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# Management strategies for single-use plastics: lessons to learn from Indian approach of minimizing microplastic waste†

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Single-use plastics (SUPs) are significant contributors to the overall generation of plastic and microplastic waste. SUPs are the chief materials used for packaging and other such purposes resulting in immediate disposal after use. Recognizing the environmental burden posed by SUPs in the form of microplastics, many countries have banned these materials. However, addressing this issue requires a more diversified approach. The present article focuses on recent initiatives adopted by India for SUP management. Drawing lessons from the experiences of other countries, India has not only imposed ban but adopted an extended producer responsibility approach as well for managing the waste emanating from SUPs. For this, India took the interventions both at the supply side as well as the demand side. Nevertheless, assessment methodologies have been developed, including surveillance, grievance redressal, digital interventions, periodic monitoring, and auditing. While the outcome of this approach will be visible after a few years, an initial appraisal is deemed necessary. Therefore, this paper outlines India's approach, implementation strategy, assessment methodology, possible implications, and future prospects. This multi-faceted nature of the approach involves a number of stakeholders in the SUP chain making it suitable for adoption by other developing nations as well.

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**Environmental significance**

Pollution due to the mismanagement of plastic waste (esp. single-use plastics) is increasing globally, which has further resulted in the generation of emerging contaminants, such as microplastics. The growing pollution has serious repercussions for the environment as well as human health. Therefore, it is imperative to develop advanced management strategies which can be practically employed. Herein, we present the initiatives adopted by India to deal with the menace of single-use plastics, which also have the potential to curb the microplastics generation. The approach adopted is unique in the sense that it is practically achievable and monitorable. Moreover, it also aligns with the UN SDGs: good health and well-being (SDG 3), clean water and sanitation (SDG 6), and responsible consumption and production (SDG 12).

## 1. Introduction

Plastics have become a necessary evil for human life despite knowing the harmful impacts that they pose on the environment and living organisms.[1] The increasing usage of plastics is driven by their light-weight, relatively non-reactive, and durable nature. Plastic production worldwide has increased from 1.5 million tonnes in 1950 to 359 million tonnes in 2018, and it is speculated that production would almost quadruple by 2050.[2,3] Furthermore, it is estimated that 60–99 million tonnes of plastic waste was produced globally in 2015, and it is expected to rise up to 155–265 million tonnes by 2060.[4] Moreover, approximately 91% of the plastics ever produced have gone un-recycled despite having sufficient evidence about the harmful impacts of unscientifically disposed plastics.[5] It has resulted in the accumulation of unattended plastic waste in the environment. This plastic waste not only contaminates various natural resources (ocean, soil, surface/ground water, and air) but also results in the generation of microplastics, after being broken down by abiotic and biotic factors, which poses serious negative impacts on the environment, humans, and other life-forms.[6–8]

In order to deal with the ever-increasing problem of plastic pollution, nations have devised a range of international and domestic policies. United Nations (UN) plastic ban resolution 2022 attracts a special mention in this aspect. UN Environment Assembly's plastic ban resolution attempts to develop a comprehensive framework addressing every facet of the plastic life cycle, encompassing production, design, and disposal. This is supposed to be an international legally binding

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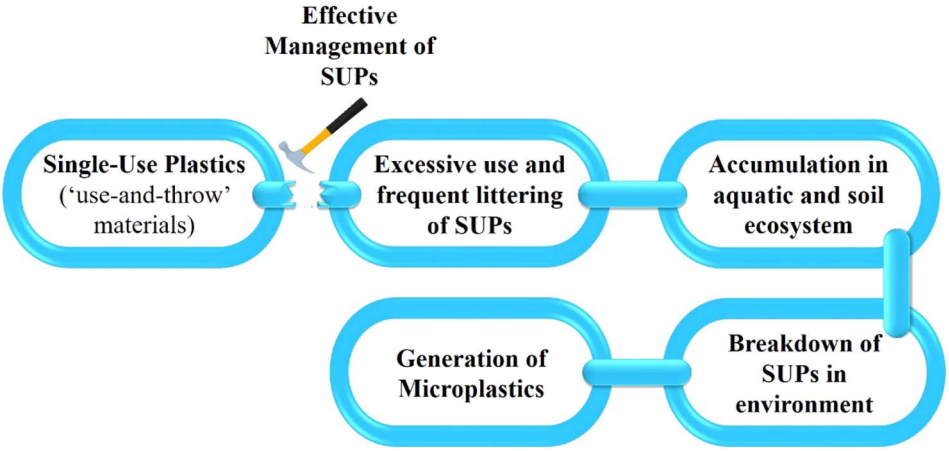


Fig. 1 Abatement of microplastics through management of single-use plastics (SUPs).

instrument for curtailing plastic pollution, which would include the marine environment as well.[9] Similarly, the Basel convention,[10] which was primarily drafted to control the transboundary movement of hazardous wastes and their disposal, has recently introduced a new plastic waste entry for clarifying the scope of control for various types of plastic wastes and mixtures thereof in order to promote environmentally sound management of plastic waste at global, regional, as well as national levels.[11] Additionally, the Stockholm Convention of 2004 aims to protect the environment and human health from persistent organic pollutants (POPs).[12] As many of the plastic components release POPs in the environment during their breakdown, this convention helps to minimize the usage of such POPs in the form of additives, plasticizers, and flame retardants during the manufacturing of plastics.[13] Sustainable development goals (SDGs) of the United Nations further promote the responsible production, consumption, and disposal of plastics (Goal no. 12), in order to protect life below water (Goal no. 14) as well as life on land (Goal no. 15).[14]

Though there are various internationally binding agreements, actions at the national and local levels are more impactful in promoting waste management practices owing to the influence of various social and demographic factors.[15] Therefore, a number of countries worldwide have adopted various strategies to manage plastic waste at the national level. Among these, restriction on single-use plastics (SUPs) is one of the significant steps that many countries have taken. It is notable here that approximately 36% of all the plastics produced are used in packaging, which includes SUPs.[16] Though SUPs share less than 40% of the total plastic production, they attract special attention owing to their usage frequency and life span. SUP-based packaging materials are the most convenient as these are resilient and light weight and thus need little space. SUPs, chiefly made up of fossil fuels *viz.* petrochemicals, are significantly cheaper as well compared to their alternatives. Hence, these are disposed of immediately after use resulting in considerable littering. Besides being used for packaging, SUPs are also used in various service-wares. As SUPs are 'use-and-throw' materials, these immediately get exposed to abiotic/biotic matrices upon being discarded and thus enter into the process of (secondary) microplastic generation. Additionally, improper disposal of SUPs also clogs the drains and/or storm water channels, resulting in frequent urban floods.[16] Since plastic waste management requires multipronged approach and restrictions at various scales, minimizing their usage might be one of the solutions to reduce the plastic waste and thereby microplastics generation in the environment (Fig. 1). In this direction, management of SUPs bears special significance. Realizing this fact, many countries worldwide have banned SUPs and other plastic items beyond a certain minimum thickness to minimize the littering effect.[16] Moreover, Directive (EU) 2019/904 of the European Parliament has also proposed a number of restrictions on the production of SUPs.[17] However, sudden ban on SUP items has also resulted in negative outcomes in some countries.

Utilising the experiences learnt from other countries, Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India has also taken steps to curb SUP waste. It is noteworthy to mention here that India is a signatory to various international treaties and agreements, such as the Basel Convention, the Stockholm Convention, *etc.* Besides, India is also committed to achieving UN SDGs. In this direction, to further promote better plastic waste management, MoEF&CC has not only banned certain SUPs but also adopted the approach of extended producer responsibility (EPR) under the overall umbrella of SUP waste management. The formulation, facilitation, and implementation of the approach were primarily carried out through the apex pollution controlling authority in India, *viz.* Central Pollution Control Board (CPCB). This paper, therefore, critically evaluates the SUP management initiatives adopted by India, which may also be a learning experience for other developing nations in the direction of minimizing microplastic waste.

## 2. Worldwide SUP management practices and lessons to learn

Since SUPs make up a significant part of the overall plastic production, consumption, and disposal, various initiatives and

practices have been adopted worldwide to put restrictions on these materials. Among these, the ban on SUPs, imposition of EPR on plastic products, and green/plastic taxes are worth mentioning.

Banning the products made up of SUPs is not a new approach. To deal with plastic and microplastic waste, SUP ban has been taken as an immediate step by more than 60 countries to date.[16] Moreover, big economies such as US and Canada have recently initiated the process of the SUP ban.[18,19] However, the outcomes of these bans have varied across different countries, depending upon the methodologies adopted and alternative options provided. In this respect, an affirmative example has been set-up by Antigua and Barbuda which implemented the ban in a phased manner. The first step was to prohibit the import and manufacturing followed by ban on sale after sufficient time was given to deplete the existing stocks. In the first year of the ban, 15% decrease in the amount of plastic litter was reported. The success of this program was contributed by the stakeholders consultations, and involvement of waste management authorities, environmentalists, and officials from trade. Moreover, awareness campaigns and the availability of alternative options further mobilised the public to restrict the use of plastics, thereby minimizing plastic/microplastic waste.[16,20] In 2017, the government of Costa Rica also determined to phase out all SUPs by banning them. However, their strategy went beyond a simple ban and adopted a 5-pronged approach to sustain the idea. The strategies were focussed on municipal incentives, guidelines for suppliers, replacement of SUPs, research and development, and investment in strategic initiatives. With this approach, Costa Rica had aimed to become SUP-free by 2021.[16] However, the data on the implementation of the policies and effectiveness of the adopted strategy is missing to date.[21]

In 2003, South Africa introduced a total ban on SUPs less than 30 microns thick and imposed charges on thicker plastic bags. However, sudden imposition of a ban without developing proper awareness and sufficient alternatives resulted in problems, especially for the poorer section of society. Over the time, consumers became ready to pay a little extra for the plastic bags, thus turning whole purpose of the ban futile.[16] Similarly, China introduced the ban in 2020 on SUPs thinner than 25 microns and levies on the thicker ones. Though the ban resulted in a significant reduction in the usage of plastic bags in urban areas, the effects in rural areas remained unnoticed owing to weak implementation. Parallel findings were also drawn from the city of Toronto (Canada), where levy on disposable plastic bags resulted in noticeable impacts only among the households with high socio-economic status.[22] Likewise, due to weak enforcement and lack of cheaper alternatives, the use of plastics remained continued in Bangladesh even after imposing the ban. In Rwanda (Africa), all types of plastics including SUPs were banned in 2008. The policy included a ban on the manufacturing, use, sale, and import of all plastics. As the decision lacked detailed consultations with all the stakeholders and weaker sections of society, it has resulted in several unwarranted practices, such as smuggling of plastic bags.[16]

As far as EPR is concerned, it deals with the responsibility of the producer for environmentally sound management of a product throughout its lifecycle. EPR is a well-established waste management mechanism that was incorporated into the European Union's Waste Framework Directive (Directive 2008/98/EC) over 20 years ago.[23,24] This approach combines the principles of circular economy and polluter-pays.[25] Energy efficiency, disposal restrictions, high taxes on virgin materials, obligation for recycling, and end-of-life disposal are some of the modes through which EPR is promoted and regulated.[26] However, different countries have implemented different EPR mechanisms. For example, in France, Norway, Italy, and Belgium, not-for-profit entities funded by plastic industries are responsible for coordination, funding, and recycling. On the other hand, return of monetary deposits to consumers upon recycling is another mode which is practiced in Finland, the United Kingdom, Sweden, Denmark, and Germany.[24,27] Nevertheless, for the success of EPR-based policies, it has been found that strong regulations for the implementation of EPR, financial responsibility of the producers, and mechanism of keeping separate entities for collection and recycling play a major role while involvement of the informal sector in the chain creates a setback.[28]

Compared to the policies of SUP bans and EPR, the concept of green taxes is rather new. Green taxes are generally introduced to motivate people to adopt environmentally friendly practices. With regard to plastic pollution, some of the countries have introduced "plastic tax" as well. In UK, a new plastic tax was introduced in April 2022 in order to promote businesses for using at least 30% recycled plastics in their products.[29] Similarly, European Union has also introduced plastic tax in 2022 as a contribution from member states based on the amount of non-recycled plastic packaging waste produced by each member state.[30]

Thus, it can be understood that the outcomes of different approaches have been different in various countries. However, it may be perceived from their experiences that country-specific meticulous planning, phase-wise transmission, and strict implementation are some of the key issues which must be taken care of for effective SUP management.

## 3. Approach of plastic waste management in India and road to SUP elimination

In India, efforts to minimize the adverse effects of plastic waste were started way back in 1998 with the formulation of guidelines for recycling of plastics.[31] Under these guidelines, the Bureau of Indian Standards (BIS) has set-up a framework for the selection, segregation, and processing of plastic waste/scrap. To provide further clarity on plastics recycling, the Recycled Plastics Manufacture and Usage Rules 1999 were framed, with various restrictions on the use of commodities made up of recycled plastics (Fig. 2). These rules also defined the minimum thickness of carry bags made up of virgin/recycled plastics as 20 microns.[32] In this sequence, a major breakthrough took place in

 

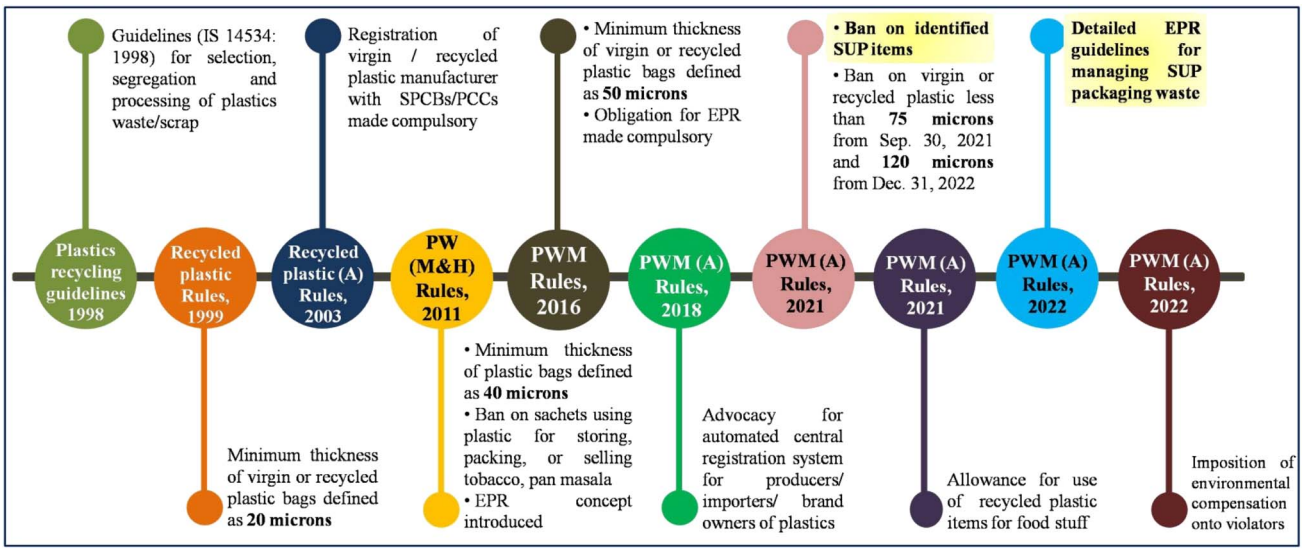


Fig. 2 Timeline of initiatives taken by Govt. of India for plastic waste management. PW(M&H): Plastic Waste (Management & Handling); PWM: Plastic Waste Management; PWM(A): Plastic Waste Management (Amendment).

2011 when the Plastic Waste (Management and Handling) Rules came into force. Under these rules, ban on the use of plastic materials in sachets for storing, packing, or selling tobacco, gutkha (a sweetened mixture of smokeless tobacco, betel nut, and palm nut), and pan masala was imposed.[33,34] Furthermore, the minimum thickness of carry bags made up of virgin/recycled plastics was increased up to 40 microns. It was the first time when the concept of EPR was introduced for plastic waste management in India. Subsequently, Plastic Waste Management (PWM) Rules were brought into force in 2016, in which obligation for EPR was made compulsory for producers, importers, and brand owners and a unified framework for EPR was prepared. Additionally, the minimum thickness of carry bags was increased up to 50 microns.[35] In order to introduce further modifications in these rules, the PWM (Amendment) Rules were re-framed in 2018.[36] These amended rules advocated for an automated central system for registering producers/importers/brand owners of plastics.

The second breakthrough in the series of plastic waste management took place in 2021, through the release of PWM (Amendment) Rules 2021.[37] These rules clearly banned the manufacturing, import, stocking, distribution, sale, and use of identified SUP items including polystyrene and expanded polystyrene commodities. Furthermore, these rules substantially increased the minimum thickness of carry bags made up of virgin/recycled plastics from 50 to 75 microns (with effect from Sep 2021) and later to 120 microns (with effect from Dec 2022). Moreover, these rules were amended again to some extent in 2021 and 2022 to add more clarity and to linearize the extended producer responsibility framework for SUP packaging waste (Fig. 2).

The role of Indian judiciary in inculcating awareness among the policymakers and stakeholders is also applaudable and worth mentioning in the context of plastic waste management. The judiciary has intervened in a number of cases to issue directions to the government to take substantial actions in order to manage plastic waste effectively.[38] Moreover, judicial intervention was also observed in the issue of microplastics pollution where the tribunal sought to develop standards and remedial measures.[39] Thus, it would not be erroneous to state that combined efforts of policymakers and proactive judicial system led the way for SUP elimination in India.

It is an accepted fact that SUP items have a wide range of functionality as well as convenience of use. Considering its wide-scale utility and absence of readily available alternatives, the idea of putting a complete ban on entire SUP items was not adopted by the Govt. of India. Nevertheless, a combinatorial approach was taken up which includes both SUP ban as well as EPR. The intent of introducing ban was to minimize the usage of certain SUP items thereby reducing the plastic littering effect, as well as developing a sense of responsibility among citizens towards the protection of environment. EPR, on the other hand, was adopted for effective management of waste generated from the SUP packaging as well as legacy SUP waste, aiming to reduce the potential and already exposed sources of (micro)plastics from the environment.

### 3.1 Ban on identified SUP items

Based on the PWM (Amendment) Rules 2021, CPCB has banned the manufacturing, import, stocking, distribution, sale, and use of SUP items with effect from July 01, 2022 (Fig. 3).[40] The banned SUP items include (a) ear buds with plastic sticks, plastic sticks for balloons, plastic flags, candy sticks, ice-cream sticks, polystyrene (thermocol) for decoration; (b) plates, cups, glasses, cutlery such as forks, spoons, knives, straw, trays, wrapping or packing films around sweet boxes, invitation cards, and cigarette packets, plastic or PVC banners less than 100 microns, and stirrers.[40] Further, the thickness of carry bags made up of virgin or recycled plastics was restricted to no less than 120 microns by


Fig. 3 Awareness poster notifying the SUP ban in India. (Image source: CPCB)

December 31, 2022. The attempt to restrict plastic bags of thickness less than 120 microns may be considered a radical move, compared to most other countries which have restricted plastic bags of much less thickness.[41,42] The rationale behind this move lies in the fact that reusability and recyclability of thicker plastic bags are high. Moreover, increased cost of thicker plastic bags also restrains end-users from their purchase, usage, and littering.

### 3.2 Extended producer responsibility for the management of SUP packaging waste

A major portion of the total SUPs is used for packaging. However, as packaging is a versatile sector and plays an integral role in the overall supply chain, banning the SUPs for packaging without having suitable alternatives in place could have serious repercussions for both the producers as well as consumers. Therefore, EPR was adopted as an efficient tool for the management of waste emanating out of SUP packaging. Notably, adoption of the EPR approach in India is not new; rather it came into practice in 2016 (Fig. 2), through the unified framework for EPR under PWM Rules, 2016 for managing all types of plastic waste generated.[43] In spite of that, distinct EPR guidelines specifically for plastic packaging were released through the PWM (Amendment) Rules, 2022 and put in place for easy understanding of all the stakeholders and effective implementation.[44]

## 4. Methodology adopted in India for SUP management

Taking examples from countries worldwide, it was realized that sudden ban on SUP items may lead to confusion, disagreement, and economic losses, which may further lead to various malpractices. Therefore, MoEF&CC/CPCB adopted a well-framed strategy to put the SUP ban directions into action. Moreover, an immediate total ban on all the SUP items was avoided and concept of EPR was put in place. A schematic of the SUP management framework adopted in India is shown in Fig. 4.

### 4.1 Stakeholders consultations and decentralized responsibility mechanism

In order to understand the viewpoints of different sections of society and enhance the adaptability of the actions taken, MoEF&CC and CPCB made a series of consultations with State Pollution Control Boards (SPCBs) (or Pollution Control Committees (PCCs), in case of union territories), Urban Local Bodies (ULBs), and various stakeholders from all across the country. CPCB also acted as a facilitator by giving training to the concerned SPCBs/PCCs, ULBs, and stakeholders. Moreover, to efficiently manage the SUP framework, designated roles were assigned to various government agencies at the center as well as in states/union territories and responsibilities were allocated in a decentralized manner (Table S1†). Publicity and awareness about the various steps adopted were also disseminated in public through ULBs (Table S1;† Fig. 4). Regular dialogues among CPCB/SPCBs/PCCs/ULBs and concerned stakeholders involved in the fulfillment of EPR obligations for efficient handling of SUP production and its waste management also took place (Table S1;† Fig. 4).

### 4.2 SUP ban mechanism

As shown in Fig. 2, significant attempts have been made by the Govt. of India for a decade to manage plastic waste. These attempts gradually kept on becoming rigorous and stricter, which ultimately resulted in the ban of specified SUP items.[37] In order to promulgate the steps adopted in an effective manner, CPCB issued the directions to SPCBs as well, for complying with the directions issued for the ban. SPCBs in turn issued directions to ULBs to implement the ban at the grass-root level (Table S1†). For effective enforcement of the ban, national and state-level control rooms were also set up and special enforcement teams were formed to check the illegal manufacture, import, stocking, distribution, sale, and use of banned SUP items. Initiatives were also taken in the States and Union Territories to

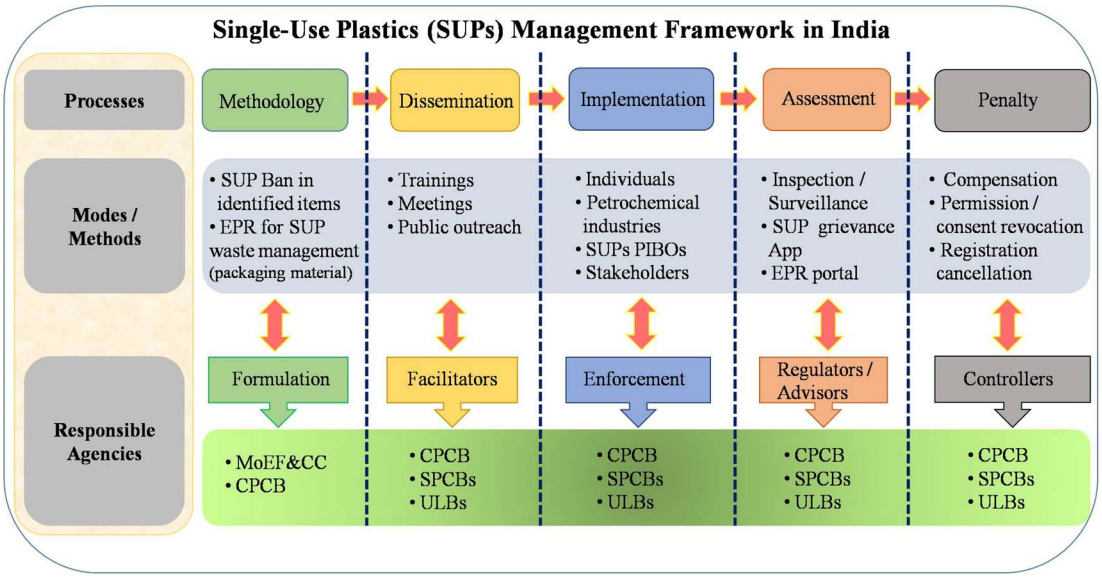


Fig. 4 Schematic of the SUP management framework adopted in India. (EPR: Extended Producer Responsibility; MoEF&CC: Ministry of Environment, Forest and Climate Change; CPCB: Central Pollution Control Board; SPCBs: State Pollution Control Boards; ULBs: Urban local bodies; PIBOs: Producers, importers, and brand owners)

set up border check points to stop inter-state movement of any banned SUP items.

However, it has been realized that SUP ban could continue satisfactorily only if there were necessary alternatives for the banned items. Hence, for a smooth transition towards alternatives of SUPs, Micro, Small and Medium Enterprises (MSMEs) were taken on board from the beginning of the program. Various workshops were organized by CPCB along with the Ministry of MSMEs and expert technical institutions for capacity building and technological assistance of MSME units for the manufacturing of alternatives to banned SUP items. MSMEs were also trained regarding the upcoming requirements of plant machineries, test requirements, regulatory aspects, *etc.* Promotion of compostable plastics was also felt necessary as many of the banned SUP items (made up of petro-based plastics) were possible to manufacture using compostable plastics. Therefore, CPCB certified approximately 200 manufacturers of compostable plastics and issued certificates to them for developing the products.[45]

### 4.3 EPR implementation mechanism

The Indian EPR framework for plastic packaging was designed after considering the experiences of various other countries, consultations with stakeholders, and past Indian waste management experience.[46] Being a developing country, the EPR approach in India is different from other developed nations. It does not stick to a single model; rather, it allows many models to co-exist together, such as fee-based models, producer responsibility organizations (PROs), and EPR credits/certificates. Under the SUP management initiatives, EPR was entrusted to the plastic producers (P), importers (I), and brand owners (BO) (*viz.* PIBOs) handling SUPs as a packaging material. These PIBOs were mandated to fulfill their respective EPR targets and obligations through plastic waste processors (PWPs) engaged in recycling, waste-to-energy conversion, waste-to-oil conversion, co-processing in cement plants, and having industrial composting facilities.[47] Through EPR implementation, PIBOs and PWPs were brought under a centralized portal, developed and maintained by CPCB and used by concerned SPCBs of their respective state. Furthermore, EPR regulations covered the (a) reuse, (b) recycling, (c) use of recycled plastic content, and (d) end-of-life disposal in respect of SUP packaging materials. In order to achieve the desired goals, different targets and obligations were set for the PIBOs.[44]

**4.3.1 EPR targets.** In order to put the responsibility in a practical and achievable manner, the EPR targets for PIBOs were set in year-wise mode. Up to one year since inception, the EPR target was set to 25% of the total eligible quantity ($Q$). Similarly, targets were set to 70% and 100% of the total eligible quantity for the subsequent year and thereafter for each year, respectively.[44] Here, the total eligible quantity ($Q$) for producers, importers, and brand owners was calculated as per the formula shown in eqn (1)–(3).

$$\text{Producers (P): } Q = (A_P + B) - C \quad (1)$$

$$\text{Importers (I): } Q = (A_I + B) - C \quad (2)$$

$$\text{Brand owners (BOs): } Q = (A_{BO} + B) \quad (3)$$

where, $Q$ = eligible quantity (MT). $A_P$ = average weight of the plastic packaging material (category-wise) sold in the last 2 financial years. $A_I$ = average weight of all plastic packaging materials and/or plastic packaging of imported products (category-wise), imported and sold in the last 2 financial years. $A_{BO}$ =

average weight of the virgin plastic packaging material (category-wise) purchased and introduced in the market in the last 2 financial years. $B$ = average quantity of pre-consumer plastic packaging waste in the last two financial years. $C$ = annual quantity supplied to the brand owners in the previous financial year. These brand owners include online platforms/marketplaces and supermarkets/retail chains other than those, which are micro and small enterprises as per the criteria of the Ministry of MSMEs, GoI.

**4.3.2 EPR obligations.** In order to meet EPR targets, obligations were also put in place for PIBOs with respect to reuse, recycling, use of recycled plastic content, and end-of-life disposal. The detailed obligations are presented in Table S2.† Furthermore, EPR targets and obligations were exempted for entities which utilize plastic packaging having 100% biodegradability in the ambient environment besides leaving no traces of microplastics, chemical residues, and other trace elements.[44]

# 5. Digital interventions for assessment of SUP management strategies

Adoption and effective implementation of the initiatives are the keys to the success of any waste management program. To ensure this, monitoring and assessment of various activities of the plastic producers, importers, and brand owners become essential. In order to carry out monitoring activities for the SUP ban and EPR implementation in a smooth and transparent manner, the Govt. of India adopted digital interventions by developing online portals and apps.

## 5.1 SUP portal and the SUP grievance redressal app

The level of implementation and assessment of the impact of SUP management initiatives were monitored through regular inspection and surveillance activities. An Android-based SUP grievance redressal application (Fig. S1(a)†) and web portal (Fig. S1(b)†) were used for real-time inspection and data sharing by the stakeholders as well as for lodging complaints by the general public. This portal helps to show the status of users registered, daily reports on inspections allocated and completed, and complaints lodged by the stakeholders. These inspections were planned to be carried out in the entities of PIBOs and PWPs. Citizen participation was encouraged through this app and redressal of the complaints was made transparent and time-bound by the competent authorities of the respective states.

## 5.2 EPR portal

Nation-wide implementation of EPR was undeniably a bold decision, considering the vastness of the country and the existence of multiple players in the field of SUP packaging. Adequate steps were taken to smoothly manage various processes; however, it was also understood that it might be difficult for some PIBOs to meet the obligations given the lack of recycling infrastructure, negligible waste-to-energy plants, and poor economics. The uptake of plastic waste as raw material by industries, such as cement plants and thermal power plants is also not optimal. Moreover, globally it has also been experienced that big giants in the production sector often delay, distract, and try to suppress the execution of EPR through various tactics.[48] Prevalence of the informal sector in India for waste collection and recycling was another major challenge to deal with.[28] Therefore, effective monitoring and regulations were considered necessary to keep the practice of EPR functioning. In view of this, CPCB has developed an EPR portal (Fig. S2†). SPCBs/PCCs of the concerned states/union territories were entrusted with the responsibility of enforcing the PIBOs and PWPs operating in their respective states/union territories, for registration, manufacture of plastic products and multilayered packaging, processing and disposal of plastic wastes as per the EPR guidelines.

Additionally, in order to promote EPR implementation and environmental sustainability, the concept of EPR certificates was also introduced. Any PIBO which meets the obligation by fulfilling its designated target can use the surplus for (a) offsetting the previous year's shortfall, (b) carry forward for use in the succeeding year, and/or (c) sell it to any other PIBO. Furthermore, a PIBO can also meet its EPR obligation under any category by purchasing the surplus EPR certificates from another PIBO of the same category.[44]

# 6. Implications of SUP management initiatives

## 6.1 Positive implications

The most evident and significant positive implication would be the reduction in usage of SUPs. This will promote the plant-based products or biodegradable items, thus reducing plastic waste in the environment. Moreover, there would be many other positive outcomes, such as reduction in microplastics, promotion of circular and blue economy, *etc.*

**6.1.1 Reduction in the amount of microplastics in the environment.** Microplastics, which are small plastic particles in the size range of 1 μm to 5 mm,[49] originate either from primary sources or from secondary sources.[6,7] However, a major portion (*viz.* 69–81%) comes from secondary sources *i.e.* from the waste plastics accumulated in the environment.[50] Consideration of microplastics is imperative here as these particles can get transported to almost anywhere, being light-weight, small in size, and sturdy. Microplastics, one of the emerging contaminants, have been reported from nearly all the environmental matrices such as surface water, groundwater, marine water, snow/glaciers, soil, atmosphere, aquatic/terrestrial biotic species including humans, food items, and even from the remotest places on the earth such as Arctic and Antarctica.[51–60] Presence of these particles has also been detected in the human lungs, blood, saliva, breast milk, colon, stool, urine, and placental tissues indicating their entry into the human body through ingestion and inhalation.[61–68] Retaining the physico-chemical properties of plastics, these tiny particles are able to affect human health as well as the environment to a significant

 

extent.[8] Moreover, microplastics also have the potential to act as a vector of various inorganic and organic moieties.[7,69] It has also been shown that these particles are able to induce cytotoxic and genotoxic effects on humans as well as plant species.[70,71] Thus, SUP management initiatives will help to deal with the increasing microplastic pollution (Fig. 1).

**6.1.2 Promotion of circular economy and stricter compliance with PWM rules.** SUP management, esp. the EPR component, is expected to promote the adoption of circular economy. Under the EPR concept of reuse, recycling, and use of recycled plastic content; the manufacturers, processors, and other associated stakeholders will adopt the best practices and tend to redesign their technologies as well as patterns of packaging, thus enabling the circular mode of consumption.[72] Moreover, a sense of complying with plastic waste management rules will also develop owing to penalties imposed and the emergence of tough competition in the market in response to EPR rewards. As the EPR framework adopts the concept of EPR certificates for those fulfilling their designated targets, it would further lead to healthy competition among PIBOs, in-turn promoting more reuse and recycling. Compliance/surveillance checks of the PWPs by the pollution control regulators would further ensure proper collection and end-of-life disposal of plastic waste according to the relevant guidelines.

**6.1.3 Promotion of blue economy.** The blue economy refers to the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem.[73] The health of ocean ecosystem depends upon clean water, health of the marine organisms, and species diversity. It is established that oceans are the biggest receivers and accumulators of plastic and microplastic waste, as a minimum of 14 million tonnes of plastic waste ends up in the oceans every year,[74] which compromises the life and health of marine organisms. Moreover, subsequent conversion of plastic waste into microplastics further enhances the probability of plastic consumption by marine fauna. Therefore, minimizing plastic waste generation through the SUP ban and EPR will result in better survival conditions for organisms in the oceans, thus promoting the blue economy.

### 6.2 Negative implications

**6.2.1 Increase in deforestation and global temperature.** An effective ban on SUP items is expected to create immense pressure on the forest resources for supplying plant-based alternative materials, resulting in the forest loss. Between 1990 and 2020, the net decrease in global forest area was reported as 178 million hectares.[75] The increased pressure of providing alternative materials may further speed-up this rate, thereby, increasing the carbon loss and global greenhouse gas emissions as well. Apart from plant-based materials, glass is another material which is considered as an option, however, it is impractical as a substitute for plastics in most of the cases, and it would also be a reason for rise in global temperature, dust, and water pollution.[76]

A life-cycle assessment study comparing plastics and glass materials for food packaging, particularly milk, revealed that recycled polyethylene terephthalate (r-PET) had the lowest environmental impacts. This assessment considered factors such as global warming potential, stratospheric ozone depletion, terrestrial acidification, fossil resource scarcity, and water consumption.[76] The comparison regarding human carcinogenic toxicity impacts was specifically made in reference to thick steel caps often used in glass bottles in contrast to r-PET.[76] Therefore, replacing plastic items with glass having metallic components for packaging may not offer a sustainable long-term solution.[77]

**6.2.2 Rise in the market of bioplastics.** Bioplastics are often considered as one of the options for minimizing the usage of conventional plastics. Bioplastics, made up of plant sources (such as corn, sugarcane, cassava, and sugarbeet) are often suggested to be one of the suitable alternatives. Moreover, public generally relates biodegradable plastics with positive attributes.[78] However, these cannot be considered as the ultimate solution, because these plastics also do not degrade automatically in the ambient environment owing to the requirement of prolonged high temperature (50 °C).[77,79,80] In particular oceans, which are the biggest repositories of plastic waste,[81] do not have such a high temperature. Cellulose-based plastics are also unsustainable due to the high manufacturing cost.[82] Moreover, bioplastics have been proven to impact humans as well as other biotic species in a negative manner.[7,83] It has also been reported that bioplastics turn into microplastics at a faster rate compared to petrochemical-based plastics, which further enhances the exposure of biotic species to this emerging contaminant.[84,85] Nevertheless, studies also show that in order to attract environmentally conscious customers, big companies often market a number of 'alternative plastic items' under the false claim of 'biodegradable products' which is a clear case of greenwashing.[86]

## 7. Improvement opportunities in the current approach and need for a paradigm shift

Undoubtedly, the SUP management plan adopted by India is a welcome step for addressing the issue of plastic waste in the environment. Effective management of plastic waste is also the key to reduce the impacts of emerging pollutants, such as microplastics, which mostly result from the mismanagement of plastic waste.[7,50] However, there is still much scope in the current approach for advancement in various aspects.

### 7.1 Policy and regulatory aspects

In order to manage SUPs or any other type of plastic waste, it is necessary to realize that a major portion of modern-day plastics originates from one of the mandatory by-products of oil refineries which is further used as feedstock by the petrochemical industry for manufacturing of plastics and a variety of other products. Notably, 97–99% of the plastics are derived from fossil fuels globally.[87] Therefore, curtailing their production at the source might not be feasible in the current scenario. Considering this fact, the Indian SUP management framework has directed the petrochemical industries not to supply plastic raw materials for the production of banned SUP items, as a means of restricting supply at its source.[45] However, industries are permitted to supply

the same raw material for manufacturing all the other types of plastics. In this situation, once the supply is done, it is difficult to ensure that the raw material is not being used in SUP production. Secondly, under the SUP management initiatives, as of now EPR has been made applicable only for plastic packaging waste, while the policy for one of the biggest contributors of plastic fibers, *viz.* textile industries, is yet to be formalized. In the current scenario, the textile sector utilizes various synthetic fibers (polymers), the most common being polyester followed by nylon. During the textile manufacturing processes, plenty of these polymeric (micro)fibers are shed in the first wash itself[88] and thus become part of the effluent which may further contaminate the surface/ground water resources. According to an estimate, globally approx. 200 000–5,00 000 tonnes of polymeric microfibers emanating from textile industries are released every year in the marine environment.[89] In this aspect, the scope of EPR may be widened so that not only the packaging waste but the textile industry's microplastic waste may also be checked through the same set of regulations. Thirdly, while imposing the regulations for recycling, it is also needed to estimate as well as enhance the recycling capacity of the country in order to comprehend the viability and achievability of the set EPR targets. Fourth, there has to be a robust and efficient audit mechanism for evaluating the "achieved EPR targets" claimed by the industries (PIBOs). As of now, it is entirely based on self-disclosure made by PIBOs, while a counter-check mechanism is yet to be in place. Furthermore, information about the quantity of plastic/plastic waste material that is generated by the industries is not available in the public domain, which makes the target set for each industry difficult to grasp. Though the proposal of third-party audits has been suggested, it is supposed to take long for realization. Moreover, third party audits should be based upon some guiding principles such as balance of perspectives, fewer and priority-wise metrics for assessment, and scope of improvement.

Additionally, in order to promote the adoption of SUP ban and EPR implementation rules, innovative interventions may also be adopted such as incentives or subsidies to the PIBOs and/or plastic carry bag manufacturers giving better performance and fulfilling the set norms.

### 7.2 Technical aspects

Besides the ban on identified SUP items, the initiatives adopted also restrict the production of plastic carry bags with thickness less than 120 microns in order to minimize the littering effect. However, there is a lack of technical intervention to implement this restriction effectively. As on date, the thickness of plastic carry bags during production is regulated through gauze-control systems in most of the cases, in which approximately two-third are based on manual adjustment systems. Thus, there is no mechanistic barrier which can completely prohibit the production of carry bags less than 120 microns. In this respect, observance of the rules is only up to the awareness and responsibility of the manufacturers. Extensive surveillance and monitoring are the only tools which can prohibit the production of plastic bags of less than defined thickness. Therefore, research and development in this area for technological upgradation needs to be promoted followed by deliberations with instruments' manufacturers for execution.

### 7.3 Social and behavioral aspects

Another major void to fill in the current management plan is the interventions for extensive public awareness and behavioral change. Human behavioral practices are the core of any waste management program,[90] and so for SUP management as well. Studies have reported that management strategies relying solely upon policy and/or regulatory tools become ineffective in the long run.[91,92] Therefore, inculcation of behavior change practices, awareness, and willingness need to be developed among the public through citizen participation. Moreover, it has also been seen that mere knowledge and awareness may not suffice for the desired purpose rather constant encouragement, influence, and enabling physical environment may help to promote the adoption of behaviors intending to minimize the usage of SUPs.[93] Hence, community involvement is not only necessary but a mandatory step along with the participation of multiple stakeholders, such as governments, non-governmental organizations, regulators, private practitioners, *etc.*

As SUP management initiatives have just been implemented, post-implementation complications and loopholes need to be well-documented. A substantial review mechanism of all the experiences has to be established for setting futuristic targets. Nevertheless, from a broader perspective, it may be said that dependency on plastic-based products needs to be reduced for being cheap and convenient (except the scenarios where plastic use is indispensable). Current estimates indicate that India's plastic production lags behind plastic consumption and therefore, this gap is filled by importing plastics from various countries, such as China, Japan, and Germany.[94] In order to fill this gap, and further reduce plastic consumption, a major paradigm shift is essential. Moreover, taking note of the rich Indian traditional practices, this shift seems feasible as well as adaptable. In primitive Indian societies, bamboo tubes, coconut shells, shells of shellfish, *etc.* were commonly used for holding solid materials, while some of the commodities were used to be wrapped in bamboo/lotus leaves. Traditional earthen pots were also very common for storing the liquid/semi-liquid, and solid food items. The use of such traditional packaging items not only tends to reduce plastic consumption and plastic waste generation, rather these also help in lessening human exposure to various chemicals/additives which are generally found in plastics, such as phthalates, bisphenol A (BPA), *etc.*[95] In light of this, some manufactures and plastic packaging industries have started to adopt substitute materials. For example, use of bamboo is now often seen in products such as cutlery, spoons, plates, bowls, *etc.* Although use of these traditional materials cannot replace plastics completely, a substantial reduction can certainly be expected. Behavioral and lifestyle change is also solicited to bring down the consumptive pattern and promote sustainability. Combined efforts at the regulatory level as well as individual level will, therefore, help to minimize plastic waste generation to a significant extent.

# 8. Future perspectives

In order to promote environmental sustainability, reduction in plastic/microplastic waste generation and adoption of appropriate mechanisms for plastic waste management are inevitable. Therefore, elimination of SUPs and thereby its waste is prioritized in various countries across the globe. As a growing economy, India has also adopted several management initiatives in a step-wise manner, based on the need of the hour and the technical knowhow available at the present time. In this sequence, realizing the increasing burden of plastic waste in the environment and its negative consequences (in the form of microplastics), India has targeted stopping the manufacturing, sale, and use of a number of SUP items besides setting up an EPR framework for efficiently dealing with the SUP packaging waste, in 2022. Keeping in mind the vastness and variability of geography as well as demography of the country, the approach adopted is undoubtedly appreciable.

However, from the environmental sustainability point of view; all the countries worldwide should realize that future approaches need to be formulated in a much more holistic manner. As the center point of "plastic management" radiates towards the policymakers, regulators, associated industries, as well as consumers, these all are supposed to bring significant changes in their approaches to address the issue of plastic waste and its negative consequences.

## 8.1 Policymakers

While dealing with plastic waste and its associated issues, policymakers often focus on some specific objective, rather than facing the problem in a holistic manner. Though reduction of plastic waste is need of the hour, the approach leading towards the ban of various plastic items overlooks many other factors of environmental sustainability. For example, studies have shown that upon comparing the life cycle impact assessment of single-use plastics with single-use glass or metal, the latter comes ahead in most of the environmental impact categories measured, such as greenhouse gas emission, energy use, *etc.*[76] Similarly, compostable plastics are often suggested as the suitable alternatives of petro-based plastics. However, this notion is superficially developed without considering all the dimensions of the environmental impacts. As the process of composting results in a significant release of carbon into the atmosphere, it may have a worse energy and greenhouse gas emission profile.[77] Therefore, for evaluating the impacts any particular product/process poses on the environment, a holistic life cycle assessment approach is recommended in future policy frameworks. The policymakers need to be extremely cautious in their planning and formulation, so that the solution of one problem should not lead to a set of other problems. In this respect, promotion of research and development is equally significant.

Furthermore, a transparent approach with clear objectives and execution mechanism along with well-thought planning to address the consequences is always better to accommodate the updates arising out of emerging research studies. Frequent amendments in methodologies often create confusion and reflect the unpreparedness in dealing with the matter. Therefore, a precise and comprehensive policy document detailing all the aspects should be placed before the public to avoid misunderstandings and overlapping of the facts.

## 8.2 Regulators

Once the policy is framed and comes into effect, compliance with the rules depends only upon the manufacturers, suppliers, sellers, and users. Therefore, enforcement becomes inevitable to expedite and ensure positive actions in order to abide by the set standards. For example, in order to regulate the ban and impose carry bag thickness restrictions, regulators play an important role, esp. in scenarios where regulations are technology-neutral, and mechanistic barriers to prohibit unlawful production are lacking. In this aspect, the possibility of remote surveillance system, online thickness gauge meters, *etc.* may be explored to monitor the appropriate usage of plastic raw materials and the process of plastic carry bag manufacturing of defined thickness. Experience may be gained from the successful implementation of remote surveillance system for continuous effluent and emission monitoring installed for highly polluting industrial sectors[96] as well as for surface water quality assessment in India.[97]

For EPR implementation as well, regulators play a major role specifically in controlling the informal sector.[28] Strict regulation at the top level would lead to better compliance of the rules by PIBOs, which would trickle down leading to better collection and recycling practices for SUP waste (Fig. 5). On the other hand, for restricting the end-users from using banned SUP items, provision may be made for imposing the instantaneous penalties by different regulatory agencies in a cohesive manner (such as police, ULB personnel, pollution control board officials, *etc.*). It might encourage the end-users to change their attitude from voluntary acceptance to mandatory acceptance of the rules.

## 8.3 Plastic producers/manufacturers/brand owners/waste processors

Plastic raw material producers/manufacturers/waste processors are the main pillars of the plastic industry. While policymakers and regulators can draft and enforce the policies, it is the plastic industry which has to abide by these policies in a realistic and transparent manner. Producers, manufacturers, importers, and other associated entities should follow the government policies not because of the fear of penalties imposed upon violation, but for having an environmentally sustainable profit-making business. Social responsibility towards citizens as well as the environment should be adopted as a proactive initiative by these sectors. These sectors are the key to implement the technological interventions and therefore, responsibility to demonstrate the positive visible impact in society belongs to them.

For example, in the Indian context, plastic waste processors run their business by turning discarded plastic materials into reusable products, thus paying zero cost for the raw material. With the advent of the EPR framework for SUP packaging waste,

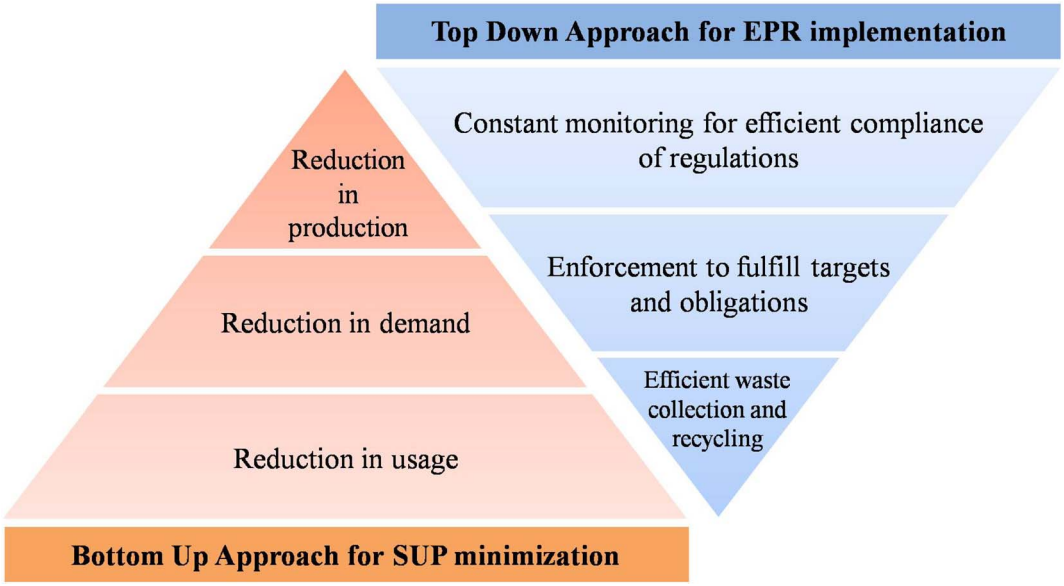


Fig. 5 Approach for successful SUP management.

these waste processors have received promotional benefits, as it has been made mandatory for PIBOs to fulfill their obligations and targets through PWPs. These processors rely on various waste collection centers situated across the country to collect plastic waste. In these centers, waste is supplied by the local rag-pickers which largely come under the informal sector. These rag-pickers are neither trained nor equipped enough to collect the waste in a safe and hygienic manner, resulting in their exposure to various poisonous gases and other hazardous chemicals. Therefore, waste processors may extend their benefits to the people working in informal sectors. Examples may be quoted from Europe and Sweden which have set a model of successfully managing waste through the waste processors. For the successful execution of EPR, mainstreaming in the informal sector is, therefore essential through the formalization of the informal sector, and regulation and standardization of safety and wages for people working in this sector.

### 8.4 Consumers

Consumers or end-users also play a vital role in plastic waste management, as these are the main drivers of the overall plastic demand and supply chain. Therefore, accountability for the responsible utilization and disposal of plastics lies with the consumers. Any plastic recycling technology is driven by the availability of segregated, clean, and dried plastic waste and therefore, consumers' roles are pivotal. Furthermore, a significant fraction of the overall SUP-based waste is generated due to the overconsumption of resources. Moreover, the preference for plastic materials over traditional ones gives consumers a false sense of progression and development. This attitude needs to be changed and mindful consumption is required to be practiced. Especially, in a country like India having rich traditional practices, innovative business models should be promoted which can introduce eco-friendly alternatives to SUPs. Reduction in the demand for plastic items would certainly trickle up ultimately leading to the reduction in production. Hence, a 'bottom-up approach' is required to be adopted for SUP minimization.

In summary, effective management of single-use plastics and minimization of microplastics in the environment requires concerted efforts of policymakers, regulators, industrial establishments, consumers, as well as entrepreneurs. The bottom-up approach for reduction in SUP production and the top-down approach for effective EPR implementation are vital for the successful management of plastic waste. Moreover, management efforts need to be inclined towards evaluating the life cycle assessment of the product, reduction of energy and material intensity, and behavioral change practices of the individuals.

## Abbreviations

| | |
|---|---|
| BBC | British Broadcasting Corporation |
| CIEL | Centre for International Environmental Law |
| CNBC | Consumer News and Business Channel |
| CPCB | Central Pollution Control Board |
| EEA | European Environment Agency |
| EPR | Extended producer responsibility |
| EU | European Union |
| GoI | Government of India |
| IUCN | International Union for Conservation of Nature |
| MoEF&CC | Ministry of Environment, Forest and Climate Change |
| MSMEs | Micro, Small and Medium Enterprises |
| MT | Million tonnes |
| PCCs | Pollution Control Committees |
| PIBOs | Producers, Importers, and Brand Owners |
| POPs | Persistent Organic Pollutants |
| PWM | Plastic Waste Management |

| | |
|---|---|
| PWPs | Plastic Waste Processors |
| SDGs | Sustainable Development Goals |
| SPCBs | State Pollution Control Boards |
| SUPs | Single-use plastics |
| ULBs | Urban Local Bodies |
| UN | United Nations |
| UNEP | United Nations Environment Programme |
| WEF | World Economic Forum |
| WITS | World Integrated Trade Solution |
| WRI | World Resources Institute |

## Data availability

All the data are included in this manuscript or its ESI.†

## Author contributions

Surya Singh: conceptualization; data curation; investigation; methodology; visualization; writing – original draft; writing – review & editing. Mrinal Kanti Biswas: data curation; investigation; visualization; writing – review & editing.

## Conflicts of interest

There are no conflicts to declare.

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