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Current Opinion in Green and Sustainable Chemistry
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https://doi.org/10.1016/j.cogsc.2021.100462

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Green and Sustainable Chemistry

Regulation of plastic from a circular economy perspective

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Plastic pollution is one of the major global environmental challenges and is, therefore, attracting increased societal attention. This has resulted in the adoption of a long array of national and international policies\ targeting plastic pollution. Whereas early plastic pollution regulation focused mainly on banning specific plastic products such as plastic bags, more recent focus has been devoted to the full plastic value chain. The aim of this focus is to facilitate a transition toward a circular plastic economy. This review first describes the historical development of policy initiatives targeting plastic pollution, followed by a review of the key legislations at each step of the plastics value chain. Finally, the review introduces policy measures most often used since 2018 to target plastic pollution and discuss the importance of regulation that facilitates the transition toward a circular plastic economy.

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Current Opinion in Green and Sustainable Chemistry 2021, **29:**100462

This reviews comes from a themed issue on **Microplastics (2021)**

Edited by **Teresa Rocha-Santos** and **Catherine Mounyrac**

https://doi.org/10.1016/j.cogsc.2021.100462

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Keywords
Plastic pollution, Environmental regulation, Circular economy, Policy measures.

Introduction

Plastic pollution has gained significant international attention as a major environmental challenge [1]. In response, numerous voluntary and regulatory initiatives have been adopted across multiple levels of government. Single-use plastic products, with little value after use, are a major reason for widespread plastic pollution [2]. A transition to a circular economy is therefore being promoted as the best solution to combat plastic pollution [3,4]. A circular economy framework aims to minimize plastic waste production and environmental contamination, addressing all phases of the value chain from design to end-of-life [3].

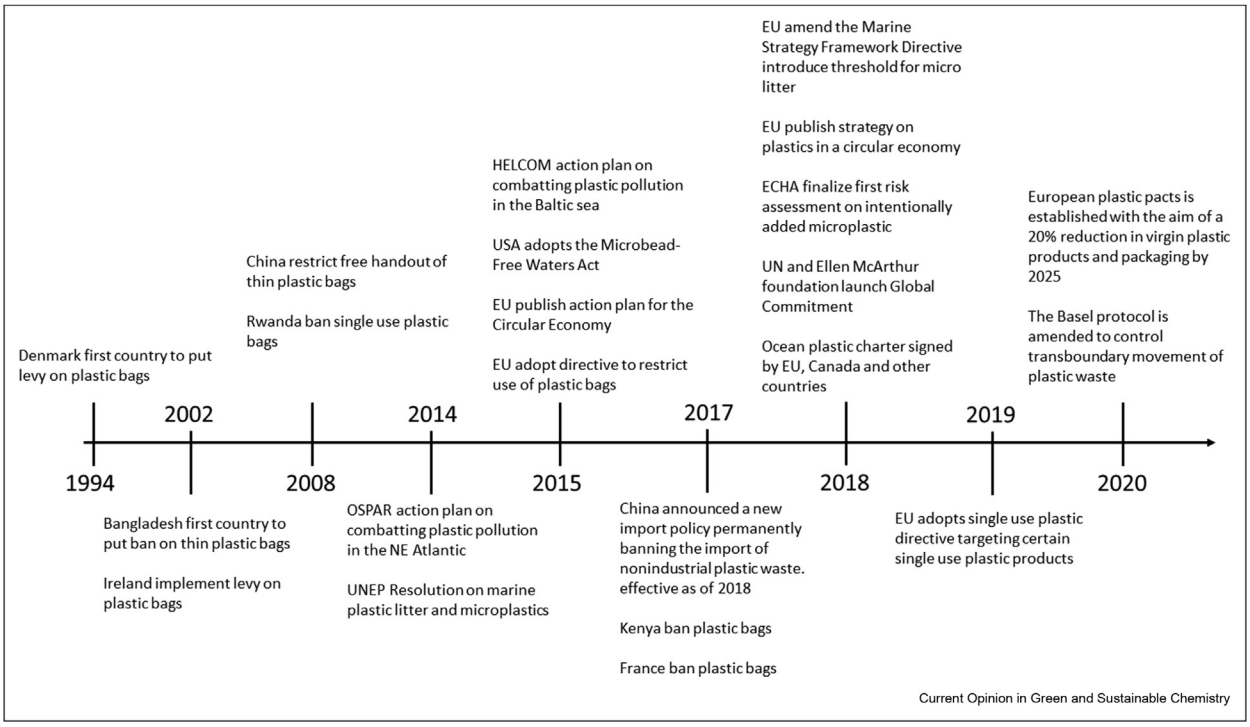
Here, we review key international regulations with respect to their importance toward a transition toward a circular economy. First, we provide a historical overview of key policy initiatives concerning plastic pollution. Then we address and discuss relevant regulations regarding each phase of the value chain: 1. Product design, 2. Production, 3. Use, and 4. End-of-life.

Regulations aimed at addressing plastic already lost into the environment, such as clean-up and monitoring activities, are not included as these address plastic pollutions beyond the value chain. For a review of regulations relevant to plastic pollution in the environment, the reader is referred to Ref. [5].

Historical overview of key plastic pollution policy initiatives

While the production of plastic accelerated from a few tons in the early 1950s to almost 360 million tons in 2018 [6], policies related to the sustainable management of the material lagged by nearly four decades, the early policies specifically targeting plastic tended to focus mostly on bans and levies as a tool to reduce plastic waste. The first example of regulation on production, to the best of our knowledge, is the levy on plastic bags implemented in Denmark in the early 1990s [7] (Fig. 1). Levies or taxes are aimed at reducing the demand for plastic products, which is expected to ultimately reduce production. The first ban on plastic products stemmed

Fig. 1



Historical overview of policy initiatives targeting plastic pollution. Historical overview of key policy initiatives specifically targeting plastic pollution. The overview contains both national and international initiatives and dates back to the first levy specifically targeting a plastic product.

from the early 2000s when countries such as Bangladesh, Rwanda, and China imposed bans on plastic bags [8]. These early bans were in response to increasing environmental pollution in wastewater infrastructure (Bangladesh), in the environment (Rwanda), and massive production of plastic waste (China). As the awareness of the issue of plastic pollution spread in the second decade of the 2000s, international action plans by organizations such as HELCOM and OSPAR targeting marine litter were adopted [9,10]. The International Convention for the Prevention of Pollution from Ships (MARPOL) prohibits the discharge of plastics into the sea [11]. Among other purposes, the convention obligates governments to ensure that ports can receive and handle ship waste, including plastic. In their action plan from 2018, an array of measures are suggested, including increased awareness and education of fishermen, a survey of existing port facilities, and a recommendation to consider marking of fishing gear mandatory [11].

A pivotal moment for the international policy was Jambeck et al. [12] publication on plastic waste emissions from the land. This seminal work played a key role in turning the international focus away from plastic debris floating in the middle of the ocean to plastic waste entering our oceans from land.

With the increased spotlight on plastic waste, countries around the world began to focus explicitly on how much plastic waste they produced, how much was managed, and whether that management was sustainable. Up until this point, plastic waste was typically targeted under general waste regulations, such as the EU waste framework directive [13]. In this phase, it was acknowledged that plastic is a valuable material, and when kept in the economy through reuse and recycling, both the environment and the economy benefit [3]. Understanding the value of plastic combined with our need to reduce plastic waste, ideas to reduce plastic production and/or keep plastics within a circular economy framework have risen to the top of the solution hierarchy [1,3]. This addressed the issue more explicitly in a value chain perspective and focused on facilitating more closed-loop production chains, not just to minimize environmental plastic pollution but also to reduce consumption of fossil fuel since forecasts have estimated that as much as 20% of total oil production could be used for plastic production under a business-as-usual scenario [14].

Regulation in relation to the production chain

With the realization that plastic pollution must be addressed throughout the value chain [14], and not just

once the plastic is in the environment, a focus on facilitating a transition toward a circular plastic economy was deemed essential [3]. In the following section, key examples of legislations that have been implemented to address each of the steps in the value chain are introduced and summarized in Fig. 2.

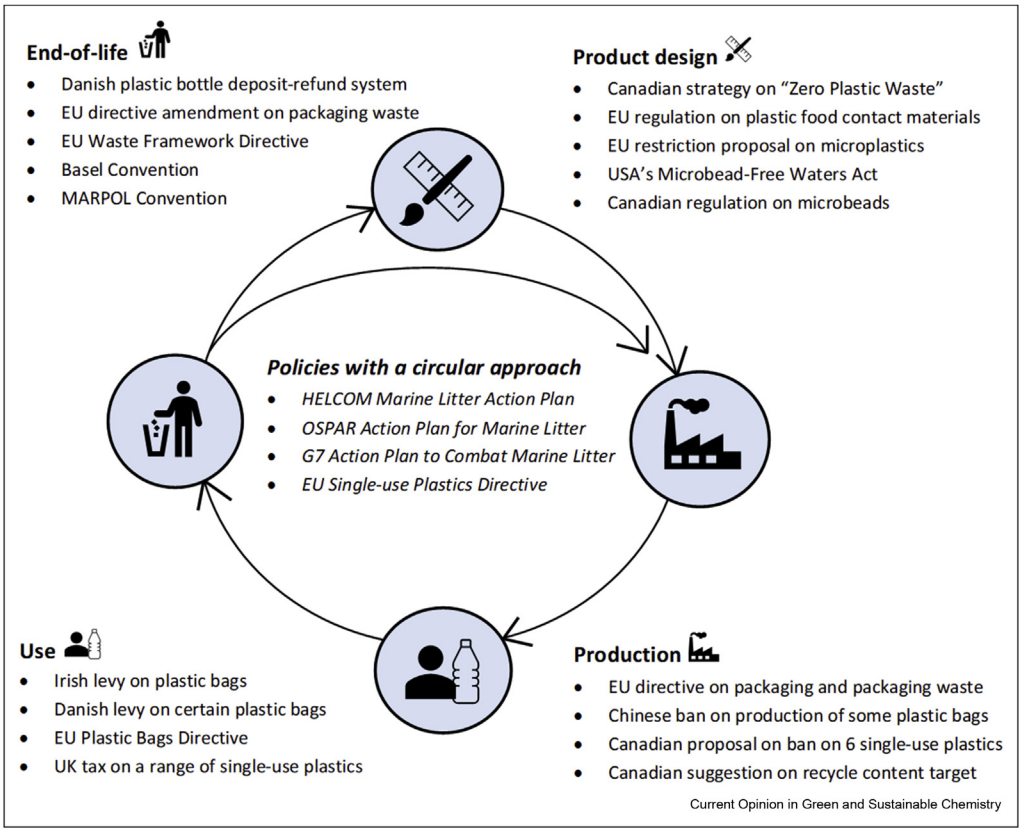
Product design

Examples of regulations aimed at product design include those that facilitate the innovation of more sustainable plastics. For instance, the EU Directive 2019/904 of June 5, 2019, aims to reduce the environmental impact of certain plastic products [15]. The Directive sets out product requirements for certain plastic products. These must be taken into consideration in the future product design and address the development of harmonized standards relating to the circular design [15]. The Directive further incorporates extended producer responsibility, which is also a cornerstone in the Canadian Strategy on 'Zero Plastic Waste' [16]. Extended producer responsibility is meant to encourage producers to change production toward products that are easier to keep within the circular value chain, and thus, reduce loss to the environment.

Another example of regulation aimed at product design is the EU Commission Regulation 10/2011 of January 14, 2011, on plastic materials and articles intended to come into contact with food, which sets out rules for the composition of food contact materials containing plastic [17]. Only the authorized substances listed in the regulation must be used in the manufacture.

Recently, a ban on intentionally added microplastics was proposed in 2019 in the EU, including products in categories such as fertilizers, plant protection products, cosmetics detergents and artificial turfs [18]. Similarly, the Microbead-Free Waters Act of 2015 in the United States of America prohibits the manufacture and introduction into interstate commerce of rinse-off cosmetics containing intentionally added plastic microbeads, and the Canadian Microbeads in Toiletries Regulations prohibits the manufacture, import, and sale of toiletries containing plastic microbeads [19,20].

Fig. 2



Overview of legislations targeting each step of the plastics value chain. Examples of key legislations aimed at facilitating the transition toward a circular plastic economy. Legislations are linked to the step in the value chain where they are meant to have an impact. The legislations mentioned in the center of the figure are those that address plastic flow in the entire value chain. References are found in the text.

The content of (hazardous) additives is another important parameter for keeping plastics within a circular value chain. Chemical legislations, such as the European REACH legislation regulates industrial chemicals, including those in plastic products [21], are, therefore, vital for ensuring that plastic products are designed with the circularity in mind. Lack of circular focus in such regulation can be an important barrier for the transition to circularity within the plastic value chain [22].

Production

Legislations aimed at production often focus either on bans or levies to reduce the production of certain plastic items. These legislations tend to be implemented at the regional, national, or even local level rather than the international level. One notable example is China's ban of June 1, 2008, on the production of ultra-thin plastic bags and the prohibition of retail stores handing out free ultra-thin plastic bags [23]. In a recent proposal, the Canadian government proposed a ban on six single-use plastic items that are commonly found in the environment that are not practically recyclable and have a potential alternative on the market. The EU single-use plastic directive similarly bans certain plastic products made for single-use purposes [15].

The shift toward a more circular plastic economy further entails a move away from using fossil fuel by increasing the production of plastics based on renewable resources, such as organic waste streams [24]. In 2020 bioplastic consumption amounted to 2.11 million tons, with the packaging being the most common product type accounting for approximately 47% [25]. The European Commission has also pointed to the need to increase investor confidence in the long-term economic viability of plastics recycling (it points out this is a challenge in times of low oil prices) [26].

Use

The most widespread item targeted in the regulation of plastic use has been the plastic bag, and up to 2018, the regulations for plastic bag uses had been implemented and adopted in 127 countries and all regions of the world [8]. Some of these regulations also aim at the production of plastic bags, like the Chinese regulation mentioned above, whereas others, such as the Irish levy implemented as early as 2002, are solely focused on the use phase. The Irish levy resulted in a reduction in pollution with plastic bags, which constituted 5% of total marine litter items before the levy and dropped to 0.13% with the introduction of the legislation [27]. In 2015, the EU implemented Directive 2015/720. According to this Directive, national measures must be taken to reduce the consumption of lightweight plastic carrier bags, e.g. by setting national maximum consumption rates, restrictions on their use, or financial measures such as imposing charges [28]. Furthermore, the EU single-use plastic Directive requires the Member States to take measures to inform consumers and to incentivize responsible consumer behavior regarding the use of single-use plastic products [15]. The Directive further aims at reducing consumption of a range of single-use plastic products, including food containers and cups for beverages by 2026, requiring the member states to adopt measures to reduce the consumption and promotion of reusable alternatives [15]. In spring 2020, the UK government announced that a range of single-use plastics would be taxed by 2022, encouraging a shift in consumption away from these products in favor of multiple-use products [29].

End-of-life

Legislations aimed specifically at waste includes initiatives that increase waste collection and divert waste from landfill with the goal to reuse or recycle the material, which among several aspects requires focus on degradability and infrastructure that ensures cleaner waste streams [30]. Extended producer responsibility plays an important role in keeping plastic waste within the product chain [31]. Deposit-refund systems are commonly used to give value to the plastic in the waste phase, typically for bottles and containers. Denmark was the first country to introduce such a system for glass bottles already in 1922, with plastic bottles being added in the 1990s [7]. Since then, other countries in Europe, Asia, and Latin America have introduced deposit-refund systems for certain plastic products. Extended producer responsibility is an important measure in the EU Directive 94/62/EC on packaging and packaging waste, which was last amended in 2018 in order to promote reuse, recycling, and other forms of recovery of packaging waste to facilitate the transition to a circular economy [3]. The single-use plastic directive is the latest EU legislation to further strengthen the transition toward a circular economy by introducing measures to ensure separate collection for recycling of certain single-use plastic products such as beverage bottles and fishing gear [3].

Several legislations have been adopted lately as a response to the growing production of plastic waste. By 2018, China had become the number one importer of plastic waste, importing a cumulative of 45% of plastic waste produced since 1992, but in 2018, China stopped this import [32]. This was followed by an international initiative to control plastic waste export by amending the Basel protocol in 2019 [33]. The Basel Convention aims at controlling transboundary movements of hazardous wastes and their disposal. The Convention adopted two amendments in May 2019, entering into force as of January 1, 2021, considering plastic waste handling, the first of them to address provisions for waste minimization. The last amendment of May 2019

addressedthe provisions pertaining to the environmentally effective management of plastic wastes [33]. Following the scientific discussion on whether plastic waste should be categorized as hazardous waste, [34] plastic waste is now considered 'waste that requires special consideration' [33]. With this new status, transboundary movement of plastic waste must be kept at a minimum, and personnel handling and managing the waste must be authorized. Further, plastic waste import from and export to a nonparty is prohibited, and import is banned [33]. As a consequence of the amendments, the parties of the treaty must comply with several new obligations. Noteworthy among these is ensuring the reduction of plastic waste to a minimum and the availability of adequate treatment and/or disposal facilities [33].

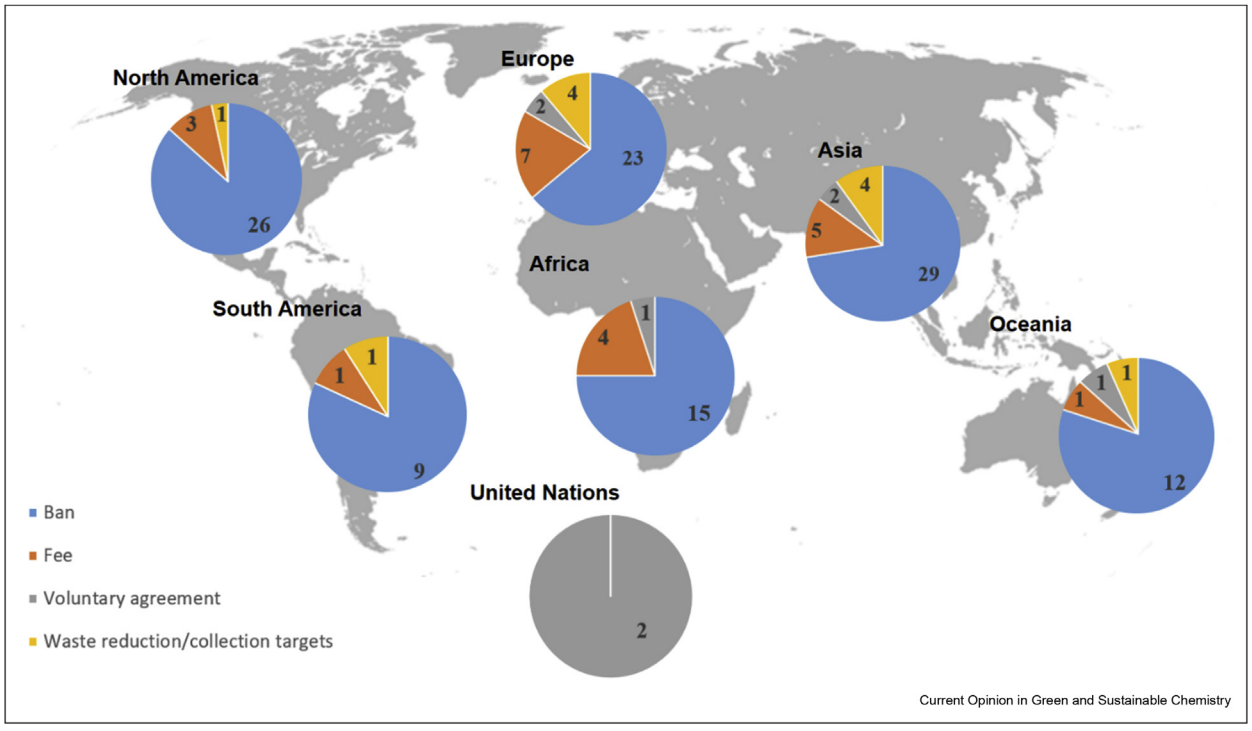
Apart from bans or levies, legislations, such as the EU Packaging and Packaging Waste Directive, aim at dematerialization and increase recycling by introducing new standards for recycled content. For example, the Canadian government and the Ocean Plastics Charter suggest a target for recycled content of new plastic products, which is also a cornerstone in the EU strategy for a circular plastic economy. These standards intend to force new technologies for broader recycling capabilities, increase recycled-content markets to drive down costs, and in general, increase recycling rates. Increased production of bioplastics from e.g. organic waste streams is furthermore promoted as an element in the transition toward a circular plastic economy [24].

Conclusions and future perspectives

Regulation of plastic pollution has shifted gradually from early bans of plastic bags and regulation of general waste handling toward facilitating the transition toward a circular economy. This shift in focus has resulted in legislation, such as the European single-use plastic directive, which aims at regulating plastic at several different stages in the life cycle, rather than focusing on one stage in the life cycle, such as the waste phase. For this transition to become successful, it is vital that proper policy measures are being implemented. Fig. 3 illustrates the most used measures implemented since 2018 in a range of key regulations globally (Fig. 3).

Bans of especially single-use products such as plastic bags are the most frequently used policy measure. For an in-depth review of plastic bag policy initiatives, we refer to Ref. [35]. Apart from bans, fees also play an important role, with new fees implemented in all parts of the world since 2018. Even with the expanding number of

Fig. 3



Most often used policy measures targeting plastic pollution implemented since 2018. Global overview of the most commonly implemented policy measures to regulate plastic pollution since 2018. Measures have been identified in important examples of regulations and include both international, national, and regional policy initiatives. Figure modified from: https://commons.wikimedia.org/wiki/File:World_map_blank_gmt.png.

legislations, there are areas that are not yet properly regulated, such as preproduction pellets [36]. This illustrates that there are still regulatory gaps that need to be addressed.

Finally, additional strong policy measures, not just targeting single-use products but focusing on the entire value chain, need to be implemented. The fall in oil prices will make the production of pristine plastics cheaper, making recycled plastic less attractive for the market. Events like the COVID-19 pandemic have resulted in the increased use of single-use plastics [37]. This implies that market-based measures, such as voluntary agreements, might not be sufficient and that there is a great need for future regulations to focus even more on facilitating the transition toward a circular plastic economy by encouraging a move away from single-use products and the use of pristine plastics.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

We acknowledge MarinePlastic, a Danish Centre for research in marine plastic pollution, sponsored by the Velux Foundation, grant number 25084, for providing the funding for the participation of KS, SFH, MBN, and LPWC.

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