here before being remobilised
305 during high flows (van Cauwenberghe *et al.*, 2015). Residence times are likely to be longer in
306 stable sediments that are infrequently disturbed, so lentic environments can act as a longer
307 term store for microplastics than fluvial environments (Eerkes-Medrano *et al.*, 2015).
308 Movement of microplastics can also be altered by absorption of other materials or
309 colonisation by microbial communities, changing particle density and causing microplastics
310 to settle more easily (Lin *et al.*, 2018; Wang *et al.*, 2018; Fan *et al.*, 2019). Research foci are
311 now changing from simple assessment of loads to efforts understand pathways, including
312 those in the subsurface (i.e. via hyporheic zone and groundwater), although such work still
313 remains limited in China (Zhao *et al.*, 2015; Su *et al.*, 2016).

314

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

322

323 Another issue relates to the temporal dimension. Most studies lack long-term, repeat
324 sampling and measurement. This is important because, when studied, significant temporal
325 differences in microplastic concentrations have been found to exist; this raises concerns over
326 the representativeness of single date or spot sampling (Stanton *et al.* 2019). Such temporal
327 differences may arise due to seasonal and/or weather-related factors, or dues to activities of

328 organisms (Crawford and Quinn, 2017b). For example, in China cyclonic effects (i.e.
329 typhoons) have been reported to increase microplastic loads in freshwaters and conveyance to
330 the marine environment (e.g. especially along the Southern and Eastern coastline of China;
331 Wang *et al.*, 2019). Studies are needed in China to elucidate the causes of temporal variation
332 in microplastics and the implications of this for accurate assessment of loads and risk.

333

334 **2.4. Sources of microplastics in urban freshwaters**

335 Urban areas play a key role as sources of microplastics in China (Zhang *et al.*, 2018; Fu and
336 Wang, 2019). These sources are summarised in Figure 3. Primary microplastics are usually
337 discharged from industrial areas associated with plastic production or residential areas
338 through wastewater treatment plants (WWTPs) (Figure 3). Microplastics could be removed
339 from sewage during the primary treatment and adsorbed by activated sludge during secondary
340 treatment in WWTPs, but even if removal reached 95-99%, as recorded in some developed
341 countries, the remaining material released to the environment could still be problematic
342 (Talvitie *et al.*, 2015). Many WWTPs do not attain 99% removal efficiency of microplastics
343 in China (Lin *et al.*, 2018); for example, a municipal WWTP equipped with activated sludge
344 techniques in Wuhan only removed about 64.4% of microplastics (Liu *et al.* 2019). Another
345 issue is that 60% of polluted sludge from WWTPs in China is disposed of in landfill sites
346 (Sun *et al.*, 2019). Microplastics can leach from landfills and find routes through soils to
347 contaminate freshwaters (He *et al.*, 2019). Thus, due to the relatively underdeveloped
348 techniques and poor management of waste treatment, WWTPs play significant roles in
349 Chinese urban microplastic pollution, as documented by W. Wang *et al.* (2017) and Lin *et al.*
350 (2018), respectively.

351 Secondary microplastics usually reach freshwater environments through non-point
352 sources. In Chinese urban areas, mismanaged plastics are the major terrestrial non-point
353 source, which includes dumping and littering of solid wastes (W. Wang et al., 2017; Zhou et
354 al., 2018; Fan et al., 2019). Fragmentation of large plastic waste generates secondary
355 microplastics on land (Zhang *et al.*, 2015), while road dusts containing car tyre fragments
356 contribute to loads entering freshwater systems as a result of runoff (Zhang *et al.*, 2018).
357 Atmospheric dispersal of microplastic may also be important in urban areas (Dris *et al.*,
358 2016). For example, Zhou *et al.* (2017) found microplastic fibres in atmospheric deposition in
359 Yantai, China. Shipping and fishing in urban catchments can also release microplastics
360 directly to aquatic environments, where fragments and fibres from fishing nets or gear have
361 been observed in urban waterbodies in Changsha City (Yin *et al.*, 2019).

362

363 ***Figure 3 is about here***

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

365

366 Previous literature has assessed factors influencing microplastic pollution in Chinese
367 urban catchments. Fan *et al.* (2019) found a direct linear relationship ($R^2 = 0.772$) between
368 microplastic abundance in water samples and population density in the Pearl River catchment,
369 where large population centres generated and released more microplastics. Similarly, Wang *et*
370 *al.* (2017) found an inverse linear relationship ($p < 0.001$) between the distance from an urban
371 centre and microplastic concentration in surface waters of the Yangtze River. Other
372 investigations have, however, failed to find such relationships (e.g. Shanghai) (Peng *et al.*,
373 2018).

374 Zhao *et al.* (2015) suggested that different economic structures might lead to different
375 microplastic sources and abundances; interestingly this hypothesis was supported by the
376 Gross Domestic Product (GDP) and microplastic data presented by Fan *et al.* (2019). Li
377 (2020) reported microplastic concentrations in urban runoff from residential roads were
378 significantly higher than from parking lots and cement pavements, which also indicates that
379 local land-use conditions will affect microplastic pollution levels in urban areas.

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

387

388 **3. Management and Legislations on microplastics**

389 **3.1. General legislation**

390 Plastic microbeads (10 – 500 µm in diameter), used in personal care products (PCPs) (Sharma
391 and Chatterjee, 2017), are a type of primary microplastics. To help reduce risks posed by
392 microbeads to wildlife, Five European countries (i.e. Netherlands, Austria, Luxembourg,
393 Belgium and Sweden) issued a joint statement calling for banning the use of microbeads in
394 PCPs (see Table 2). In 2014, the State Government of Illinois (USA) enacted the first
395 prohibition of production and sales of PCPs that contain microbeads (see Table 2), which
396 subsequently led to the US ‘*Microbead-Free Water Act of 2015*’ (see Table 2). In 2015

397 Canada also limited the addition of microbeads in PCPs, by adding microbeads as a new toxic
398 substance to the 1999 ‘*Environmental Protection Act*’ (Table 2). European nations also
399 expressed the concerns about Microbead pollution in cosmetics through the proposal
400 ‘*Cosmetics Europe Recommendation on Solid Plastic Particles (Plastics Micro Particles)*’
401 (Table 2). This recommendation has implications for future legislation worldwide (i.e.
402 Microbeads in Toiletries Regulations by Canada in 2017). Following these first pieces of
403 legislation, more countries (including the UK, France, South Korea, Italy, New Zealand, India
404 and South Africa) joined in this ‘*Microbead-free*’ action (see Table 2), which will make
405 efforts to reduce the global release of microbeads. Nonetheless, microbeads are only a small
406 part of the total microplastic load, approximately accounting for 0.1~ 4.1% (McDevitt *et al.*,
407 2017) of total global microplastic pollution in aquatic environments, so broader action is also
408 needed.

409 In October 2019, the Chinese government officially issued the “Economic Structure
410 Adjustment Guidance Catalogue”, which included the prohibition of light plastic bags (<
411 0.025mm thickness), disposable-foamed plastic tableware, disposable plastic swabs, daily
412 chemical products containing microbeads and polyethylene agricultural films (< 0.01 mm
413 thickness) (Table 2). This catalogue not only highlights microbeads problem in both PCPs and
414 cosmetics, but also looks at other commonly used in China but potentially polluting plastic
415 products (NDRC, 2019).

416

417 ***Table 2 is about here***

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

421

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

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

439

440 ***Table 3 is about here***

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

443

444 **3.2. Legislation directly relevant to freshwaters in China**

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

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

468 reflects an official desire to update existing freshwater quality standards in China; it may be a
469 timely opportunity to include artificial polymers as indicators or parameters of water quality
470 in standards.

471

472 ***Table 4 is about here***

473 *Table 4. Legislation and progress for catchment management in China*

474

475 **4. Mitigation of microplastic pollutions in Chinese urban freshwater environment**

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

483

484

485 ***Figure 4&5 is about here***

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

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

488

489 **4.1. Toxicology.**

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

502 **4.2. Recognising different types of microplastics**

503 China should apply specific management measures for different types of microplastics.
504 Microplastic is actually a general term, encompassing plastic debris with a wide variety of
505 characteristics. These characteristics (e.g. sizes, shapes, chemical composition) affect their
506 distribution patterns and environmental impacts, and require different solutions to manage
507 each type of them. ‘*Microbead-free*’ action is a successful case for the management of a
508 single group of microplastics, but micro-fibres are far more abundant in many freshwaters,
509 especially in urban catchments (see Table 1). Domestic household discharge (e.g. via washing
510 clothes on urban rivers) is one of the main sources of fibres in freshwater environments (see
511 Figure 3). Yang *et al.* (2019) found that polyester fabric releases fewer fibres during laundry
512 compared to polyamide fabric and acetate fabric and so developing textiles that do not as

513 readily shed fibres would be beneficial. Also, improving laundry and fabric filter techniques
514 of washing machines may reduce the amount of fibres from washing machines into sewage
515 pipes in residential areas, is a way to cut the transportation of microplastics. Compared to
516 platen laundry machines, fibres are easier to peel off in pulsator laundry machine (Yang *et al.*,
517 2019). Another way to cut the transportation of synthetic fibres is to improve the microplastic
518 removal rate of WWTPs in China. Legislation aiming at those three points can effectively
519 control the amount of synthetic fibre emitted in densely populated areas. This approach to
520 controlling fibre pollution could also be extended to other types of microplastics.

521 ***4.3. Consumption rates***

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

535 **4.4. Management strategy**

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

554 Complex land-use patterns and a multitude of industrial and urban activities create
555 substantial challenge for employing a unified approach to freshwater management in China.
556 As microplastic pollution is related closely to land-use function and local economic structure
557 in Chinese cities, the country’s urban planning system is well placed as to help integrate

558 considerations of land-use demand and microplastic pollution, as part of strategies to promote
559 more sustainable development.

560

561 **5. Conclusion**

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

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

578

579 **Disclosure statement**

580 We would like to send our gratitude for the support from the National Natural Science
581 Foundation of China (NSFC) (Grant number: 41850410497); the National Key R&D Program
582 of China (Grant number: 2019YFC1510400) and the Faculty of Science and Engineering
583 (FoSE) Postgraduate Research Scholarship of University of Nottingham Ningbo China.

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991

- 992 **Appendix: Abbreviation of organization names**
- 993 ACSIQ: Administration of Quality Supervision Inspection and Quarantine (中华人民共和国
994 国家质量监督检验检疫总局)
- 995 GOSC: General Office of the State Council of the People's Republic of China (中华人民共和国
996 国务院办公厅)
- 997 IMO: International Maritime Organization
- 998 MEE: Ministry of Ecology and Environment of the People's Republic of China (中华人民共和国
999 生态环境部)
- 1000 MLR: Ministry of Land and Resources of the People's Republic of China (中华人民共和国
1001 国土资源部)
- 1002 MOF: Ministry of Finance of the People's Republic of China (中华人民共和国财政部)
- 1003 MOH: Ministry of Health of the People's Republic of China (中华人民共和国卫生部)
- 1004 MOHURD: Ministry of Housing and Urban-Rural Development of the People's Republic of
1005 China (中华人民共和国住房和城乡建设部)
- 1006 MWR: Ministry of Water Resources of the People's Republic of China (中华人民共和国水利
1007 部)
- 1008 NDRC: National Development and Reform Commission of the People's Republic of China (
1009 中华人民共和国国家发展和改革委员会)
- 1010 NPC: The National People's Congress of the People's Republic of China (中华人民共和国
1011 全国人民代表大会)
- 1012 UNEA: United Nations Environment Assembly
- 1013 WHO: World Health Organization
- 1014

1015 **Additional information**

1016 *Funding Details*

1017 This study was supported by the National Natural Science Foundation of China (NSFC):
1018 International Young Scientist Program NSFC under Grant NSFC 41850410497; and the
1019 Faculty of Science and Engineering (FoSE) Postgraduate Research Scholarship of University
1020 of Nottingham Ningbo China.

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1022 *Disclosure statement*

1023 The authors have no conflict of interest.

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