# Source Control Strategies for Plastic Waste and Microplastic Pollution in China: Postprint

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## Abstract

In recent years, microplastic pollution has gradually emerged as a prominent issue of global concern. The majority of microplastics in the environment originate from the fragmentation and degradation of plastic materials; therefore, effective control of plastic waste constitutes a crucial measure for addressing microplastic pollution. This paper proposes policy recommendations for the source control of plastic waste and microplastic pollution based on an analysis of existing challenges in China's plastic waste management system. These recommendations include improving legislation for plastic pollution control, supplementing and revising relevant standards for plastic management, and enhancing policy measures for plastic waste governance. Drawing upon international experience, China should also strengthen the regulation of plastic microbeads, with a recommendation to promptly prohibit the production and sale of personal care products containing plastic microbeads. Furthermore, research and development of microplastic removal technologies should be intensified. Ultimately, fundamental solutions to plastic waste and microplastic pollution lie in promoting technological innovation within the plastic processing industry, encouraging manufacturers and consumers of plastic products to adopt cleaner production practices and resource recycling, thereby reducing the discharge of plastic waste and microplastics.

## Full Text

## Environmental Pollution and Control Strategy of Microplastics

### Source Control Countermeasures for Plastic Waste and Microplastic Pollution in China

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In recent years, microplastic pollution has gradually emerged as a hot-button issue both domestically and internationally. Most microplastics in the environment originate from the fragmentation and degradation of plastics, making effective control of plastic waste a crucial measure for addressing microplastic pollution. Based on an analysis of existing problems in China's plastic waste management system, this paper proposes countermeasures for source control of plastic waste and microplastic pollution, including improving legislation on plastic pollution control, supplementing and revising relevant standards for plastic management, and refining policy measures for plastic waste management. Drawing on international experience, China should also strengthen management of plastic microbeads and promptly ban the production and sale of personal care products containing plastic microbeads. Additionally, research and development of microplastic removal technologies should be enhanced. Ultimately, intensifying technological innovation in the plastic processing industry and encouraging producers and users to adopt cleaner production and resource recycling practices to reduce emissions of plastic waste and microplastics represents the fundamental solution to this pollution problem.

**Keywords:** plastic waste, microplastics, source control, management countermeasures

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### International Attention on Plastic Waste and Microplastic Pollution

International concern over the environmental hazards of plastic waste and microplastics has grown increasingly prominent in recent years. Microplastics have now been detected in the digestive tracts of 233 marine species worldwide, including 100% of sea turtle species, 36% of seal species, 59% of whale species, 59% of seabird species, and 92 fish species and 6 invertebrate species [2]. According to the United Nations Environment Programme (UNEP), an estimated 99% of seabirds will have ingested plastic by 2050 [3]. In 2015, microplastic particles of different materials, quantities, and shapes were detected in various products including table salt (lake salt, rock salt, and sea salt), seafood (fish, shellfish), beer, and honey in multiple countries including China. In 2017, microplastics (fibers) of different materials were found in drinking water samples from 126 locations across the United States, Europe, and Africa [4].

Since 2011, UNEP has been paying continuous attention to plastic waste in the ocean, particularly focusing on microplastic pollution. Marine debris was included as one of three major themes in the *2011 UNEP Yearbook*, which specifically highlighted microplastics as an emerging environmental issue. In 2014, the first United Nations Environment Assembly (UNEA-1) passed a resolution on "marine plastic debris and microplastics" and published the *UNEP Yearbook 2014* and *Valuing Plastics*, noting that large quantities of plastic waste in oceans increasingly threaten marine life, causing conservative annual economic losses of $13 billion, and listing marine plastic pollution among the top ten most

urgent environmental issues of the decade. In April 2015, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) released a report equating the harm of microplastics to marine life with that of large marine debris. UNEP has called on countries to adopt precautionary measures in microplastic management, and UNEA-2 in 2016 further promoted international legal and policy frameworks for marine microplastic management and control. UNEP is currently studying the possibility of establishing and implementing binding legal mechanisms for marine plastic waste and microplastics. The issue has become an important topic for UNEP, which designated "Beat Plastic Pollution" as the theme for World Environment Day 2018, calling on countries worldwide to work together to combat single-use plastic pollution [6,7]. It is foreseeable that marine plastic waste and microplastic pollution will remain among the global and regional marine environmental hot-button issues and major topics in international treaty negotiations for the foreseeable future.

**China's Plastic Production and Waste Situation**

China's plastic industry has developed rapidly, consistently ranking among the top globally in plastic product output, with several products such as polyvinyl chloride (PVC) and amino plastics already leading worldwide production. In 2017, China's total plastic product output reached 75.1554 million tons [8]. Plastic products constitute an important foundation for China's petrochemical and light industries, primarily including ten sub-sectors such as plastic films, sheets, pipes and fittings, foam plastics, packaging boxes and containers, and daily-use articles. Traditional plastic products were mainly used in agriculture, construction, and daily necessities, but with continuous development and strengthening of production processes, the plastic industry has gradually expanded into high-end fields such as automotive and medical industries. According to the *Guiding Opinions on the 13th Five-Year Development Plan for the Plastic Processing Industry*, the average annual growth rate of plastic products from enterprises above designated size will reach 4% during 2016-2020 [9]. The *Guiding Opinions on Technological Progress for the 13th Five-Year-Year Development Plan for the Plastic Processing Industry* emphasizes adhering to a "resource-saving, environment-friendly, and technology-innovative" industrial direction, vigorously implementing a "high-efficiency, safe, circular, and ecological" development strategy to promote healthy and sustainable development of the plastic processing industry [10].

China's plastic waste problem has primarily focused on plastic fast-food containers, plastic bags, plastic packaging, and agricultural plastic films since the late 20th century. These plastic wastes have low recycling value and wide usage, making them easily discarded and dispersed into the environment. In addition to affecting environmental aesthetics, they further fragment into plastic pieces and microplastics, which can be accidentally ingested by wildlife, clogging their digestive systems, harming ecosystem safety, and ultimately threatening human health through the food chain.

China's overall plastic pollution situation remains concerning. Discarded plastics in the environment decompose into microplastic particles that can enter organisms through ingestion and potentially affect human health through the food chain. According to the *2016 China Marine Environmental Status Bulletin*, the average density of floating microplastics in surface waters of monitoring sections in the Bohai Sea, East China Sea, and South China Sea was 0.29 particles/m^{3}, with a maximum of 2.35 particles/m^{3} [5].

### Emerging Challenges from E-commerce

In recent years, the rapid growth of plastic packaging from express delivery and food delivery services has created new challenges for plastic waste prevention and control. In 2016, China's express delivery industry used approximately 14.7 billion plastic bags, with about 6.8 billion used directly by express services [14]. The retail industry consumes about 500 billion plastic bags annually. In 2017, Chinese consumers spent 200 billion yuan on food delivery, with major online ordering platforms using 40 million meal boxes and plastic bags daily, totaling 14.6 billion annually [15]. In 2017, China's express delivery business volume exceeded 40 billion parcels, generating 8 million tons of express waste [16,17]. This dramatic growth in plastic packaging usage has placed enormous pressure on plastic waste prevention and control.

### Deficiencies in China's Plastic Waste Control System

**Insufficient Legislation on Plastic Waste Management** China currently lacks legislation specifically targeting microplastic management. Relevant laws, administrative regulations, and industry standards primarily include: the *Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste* (1995), the *Emergency Notice on Immediately Stopping Production of Disposable Foam Plastic Tableware* issued by the former State Economic and Trade Commission in 2001 (the "Plastic Ban"), the *Notice of the General Office of the State Council on Restricting the Production, Sale, and Use of Plastic Shopping Bags* (2007) (the "Plastic Limit Order"), and the *Technical Specifications for Pollution Control of Waste Plastic Recycling and Regeneration* issued by the former State Environmental Protection Administration in 2007. Additionally, the *Law of the People's Republic of China on the Promotion of Clean Production* and the *Law of the People's Republic of China on the Promotion of Circular Economy* also address plastic waste recycling and utilization [18].

Comprehensive analysis reveals three main deficiencies in current legislation: First, relevant provisions are overly abstract and principle-based, with few punitive measures for violations, making enforcement difficult. Second, government department responsibilities are unclearly defined, with ambiguous divisions among ecological and environmental authorities, market supervision departments, agricultural and rural departments, and housing and urban-rural development departments, leading to difficulties in implementing regulatory re-

sponsibilities [18]. Third, economic instruments are insufficiently applied, with no clear provisions on how costs for plastic recycling and treatment should be borne by polluters.

**Suboptimal Enforcement of Some Plastic Waste Management Regulations** Although China has issued regulations on plastic waste management, actual enforcement efficiency falls significantly short of expectations due to the vast number and wide dispersion of plastic product manufacturers and the ubiquitous use of plastics in daily life. For example, despite the 2001 ban on disposable foam plastic tableware, substantial use continues in society [19]. The 2007 "Plastic Limit Order" has also proven ineffective. Initially, media surveys showed 70% of consumers were willing to use eco-friendly shopping bags, but over time, plastic bag consumption gradually rebounded as people adapted to the charges. Some argue that plastic bag usage actually increased after the "Plastic Limit Order" [20]. Moreover, the charge mainly applied to large supermarkets, while free distribution continued in poorly regulated small shops, farmers' markets, and rural areas, undermining the authority and effectiveness of the policy. These issues have led some to suggest the "Plastic Limit Order" has become a "Plastic Selling Order" [21].

**Incomplete Plastic Waste Recycling System** China has numerous plastic production enterprises with strong dispersion, and these enterprises basically do not undertake responsibility for recycling waste plastics. Meanwhile, having individual enterprises or even corporate giants directly conduct plastic waste recycling is difficult to manage and often uneconomical. The recycling system faces three main problems: First, recycling costs are high while returns are low, typically making it unprofitable, yet relevant policy incentives are insufficient. Without government subsidies and with ineffective tax policies, plastic recycling progress has been extremely slow. Second, even when collected, most plastic waste with low recycling value is disposed of through landfilling, merely changing its location while remaining in the environment long-term and risking re-entry into water bodies and soil. The slow degradation of plastics releases harmful substances that pose potential risks to groundwater [22]. Third, after the "Plastic Limit Order," the revenue from plastic bag charges went to supermarkets without being converted into recycling and treatment costs, failing to reflect the polluter-pays principle.

**Imperfect Management System for Biodegradable Plastics** Biodegradable plastics (BDP), also called environmentally friendly degradable plastics, currently include photodegradable plastics, biodegradable plastics, photo/biodegradable plastics, and completely degradable plastics [23]. Biodegradable plastics represent an important branch of plastic production development and have been consistently supported and encouraged by policies. However, compared with petroleum-based plastics, biodegradable plastics have higher costs and typically inferior performance, leading to the description "popular in name but not in practice" [24]. To provide more policy incentives and encourage use of environmentally friendly biodegradable plastics, certification

standards and labeling systems need to be established promptly. Additionally, some claimed biodegradable plastics are not completely degradable, and the remaining plastic fragments after the degradable components break down can cause more serious environmental problems that are harder to collect and treat.

**Blank in Microplastic Control Measures** Microplastic control is a recent international hot topic. Although China's former Ministry of Environmental Protection (now Ministry of Ecology and Environment) included "cosmetics and cleaning products containing plastic microbeads" and "plastic microbead additives" in the *Comprehensive Catalog of Environmental Protection (2017)* as "high-pollution, high-environmental-risk" products [25], the catalog does not restrict their use. Investigations show products containing microplastics continue to be produced, sold, and used. China's management of environmental microplastics, represented by personal care products, remains blank, undoubtedly leading to continued ecological and human health risks. Meanwhile, foreign-produced products containing microplastics may be dumped in China, increasing pressure from microplastic pollution.

### Source Control Countermeasures for Plastic Waste and Microplastic Pollution

**Improve Legislation on Plastic Pollution Control** Improving legislation is fundamental to strengthening plastic pollution control. Based on existing laws and regulations, more explicit implementation rules need to be formulated. Specifically: First, clarify responsibilities of government departments at all stages of plastic production, use, recycling, and treatment to avoid confusion and ineffective performance. Second, specify detailed penalties for violating enterprises and individuals, clearly defining illegal acts and corresponding economic and administrative sanctions. Third, improve the role of economic instruments such as taxation, fully reflecting the polluter-pays principle in plastic waste reduction and recycling.

**Improve Relevant Standards for Plastic Pollution Control** China should strengthen and improve standards for plastic waste and microplastic management, promptly issuing standards to regulate plastic product production and recycling treatment. Priority areas include standards for agricultural plastic films, plastic bags and other packaging, wastewater and air emission standards for plastic treatment enterprises, and certification standards for biodegradable plastics. Simultaneously, strengthen formulation of microplastic monitoring specifications and timely establish discharge standards for microplastics in municipal and industrial wastewater treatment plant effluents.

### Improve Plastic Waste Management Policies

**Control Transboundary Movement of Plastic Waste** In 2017, the General Office of the State Council issued the *Implementation Plan for Prohibiting Foreign Waste Imports and Promoting the Reform of the Solid Waste Import Management System*. This marked China's first declaration of war on trans-

boundary plastic waste movement and will play a positive role in controlling domestic plastic waste pollution while helping other countries strengthen plastic waste treatment and recycling [29]. Currently, China only prohibits waste plastics from household sources; the scope should be expanded to include non-household waste plastics. China should also prohibit transferring its own plastic waste to other countries to establish its image as a responsible major country controlling transboundary waste movement.

**Strengthen Plastic Packaging Management** With the rapid development of express delivery and catering industries, demand for plastic packaging has grown sharply, but China's overall recycling rate for express waste remains low at less than 20% [17,30]. On February 7, 2018, the General Administration of Quality Supervision and the Standardization Administration released the new edition of the *Express Packaging Supplies* series of national standards. The new standards reduce quantitative requirements for paper express envelopes, air-cushion film express bags, and plastic woven cloth express bags, decrease thickness requirements for plastic film express bags, and recommend using biodegradable plastics for express bags [31]. However, the new standards face questions about high costs and implementation difficulties, mainly regarding the high cost and insufficient performance of biodegradable express bags and high recycling costs for express boxes. Practice shows that neither express companies nor consumers have high enthusiasm for packaging recycling [32].

International strategies vary. The United States offers tax reductions for packaging recycling enterprises, Japan encourages packaging recycling and reuse, and Germany legislates mandatory recycling [33]. Given China's rapidly growing express packaging sector, promoting biodegradable plastics remains difficult and cannot fundamentally solve the problem of rapidly increasing plastic packaging in the express industry. Possible solutions include strengthening supervision of the express industry, implementing full-process management of plastic packaging use to avoid excessive packaging, using alternative products, and maximizing reuse rates. Since most express plastic packaging is discarded as household waste and recycling by express companies is neither economical nor realistic, an environmental tax on packaging recycling could be levied on express parcels, with revenues used to subsidize classification, recycling, and treatment of plastics in household waste [34]. Finally, China should strengthen clean production certification for express enterprises to enhance industry self-discipline.

**Restrict Direct Landfilling of Plastic Waste** For a long time, due to cost and technical reasons, landfilling has been the primary method of waste treatment in China, with large amounts of plastic waste buried underground. Plastic waste degradation is extremely slow, taking 400-500 years, far exceeding the 200-year design lifespan of most landfills [35], creating significant long-term risks. Drawing on EU experience, plastic packaging recycling rates increased from 14.6% to 16.7% between 2006-2016, with recycling and energy recovery rates rising from 3.9% and 3.8% to 6.8% and 6.5% respectively, while landfilling decreased from 7.2% to 3.4% (a 53% reduction) [1]. Germany banned direct waste

landfilling nationwide after 2005 [36], and the United States has also seen an overall decline in landfilling rates. European and American experiences show that reducing landfilling rates for all waste, including plastics, is the general trend. China should promptly legislate to require classification and cleaning before landfilling and prohibit direct landfilling of plastic waste.

**Improve Plastic Recycling Systems** Europe's average plastic recycling rate exceeds 45%, with Germany reaching 60% [22]. By 2030, the EU plans to achieve 100% recycling of plastic packaging [37]. According to data from the National Development and Reform Commission's *Annual Report on Comprehensive Resource Utilization in China (2014)*, China's waste plastic recycling rate was 23%-29% between 2009-2013 [38], significantly lagging behind developed countries but indicating huge potential. Plastic and microplastic waste recycling should strictly implement the Extended Producer Responsibility system, adopting the "polluter pays" principle to improve recycling rates. Establish subsidy mechanisms for recycling renewable resources such as plastic bags to encourage manufacturers to innovate green products and increase recycled material proportions. Explore environmental tax mechanisms for plastic bags and other disposable plastic products (such as plastic straws), levying taxes on producers or consumers to establish special funds for plastic waste recycling and other environmental activities. Simultaneously, clarify responsibilities of tax and regulatory departments, and grant reasonable rights and obligations to regulated entities. Additionally, strengthen control of secondary pollution from plastic recycling enterprises to avoid re-pollution from plastic recycling.

**Strengthen Plastic Microbead Management** On World Oceans Day, June 8, 2015, UNEP issued a report advocating that countries and regions worldwide gradually phase out and ban plastic microbeads in personal care products and cosmetics [39]. This initiative received positive global responses, with the EU, United States, United Kingdom, South Korea, New Zealand, Australia, Netherlands, Austria, Luxembourg, Belgium, and Sweden issuing statements banning plastic microbeads in personal care products [40,41]. According to the list published by the China Food and Drug Administration, among 1,008,126 registered personal care products in 2017, 36,993 products (3.67%) contained polyethylene, polypropylene, or both, including rinse-off products (facial cleansers, shower gels, etc.) and leave-on products (lipstick, eye shadow, etc.) [26]. Considering both domestic pollution risks and international treaty pressures, China should take banning plastic microbeads in personal care products as an entry point to strengthen environmental microplastic pollution risk control.

**Develop Microplastic Removal Technologies** Personal care products such as cosmetics and toothpaste containing plastic microbeads directly generate large quantities of microplastic particles. Another important source of microplastics in daily life is washing machines, which discharge large amounts of plastic fibers into municipal sewer systems. Adding microplastic removal processes in municipal wastewater treatment plants would help reduce microplastics from domestic sewage. Current potential removal methods include air flotation

and flocculation [42,43], requiring research on specific materials and process parameters. In recent years, biological methods for plastic removal have attracted attention for their energy efficiency and environmental benefits. Reports of biological plastic degradation have emerged both domestically and internationally, such as mealworms (*Tenebrio molitor*, China) [44,45] and bacteria *Ideonella sakaiensis* 201-F6 (Japan) [46]. However, the most urgent and feasible measure remains strengthening resource recycling of plastic waste, including producing new plastics from waste plastics and generating oil through pyrolysis. Simultaneously, improve efficient combustion systems to utilize waste plastic thermal energy while avoiding pollution from volatile organic compounds (VOCs) and dioxins.

**Expand Public Participation** Public participation plays a vital role in plastic waste and microplastic pollution management. Indeed, it was public recognition of the hazards of plastics and microplastics to ecosystems and human health that made this an internationally prominent issue. The theme of World Environment Day 2018, "Beat Plastic Pollution," aimed to increase pressure on governments and enterprises through public participation to strengthen plastic and microplastic pollution control [47]. China currently has multiple non-governmental environmental organizations participating in coastal cleanup activities, raising public awareness of marine environmental protection through beach waste recycling [48]. To improve public participation in plastic waste and microplastic control, China should increase disclosure of plastic waste pollution information, enhance public awareness, and encourage reduced use of disposable plastic products. Simultaneously, improve public participation channels and feedback mechanisms. Furthermore, China should fully leverage environmental protection NGOs and improve public interest litigation mechanisms for citizens and non-governmental environmental organizations.

## Conclusion

In recent years, with joint promotion by the United Nations and other international organizations and countries worldwide, controlling plastic waste and microplastic pollution has become a major global environmental issue. The fundamental means of controlling microplastic pollution is preventing plastic waste from entering the environment and subsequently fragmenting into microplastics. As the world's largest plastic producer and consumer, China faces significant environmental challenges from plastic waste and microplastic pollution, most notably from plastic bags, food containers, and agricultural films. The rapid growth of plastic packaging usage accompanying the rise of the express delivery industry has created substantial difficulties for pollution prevention and control. Overall, China's plastic waste control system still has many deficiencies. To gradually solve these problems, China should promptly enact relevant legislation, improve standards, and refine management policies targeting specific plastic waste issues. Additionally, China should strengthen microplastic control by taking banning plastic microbeads in personal care products as a break-

through point. Furthermore, China should continuously develop microplastic removal technologies, intensify technological innovation in the plastic processing industry, emphasize cleaner production and resource recycling, and reduce the amount of plastic waste and microplastics entering the environment. Finally, public participation should be expanded to improve public awareness and supervision of government and corporate efforts in controlling plastic waste pollution.

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*Note: Figure translations are in progress. See original paper for figures.*