December 2020

PLASTIC WASTE MANAGEMENT
Turning Challenges Into Opportunities

THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future

Authors
Suneel Pandey, Senior Fellow and Director, Environment & Waste Management Division, TERI

Sourabh Manuja, Fellow, Centre for Waste Management, Environment & Waste Management Division, TERI

Advisor
Dr Syamal Kumar Sarkar, Distinguished Fellow & Program Director, TERI

Suggested Format for Citation
Pandey,S. and Manuja,S. 2020. Plastic Waste Management-Turning Challenges into Opportunities. New Delhi: The Energy and Resources Institute

TERI Press
Abhas Mukherjee
Rajiv Sharma

Published by

The Energy and Resources Institute, New Delhi, India

FOR MORE INFORMATION

Project monitoring cell, The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi 110 003, India | Tel.: +91 11 2468 2100 or 2468 2111 | Fax: +91 11 2468 2144 or 2468 2145
Email: pmc@teri.res.in | Web: www.teriin.org

CONTENTS

1. PLASTIC WASTE—HOW BIG IS THE ISSUE?

Plastics not only are enduring, lightweight and available at low prices, but also have very good thermal and electrical insulation properties. The versatile properties of various plastic polymers—being water resistant, non-porous, ductile and malleable—make them suitable for manufacturing a wide range of products that also bring medical and technological advances in our modern society. We have seen how plastics proved beneficial in making personal protective equipment (PPE) during the COVID-19 outbreak around the world. Sectors such as food production and preservation, electronics, packaging, textile and transportation are highly dependent on plastics in our present day life. Plastic packaging has also facilitated ease in transportation of a wide range of food, beverages, and other goods to far-off locations, which was earlier not possible. The light weight of plastics makes transportation economical and its barrier properties help in increasing the shelf life of food items, thus leading to reduction in food waste. As a result, plastics are gradually displacing other packaging materials.

Increasing Plastic Demand

Statistics reveal that plastic production around the world has increased from 1.5 million tonne per year as reported in 1950 to 359 million tonne per year in 2018 (Garside 2019). About 40% of the global plastic is consumed by the packaging industry with the combination of rigid and flexible plastics (Trade Promotion Council of India 2019).

India consumed around 18.45 million tonne of plastics in 2018–19 (PlastIndia, 2019), and was expected to grow to 22 million tonnes by end of this decade (Federation of Indian chambers of Commerce and Industry, 2017). In India, total plastics consumed for packaging in 2018 was around 59%, 42% consumption was for flexible and 17% consumption was for rigid packaging (PlastIndia, 2019). As the number of middle-class consumers increases in the country and rising GDP, the Indian flexible packaging market is further expected to grow at a compound annual growth rate (CAGR) of ~10% from 2018 to 2023 and reach INR ~640.38 billion by 2023 (Netscribes (India) Pvt Ltd, 2019). Consumption of plastic also varies in different regions of the country. Western India has traditionally been the largest consumer of plastics accounting for almost 47% of the total consumption whereas Northern, Eastern, and Southern regions consume 23%, 21%, and 9%, respectively (FICCI, 2014).

Increasing Plastic Waste

One of the consequences of using excess plastics is generation of plastic waste, especially through products which are of single use. The trends of waste generation over the past years showcase that by 2025, waste generation from lower-middle income countries will increase drastically by about 159% from the 2010 levels. However, over the same duration waste generations from upper middle income countries will grow by about 48% only (Hoornweg and Bhada-Tata 2012). The World Bank has also reported that the total waste generation in South Asian region is expected to double by 2050, out of which plastics constitute about 57% at present (Kaza, Yao, Bhada-Tata, et al. 2018).

> In India, the average plastic waste comprises of high-density polyethylene (HDPE)/low-density polyethylene (LDPE) (66.91%), polyethylene terephthalate (PET) (8.66%), polyvinyl chloride (PVC) (4.14%), polypropylene (PP) (9.9%), polystyrene (PS) (4.77%), and others (6.43%) (Central Pollution Control Board, 2015)

The Central Pollution Control Board (CPCB) estimated that in 2017, Indian cities generated about 9.47 million tonne of plastic waste. This was because roughly 70% of the plastic packaging products are converted to waste in a short span of time (CPCB 2018, MoHUA2019). Though India's commodity plastic consumption was only 13.6 kg per capita per year in 2018–19 against the world average of 30 kg per capita per year (PlastIndia 2019), plastic waste generation is expected to increase to 31.4 million tonne by 2031 and further to 55 million tonne by 2041 (Statista 2019), thus showcasing an urgent need to address the concerns from the growing plastic waste in our country.

2. ISSUES AND CHALLENGES WITH GROWING PLASTIC WASTE

The invention of plastics came as a blessing, but single-use plastics or those uneconomical for collection and recycle,[1] in association with lack of awareness and poor solid waste management in cities, has resulted into its littering and finally reaching marine environment from land-based sources. Globally since 1950, nearly 8.3 billion tonne of virgin plastics have been produced and 6.3 billion tonne of plastic waste have been generated, of which 9% has been recycled, 12% incinerated, and 79% accumulated in landfills or abandoned in the environment (Geyer, Jambeck, and Law 2017). Unlike organic waste, plastics can take hundreds of years to decompose in nature (New Hampshire Department of Environmental Services n.d.). Most plastics do not biodegrade, and instead, they defragment as micro plastics (United Nations Environment Programme 2018).

Globally, the total packaging waste generated in 2013 was 78 million tonne. It is estimated that only 14% of this plastic was recycled. Figure 1 represents the global plastic waste management scenario in 2013 to further justify the impact that mismanaged plastics pose to our environment (World Economic Forum 2016). However, some sources note 18% as global recycling rates too (Jambeck, Geyer, and Law 2017).

Recycling Issues

Unlike glass and aluminium, which can be recycled any number of times without any loss of materials, plastics are often downcycled and even lost in the recycling process (National Geograpic Society 2018, OurAukland2016). Further, plastic recycling rates vary significantly across different countries and polymer types (OECD 2018).

> Total plastics entering marine environment was estimated to be 12.2 million tonne in 2015. Out of this, 94% was estimated to have gone onto sea floors, 1% floating on ocean surface, and 5% remaining onto beaches. When sources of marine plastic pollution were assessed, 4.1% originated from land-based inland activities, 73.77% originated through land-based coastal activities, 14.34% originated from sea- based activites (66% from fishing litter and 34% from shipping litter), and 7.79% orginated from primary microplastics (Eunomia 2016)

Though, plastics can be upcycled through chemical recycling routes whereby it can be turned back to monomer that can be polymerized, some hindrances still exist, including energy cost, de-polymerization selectivity, de-polymerizability, and performance trade-offs, which need to be addressed (Tang, *et al*. 2018).

Proper management of plastic wastes in an environment-friendly manner, routing them into circular economy loop, still remains a challenge to be addressed.

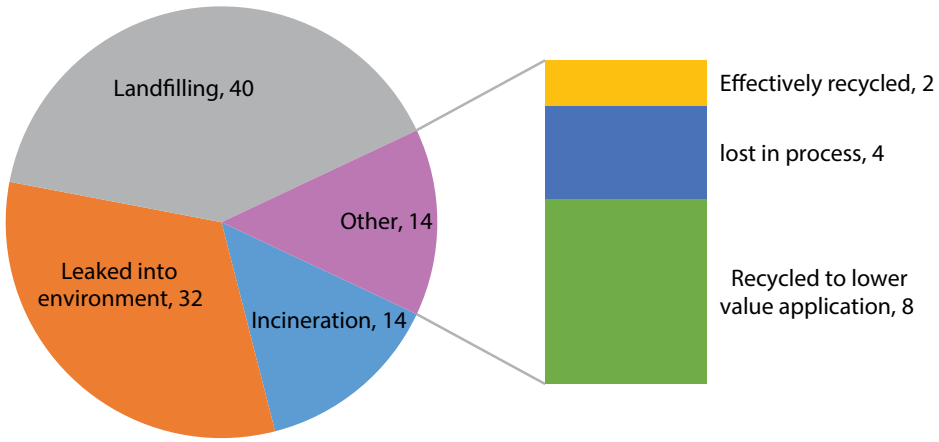

Figure 1: Global packaging waste management in 2013 (World Economic Forum, 2016)

[1] Also referred to as single-use plastics, which are not planned, designed, or sold with circular economy approach.

Environmental Challenges

The CPCB reports that 94% of the plastics that we consume are recyclable (CPCB 2018). Recent reports suggest that of the 15.71 million tonne of plastics we consumed in 2018–19, about 42% entered into waste stream within 1 year and 12.73% within 5 years, the remaining being long-term usage plastics. Of the 8.6 million tonne of waste plastics, about 70% gets recycled (PlastIndia Foundation 2019). The uncollected and non-recycled plastics are either dumped in terrestrial or aquatic environment or are openly burnt in cities, posing environmental challenges. It is also estimated that India was the 12th largest contributor to marine litter, and contributed 0.09–0.24 million tonne of plastic marine debris in 2010 (Jambeck, Geyer, and Law 2017).

Studies by the Ocean Conservancy and the UNEP have also established that on a global scale, 80% of litter in oceans originates from land-based activities (Jeftic, Sheavly, and Adler 2009). About 90% of this comprises plastic waste—mostly single-use plastic (Griffin, Wilkins, and Bowen 2019).

Plastics in the environment degrade into particles in due course of time. These particles are categorized based on their size, shape, and type of material from which they are made of. Macro-plastic products, whole or in fragments, are large items that can be seen by the naked eye and include plastic bags, bottles, cups, lids, straws, containers, and fishing nets. Microplastics refer to tiny plastic fragments less than around 5 millimetres in diameter, and nanoplastics are extremely small microplastics (<1 micron size). Microplastics mostly enter the environment through vehicle tyres dust, pallet spells, textiles, building paints, road paints, cosmetics, and marine paints (Eunomia 2016). Macroplastics have been shown to cause physical harm to wildlife. A lot of harm stems from the physical effects of plastics when animals eat macro-plastics, which then block their digestive systems. Wildlife can also get entangled in macro-plastics that can prevent them from moving, feeding, or breeding. Macro-plastics are a threat to marine ecosystems because oceans and seas, the final reservoir for flowing waters, also carry plastic trash. When microplastics enter the oceans, these cannot be filtered out. The plastic marine debris affects adversely about 267 species globally, including 86% of sea turtles, 44% of seabirds, and 43% of marine mammals (Agency 2017). Figure 2 highlights other additional impact of plastic waste on terrestrial and marine environment. It is further estimated that in 2014, there was 1 kg plastic in the ocean for every 5 kg of fish, and by 2050 there will be more plastic than fish (MoHUA 2019).

There is evidence that the toxic chemicals added during the manufacture of plastic (additives) transfer to animal tissue, eventually entering the human food chain. Styrofoam products, which contain carcinogenic chemicals such as styrene and benzene, are highly toxic if ingested, damaging the nervous systems, lungs, and reproductive organs

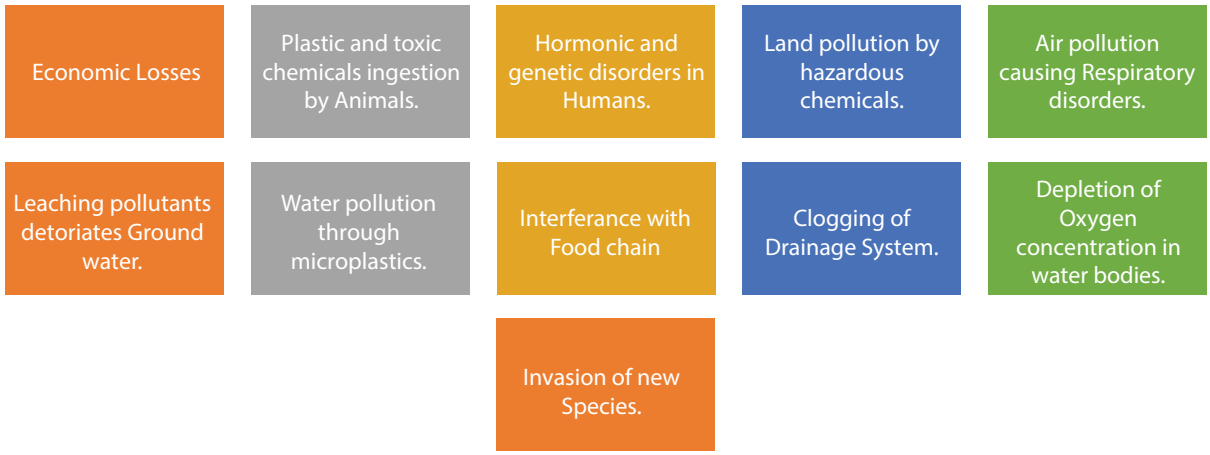

Figure 2: Impacts of plastic waste

(UNEP 2018). Disposing MSW-containing plastics by indiscriminate burning releases toxic gases such as dioxins, furans, mercury, and polychlorinated biphenyls into the atmosphere. If PVCs are burnt with MSW they liberate hazardous halogens and pollute air, the impact of which is climate change. Thus, burning plastics under uncontrolled conditions pose a threat to biodiversity, vegetation, and environment. Indiscriminate burning may also increase risks to cardiovascular diseases, aggravate respiratory ailments such as asthma and nausea or headache, and damage the nervous system (Verma, et al. 2016).

Irrespective of the positive aspects of using plastic products, the significant negative impact of mismanaged plastic waste, especially from single-use plastic products that cannot be ignored. The plastics' share of global oil consumption and carbon budget have been 6% and 1%, respectively in 2012, which are further expected to reach 20% and 15%, respectively by 2050 (Rudolph, Kiesel, and Aumnate 2017) (Hopewell, Dvorak, and Kosior 2009).Thus, showcasing that there are strong environmental and economic reasons (due to damage) to combat the threats raised by growing mismanaged plastics.

3. REGULATIONS ON PLASTIC WASTE MANAGEMENT

Since 2014, global policy actions directed towards plastic waste have tremendously increased, implementing legislations and actions to curb consumption of single-use plastics. Unfortunately, with more than one-fourth of the waste dumped openly and many formal disposal sites managed improperly, plastic litter is increasing. Even when plastic waste is collected, many countries lack the capacity to process the waste (Kaza, Yao, Bhada-Tata, *et al.* 2018).

Bans on Single-Use Plastics

In view of the above, more than 60 countries have introduced ban or levies on single-use plastics like plastic bags and foamed plastic products (United Nations Environment Programme 2018). However, till date no robust conclusions on

Figure 3: Cattles feeding on municipal solid waste often consume food discarded in plastic bags

the environmental impact of these bans and levies have been drawn. As in half of the cases, information about their impact is lacking, either because of being implemented recently, or being monitored inadequately. In the remaining, about 30% of countries have registered drastic drops in the consumption of plastic bags within the first year and the remaining 20% of countries have reported little to no change, either due to lack of enforcement or affordable alternatives. These bans in some cases have increased environmental problems, due to subsequent cases of smuggling and the rise of plastic bags being black marketed or switching to thicker plastic bags that are not covered by the ban (United Nations Environment Programme 2018).

Experts believe that though the ban on single-use plastics could be an immediate solution to the problem, but will have a long-term degrading effect on the economy, particularly on the local plastic industry sector. Bans can also lead to that end of plastic products that have no end of life solutions for safe disposal, if these are smuggled into the country (Godfrey 2019).

It is also important to note that change in consumer behaviour to avoid littering and promoting reuse of materials is very important. Even compostable plastics, which may biodegrade (decompose) and litter less, can be the worst choice in terms of climate impact, acidification, eutrophication, and toxic emissions (UNEP 2020).

Regulations on Plastic Waste Management in India

In India, the Ministry of Environment, Forest and Climate Change (MoEFCC) notified the most recent Plastic Waste Management (PWM) Rules on March 18, 2016 and amendment on March 27, 2018. These rules are applicable to every waste generator, local body, gram panchayat, manufacturer, importer, and producer. The rules restrict the use of carry bags and plastic sheets less than 50 micron thickness, restrict supply of raw materials (plastics) to unregistered units, stipulate guidelines (IS code) of recycling plastics, and stipulate standards (IS code) for compostable carry bags. The PWM Rules also encourage the use of non-recyclable plastic waste in road construction or for energy recovery in cement kilns or for waste to oil, etc.

The regulations require urban local bodies to develop and set up infrastructure for segregation, collection, storage, transportation, processing and disposal of plastic waste—recyclable plastics to be channelized to registered plastic waste recyclers. As per the regulation, urban local bodies are also responsible for creating awareness among all stakeholders about their responsibilities and ensure that no plastics are openly burnt.

The rules also require producers, importers, and brand owners who introduce the products in market to collect back the plastic waste generated due to their products through the extended producer responsibility (EPR) mechanism (MoEFCC 2016). However, proper implementation and monitoring of these rules are still not being done in many parts of the country, leading to plastic waste becoming a littering problem.

Challenges in Plastic Waste Management

Studies reveal that diverting waste from landfills towards recycling can create six times more jobs (LeBlanc 2019), estimating that the management of mismanaged plastics, which are currently not recycled in India, could create about USD 2 billion income with 1.4 million additional jobs (Lewis, Retamal, and Atherton 2018). But to manage the mismanaged plastics, a number of challenges will have to be addressed. These are as follows:

- Challenges due to intermittent supply of feedstock from the informal waste sector for recycling.
- Lack of awareness, technical knowledge, and limited finances.
- Lack of accountability of waste generators, including urban local bodies.
- Inadequate implementation of Plastic Waste Management Rules and EPR policy with consistent monitoring, review, and verification mechanism.

- Issue of taxes (goods and services tax) on recycled plastic pellets and products.

4. POSSIBLE SOLUTIONS TO MANAGE PLASTICS

If we look into the Indian scenario— alternatives to plastics do exist but are not commonly opted by common man, because besides being expensive, these are often functionally inefficient. Plastics do get recycled at higher rates in India than in other parts of the world but plastic waste still leaks out of the circular economy loop.

"The issue lies in management of plastics and not in plastics themselves."

The section below provides recommendations for addressing situation arising out of mismanaged plastic waste.

Alternate Choices

Alternatives such as paper/metal straws for plastic straws, cotton paper or jute bags for LDPE or PP bags, wooden cutleries for plastic ones, bamboo brushes for plastic toothbrushes, do exist. Looking further, paper bags can be recycled maximum up to 4 times and they generate 7 times more waste than recyclable plastic bags. It also has 2–3 times more global warming potential than plastics bags. Glass is heavy. For instance, for packaging 100 kL of milk, plastic packaging required is 400 kg, in comparison to 45,400 kg of glass. Further, manufacturing, packaging and distribution of milk through these glass containers will require 13.23 times more energy than plastic packaging, if we consider 100% recycling of both the products. For instance, 45,400 kg of glass will require 501.67 Gj of energy, compared to only 4.56 Gj needed for 400 kg of plastics. Similarly, 100,000 tonne of wheat flour requires 680 tonne of plastic packaging, compared to 1960 tonne of jute bags. Further, production and manufacturing of this jute packaging will require only 9.8% more energy compared to plastic packaging. But, while distributing wheat due to high weight, the energy required by jute will also be high. If we consider replacing plastic cans with tin, for packing 1 million tonne of 'lube oil', 36.36% more raw material will be required. Similarly, 18.91% more energy will be required for tin can raw material production, manufacturing, distributing, and recycling (100%) compared to HDPE plastic cans (FICCI 2015). Hence, these alternatives, though being eco-friendly, are not always affordable and sustainable choices.

Versatile properties of plastic products help us deliver more with less. As plastics are light in weight, they have high product to packaging ratio. This helps bringing down fuel consumption and the overall transportation cost (FICCI 2016). This indicates that the issue lies in management of plastics and not in plastics themselves.

To replace plastics, we will require materials which are even better and can easily be upscaled for commercial applications. We have seen how plastics came out as a hero during the COVID-19 outbreak in manufacturing PPEs or providing packaging for products, which are safe and hygienic. There have been researches who have explored the possibilities of replacing plastics with compostable plastics from substrates, such as poly lactic acid (PLAs). Several studies have indicated that PLAs do not have lower environmental impacts for most environmental indicators, when compared to alternatives and other plastics (Gibbens 2018, CPCB 2018). Compostable plastics also have certain disadvantages in terms of poor melting properties (requiring industrial composting), mechanical brittleness, low heat resistance and slow crystallization, thus requiring co-polymerization. Now with these additives, it was also found that bio-based plastics including PLA showed no degradation over a year at ambient temperature of 25°C in sea water (Tobias, Vçlker, Kramm, et al. 2019), thus indicating no difference on impact as marine litter, when swallowed by aquatic organisms (National Geographic 2018).

So, the solution to manage the problem is to have sustainable alterative choices, based on the principle of waste management hierarchy. With the concept of 4Rs (Reduce, Reuse, Recycle, and Recover), we must try to implement policies which focus on reduction of waste from societies.

These include using our own water bottles and water kiosks, own reusable shopping bags/baskets rather than paper bags (which have one time use), establishing reusable utensil banks to be rented for public functions, own vessels to bring in milk, among others.

Options could also be explored to use waste products as packaging materials, to reduce environmental burdens. Such options include using agriculture residues as alternate packaging, which can even help reduce environmental burden as well as substitute plastics. Although, these should further have to be linked to organic waste management facilities in the city.

Strengthened Waste Management Systems and Awareness

Recycling of materials in most developing countries, including India, is driven by economy, which in turn relies on the amount of energy it takes to segregate, transport, and recycle. Around 30–40% of plastics is let into the environment either as mixed waste, or it is economically not feasible to segregate and collect the lightweight materials for further recycling. Although, regulations in India are in place for implementing segregated collection of plastic waste and recycling, their strict implementation and monitoring is lacking. Establishing material recovery facilities can prove beneficial in getting more plastics routed to recycling (along with other recyclables, considering PWM Rules and Solid Waste Management Rules of 2016 together). There is also a need to upcycle plastic waste rather than downcycle it.[2] Re Tuna mall in Sweden, whereby waste products are upcycled to make new products, is a good example of upcycling plastic waste (Shaw 2019). As a last resort, cities should collaborate to work in the direction whereby the nonrecyclable plastics are used for road making with bitumen and, thereafter, recovered for energy via cement plants, using them as alternate fuels. Further, for recovering energy, industry, and local governments will have to work together to arrive at mechanisms to obtain the desired quality of alternate fuels to replace fossil fuels as per "Guidelines on usage of refuse derived fuel in various industries" laid down by MoHUA.

The waste management systems need to be strengthened, starting from awareness among various stakeholders, ranging from waste generators, collectors including city managers, recyclers, to consumers for recycled/upcycled products. This will not only create more demand among the consumers for recycled products but also motivate generators and collectors to keep plastic waste (resources) separate, making recycling of light weight products feasible.

> In India, small towns like Ambikapur in the state of Chhattisgarh has set examples for other urban areas by showcasing appropriate management of waste and segregating waste into 156 separate categories for putting them back to circular economy loop, involving community, marginalized women, and waste pickers.

Like Japan, India will also have to seek support from policy interventions and instruments that can help catalyse this circular economy approach. However, policy instruments have to be backed up with strong monitoring and enforcement mechanisms to oversee their complete implementation. This is the only way we can decouple our economic growth and waste disposal rate and also increase our Recycle Recovery Rates and dependency on natural resources. The Government of India will also have to ensure that principle of 'one India - one policy' is put in place and such mechanisms are implemented on full scale as early as possible.

Economic Relevance of the Plastic Sector

It is reported that plastic manufacturing sector in India provides employment to more than 1.2 million people, including both direct and indirect employees (Plastindia Foundation 2018, FICCI 2017) and during 2016–17, with about 3500 organized and 4000 unorganized recycling units, the labour

[2] also referred to as single-use plastics, which are not planned, designed, or sold with circular economy approach. also known as creative reuse, is the process of transforming by-products, waste materials, useless, or unwanted products into new materials or products perceived to be of greater quality, such as artistic value or environmental value.

involved in the recycling of the plastic waste (including the waste pickers) was more than 1 million. Overall, 5.5 million tonne of plastics was reported to be recycled (Plastindia Foundation 2018), thus indicating importance of the sector in the economic growth of India.

Strengthening Reverse Logistics Chain

Interventions to strengthen reverse logistics chain, and mainstreaming informal recycling chains (leveraging their existing networks) are also required. Merely increasing the thickness of plastic bags to more than 50 microns and issuing IS codes for compostable plastic carry bags will not address the global issue associated with plastic litter. EPR through Producer Responsibility Organisations (PROs) that help delivering the produced plastic waste back to the recycling chain needs to be strengthened and appropriately monitored.

> Environmental impact of any disposed plastic bags is a characteristic of its weight and material. Impact will be directly proportional to its weight unless a bag is reused more number times or for carrying more goods (UNEP, 2020)

Further, there is a strong need that trade-off between functionality and design for recyclability are appropriately balanced. Lighter products may lessen the environmental impact, but may escape the recycling loop. There is a need to have better engineered packaging materials as well as sound management systems to refrain plastics from leaking out of the recycling loop.

5. RECOMMENDATIONS

Given the country's socio-economic standing, the problems of plastic waste management can be turned into opportunities. This paper suggests the following recommendations for this:

1. Sustainable alternative choices based on the principle of 4Rs (Reduce, Reuse, Recycle, and Recover): Focus should be on implementing policies which help reduce waste from societies, like fewer and reusable packaging, buyback schemes to put back plastics into circular economy loops, and initiatives like agriculture residues as alternate packaging, that target reduction of stubble burning as well as plastics in the environment. We also need to further research and development to develop products which have similar barrier properties and are easily biodegradable under standard temperature and pressures and leave lesser water and carbon footprint with lifecycle assessment (LCA) approach. It will be, however, equally important to develop ways to tackle the newly developed products. This would, however, require regulation supporting incentive structure to make alternatives affordable for large-scale adoption and use. The prices can gradually be expected to come down once the economy-of-scale is achieved. This will be in line with requirements of SDG 12 (sustainable consumption and production). The Indian government can target implementing these strategies in phases, with the first phase targeting products, which are major contributors to marine litter.
2. Simply banning single-use plastics might not result in completely eliminating plastic waste challenges from society: Strengthening the waste management practices (segregated collection and processing waste through material recovery facilities in cities) can help put plastic waste back to circular economy loop. The manufacturers and producers operating in India have agreed under the EPR mandate to collect the equivalent amount of plastic waste which they put out in market on annual basis. The companies based on their recycling targets can be issued plastic recycling credits which they can trade in future. This will also ensure collection of difficult-to-collect low- value and difficult-to-recycle products like multi-layer plastics. There is also a need that packaging

for specific product is designed in a manner that it is easy to recycle and has standard characteristics (via BIS standards).

3. Upcycling the plastic waste, rather than downcycling, help obtain sustainability in management: This would need substantial design and functional improvement to make these alternatives viable. As a last resort, cities should work towards using non-recyclable plastics to make roads or recover energy from non-reusable and non-recyclable plastics, using them as alternate fuels to replace fossil fuel.
4. Appropriate and effective awareness among various stakeholders ranging from waste generators, collectors including city managers, recyclers, till consumers for recycled/upcycled products to be strengthened: A design benchmark will have to be developed by the Bureau of Indian Standards (BIS) for quality control and creating market for products produced from recycled feedstock.[3]
5. Interventions are required for strengthening reverse logistics chain, and mainstreaming informal recycling with formal recycling as per the circular economy approach: It can be achieved through PROs funded by organizations who can provide incentives to informal sector for collection of low-value plastics and tie up with existing recycling infrastructure companies to produce products with higher economic potential. Local bodies and state governments will also have to play a vital role in establishing infrastructure that can help with consistent supply of raw materials to recyclers and also establish recycling units closer to the cities (to reduce energy involved in transportation). The government will also have to come up with better strategies to identify mechanisms for integrating informal sector actors into formal chains and implement better waste management.
6. EPR implementation through PROs that help deliver the produced plastic waste back to recycling chain need to be strengthened—appropriately implemented and monitored: The Indian government will have to leverage finances in mechanisms that allow segregation and segregated waste collection from cities and strongly apply EPR policies in consensus with state urban development bodies. Increasing sustainability of plastics can bring new opportunities for modernization, competitiveness, and job creation, consistent with global economic, energy, and environmental objectives. We will have to adopt strategies which align with socio-economic upliftment of our informal sector and transit plastic waste management from a challenge to an opportunity.

[2] also referred to as single-use plastics, which are not planned, designed, or sold with circular economy approach. also known as creative reuse, is the process of transforming by-products, waste materials, useless, or unwanted products into new materials or products perceived to be of greater quality, such as artistic value or environmental value.

6. REFERENCES

Griffin, J., Wilkins, J., and Bowen, D. (2019). The plastic problem: How much plastic pollution is in our ocean? (Two Oceans Aquarium.) Retrieved January 12, 2020, from https://www.aquarium.co.za/: https://www.aquarium.co.za/blog/entry/The-plastic-problem-How-much-plastic-pollution-is-in-our-ocean

Jeftic, L., Sheavly, S., and Adler, E. (2009). *Marine Litter: A Global Challenge.* Nairobi: United Nations Environment Programme

Agency, E. P. (2017). *Impacts of Plastic mismanged trash*. Retrieved December 28, 2019, from Environmental Protection Agency: https://www.epa.gov/trash-free-waters/impacts-mismanaged-trash

Amemiya, T. (2018). Current state and trend of waste and recycling in Japan. *International Journal of Earth & Environmental Sciences. 3*(155)

Business Standard. (n.d.). *IMF slashes India's FY20 GDP growth forecast to 6.1% from 7%*. Retrieved from www.business-standard.com

Central Pollution Control Board. (2018). *Annual Report of 2017-18 on Plastic Waste Mangement Rules, 2016.* New Delhi: CPCB

Central Pollution Control Board. (2018). *Life Cycle Assessment (LCA) Study Of Plastic Packaging Products.*. New Delhi: CPCB. Retrieved Feburary 1, 2020, from http://cpcb.nic.in/uploads/plasticwaste/LCA_Report_15.05.2018.pdf

Central Pollution Control Board. (2019). *Annual Report for 2018-19 on implementation of Plastic waste Management Rules.* New Delhi: CPCB.

Central Pollution Control Board. (2015). *Assessment & Quantification of Plastics Waste Generation in Major Cities.* Delhi: Ministry of Environment & Forests

Dougal Shaw. (2019). *Welcom to my high-fashion,trash shopping mall*. (BBC News)

DownToEarth. (2019). *No ban on single-use plastics, to be phased out by 2022*. DownToEarth, October 2

Eunomia. (2016). *Plastics in the Marine Environment.* Bristol, U.K.: Eunomia Research & Consulting Ltd. Retrieved December 23, 2019, from https://www.eunomia.co.uk/reports-tools/plastics-in-the-marine-environment/

Federation of Indian Chambers of Commerce and Industry. (2017). *Plastics Processing Industry Poised to Grow at CAGR of 10.5% Till.* New Delhi: FICCI. Retrieved December 29, 2019, from http://ficci.in/PressRelease/2681/press-release-ficci-Sustainable-Infrastructure-with-Plastics.pdf

Federation of Indian Chambers of Commerce and Industry. (2016). 2nd National Conference: Plastic Packaging-The sustainable choice: A Report on Plastic Industry. Delhi: FICCI. Retrieved December 25, 2019, from http://ficci.in/spdocument/20690/Plastic-packaging-report.pdf

Federation of Indian chambers of Commerce and Industry. (2017). 3rd National Conference on sustainable infrastructure with plastics. *A Knowledge Paper on Plastic Industry for Infrastructure.* New Delhi: FICCI. Retrieved December 25, 2019, from http://ficci.in/spdocument/20872/report-Plastic-infrastructure-2017-ficci.pdf

Federation of Indian Chambers of Commerce and Industry. (2015). *FICCI Representation on Behalf of FMCG & Food Processing Industry To Bureau Of Indian Standards (BIS).* Retrieved February 1, 2020, from https://india-recycling.com/wp-content/uploads/2018/07/FICCI-Representation-on-Plastic-Ban-BIS.pdf

FICCI. (2014). *Potential of Plastic Industry in Northern India with Special Focus on Plasticulture and Food Processing.* New Delhi: FICCI. Retrieved from http://ficci.in/spdocument/20396/Knowledge-Paper-ps.pdf

FICCI. (2017). *Sustainable Infrastructure with Plastic.* New Delhi: FICCI. Retrieved from http://ficci.in/spdocument/20872/report-Plastic-infrastructure-2017-ficci.pdf

FOUNDATION, P. (2018). *Report on the Indian Plastics Industry.* Retrieved from https://plastindia.org/pdf/Indian-Plastics-Industry-Report-2018-2.pdf

Garside, M. (2019). Distribution of global plastic materials production in 2018, by region.

Retrieved December 29, 2019, from statista.com: https://www.statista.com/statistics/281126/global-plastics-production-share-of-various-countries-and-regions/

Garside, M. (2019). Global plastic production 1950-2018. Retrieved December 25, 2019, from www.statista.com: https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/

Geyer, R., Jambeck, J. R., and Law, K. L. (2017). Production,use and fate of all plastics ever made. *Science Advances, 03*(7). doi: 10.1126/sciadv.1700782

Gibbens, S. (2018). *What you need to know about plant-based plastics. Can bioplastics truly relieve pressure on the environment? Experts weigh in*. (National Geographic Society.) doi:15/11/2018

Godfrey, L. (2019). Waste Plastic, the Challenge Facing Developing Countries—Ban It, Change It, Collect It.

Heam, S. (2018, November 25). *Can plastics be good?* doi:25/11/2018

Hindustan Times. (2019, September 9). *Highlights| 'Time to say goodbye to single use plastic': PM Modi at COP 14 UN Convention in Greater Noida.* Retrieved January 8, 2020, from https://www.hindustantimes.com/india-news/highlights-time-to-say-good-bye-to-single-use-plastic-pm-modi-at-cop-14-un-convention-in-greater-noida/story-bVnKbSTBK3R8pOfgDLHmsI.html: https://www.hindustantimes.com/india-news/highlights-time-to-say-good-bye-to-single-use-plastic-pm-modi-at-cop-14-un-convention-in-greater-noida/story-bVnKbSTBK3R8pOfgDLHmsI.html

Hiratsuka, J. (2005). *Japanese Initiative toward Sound Material-Cycle Society.* Ministry of Environment, Waste Management and Recycling Department, Japan. doi:06/2004

Hoornweg, D., & Bhada-Tata, P. (2012). *What a waste: A Global review of solid waste management.* Washington D.C.: The World Bank. Retrieved December 29, 2019, from www.worldbank.org: http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/ 336387-1334852610766/What_a_Waste2012_Final.pdf

Hopewell Jefferson, D. R. (2009). Plastics Recycling Challenges and opportunities. *NCBI*, 1-3. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873020/

Hopewell, J., Dvorak, R., & Kosior, E. (2009, July 27). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 364*(1526), 2115-2126. doi:10.1098/rstb.2008.0311

Indian Flexible Packaging & Folding Carton Manufacturers Association. (n.d.). *Solid and Liquid Resource Management: Plastic waste management - draft implementation framework.* Retrieved from http://ifca.net.in/: http://ifca.net.in/pdf/Resource_book_Plastic_Waste_Management.pdf

International Monetary Fund. (2019). *International Monetary Fund*. Retrieved December 29, 2019, from https://www.imf.org/en/Countries/IND#whatsnew

Jambeck, J. R., Geyer, R., & Law, K. L. (2017, July 19). Plastic waste inputs from land into the ocean. *Science Advances., 3*(7). doi:10.1126

Joshi, R., & Ahmed, S. (2016, Feburary 17). Status and challenges of municipal solid waste:A review. (C. A. Ng., & E. T. Zurich, Eds.) *Cogent Environmental Science., 2*(1139434), 4. Retrieved January 8, 2020, from http://home.iitk.ac.in/~anubha/H13.pdf

Joshi, S., Chattopadh, S., & Kumar, N. (2019). *The un-plastic strategy: why and how to minimize extenalities.* New Delhi.: Confederation of Indian Industry. Retrieved January 12, 2020, from file:///C:/Users/user/Desktop/1567065823CII_ITC_UN-PLASTIC_REPORT_final.pdf

Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerdan, F. (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.* Washington D.C.: The World Bank . Retrieved December 29, 2019, from https://openknowledge.worldbank.org/handle/10986/30317

Khajuria Anupam, Y. Y. (2008, May). *Solid waste management in Asian countries: Problems*

and issues. Retrieved December 29, 2019, from www.researchgate.com: https://www.researchgate.net/publication/271450046_Solid_waste_management_in_Asian_countries_Problems_and_issues

LeBlanc, R. (2019, October 07). *www.thebalancesmb.com.* Retrieved February 08, 2020, from https://www.thebalancesmb.com/recycling-and-new-job-creation-2878003: https://www.thebalancesmb.com/recycling-and-new-job-creation-2878003

Lewis, H., Retamal, M., & Atherton, A. (2018). *Addressing plastic pollution in India.* doi:2018

Ministry of Housing & Urban Affairs Government of India. (2019). *Plastic Waste Management issues,solutions & case studies.* New Delhi. doi:2019

MoEFCC. (2016). *Plastic Waste Managemebt Rules 2016.* Ministry of Environment, Forest and Climate Change. New Delhi: Govt. Of India. doi:18/3/2016

Montevecchi, F. (2016, May 4). Policy Mixes to Achieve Absolute Decoupling: A case study of Municipal Waste Management. (V. Torretta, Ed.) *Sustainability., 8*(5). doi:04 May 2016

Mordor Intelligence. (n.d.). *https://www.mordorintelligence.com/industry-reports/packaging-industry-in-india.* Retrieved December 25, 2019, from www.mordorintelligence.com: https://www.mordorintelligence.com/industry-reports/packaging-industry-in-india

National Geographic. (2018, November 15). *What you need to know about plant-based plastics.* Retrieved February 08, 2020, from www.nationalgeographic.com: https://www.nationalgeographic.com/environment/2018/11/are-bioplastics-made-from-plants-better-for-environment-ocean-plastic/

National Geograpic Society. (2018, April 4). *7 Things you didn't know about Plastic (and Recycling).* Retrieved January 4, 2020, from https://blog.nationalgeographic.org/: https://blog.nationalgeographic.org/2018/04/04/7-things-you-didnt-know-about-plastic-and-recycling/

Netscribes (India) Pvt Ltd. (2019). *Flexible Packaging Market in India (2018-2023).* Netscribes (India) Pvt Ltd. Retrieved December 31, 2019, from Research & Markets: https://www.researchandmarkets.com/reports/4787270/flexible-packaging-market-in-india-2018-2023#description

OurAukland. (2016, August 10). *How many times can it be recycled?* Retrieved January 12, 2020, from https://ourauckland.aucklandcouncil.govt.nz/: https://ourauckland.aucklandcouncil.govt.nz/articles/news/2016/08/how-many-times-can-it-be-recycled/

Plastic Europe. (n.d.). *How plastics are made*. Retrieved December 31, 2019, from Plastic Europe: https://www.plasticseurope.org/en/about-plastics/what-are-plastics/how-plastics-are-made

PlastIndia. (2018). *Report on The Indian Plastic Industry.* Mumbai: Plastindia Foundation. Retrieved December 25, 2019, from https://plastindia.org/pdf/Indian-Plastics-Industry-Report-2018-2.pdf

Plastindia Foundation. (2018). *Report on The Indian Plastics Industry.* MUMBAI: PLASTINDIA FOUNDATION. Retrieved DECEMBER 29, 2019, from www.plastindia.org

Plastindia Foundation. (2018). *Report on The Indian Plastics Industry.* MUMBAI: PLASTINDIA FOUNDATION. Retrieved DECEMBER 29, 2019, from www.plastindia.org

Plastindia Foundation (2019) *Indian Plastic Industry report.* MUMBAI: PLASTINDIA FOUNDATION. Retrieved JULY 07, 2019 from https://www.plastindia.org/plastic-industry-status-report.html

Programme, U. E. (n.d.). *Plastic planet: How tiny plastic particles are polluting our soil*. Retrieved December 28, 2019, from UN Environment Programme: https://www.unenvironment.org/news-and-stories/story/plastic-planet-how-tiny-plastic-particles-are-polluting-our-soil

Roser, H. R. (2018, September). Plastic Pollution. *Our world data*, 3-12. Retrieved December 28, 2019, from https://ourworldindata.org/plastic-pollution

Rudolph, N., Kiesel, R., & Aumnate, C. (2017). *Understanding Plastics Recycling: Economic,Ecological and Technical aspects*

of Plastic handling. Göttingen, Germany: Hanser Publications. Retrieved January 4, 2020, from http://dl.booktolearn.com/ebooks2/engineering/environmental/9781569906767_Understanding_Plastics_Recycling_6264.pdf

Shrivastav, R. (2019, October 3). *India's plastic waste situation wasn't created today* . Retrieved December 29, 2019, from www.downtoearth.org.in: https://www.downtoearth.org.in/blog/waste/india-s-plastic-waste-situation-wasn-t-created-today-67061

Statista. (2019, September 23). *Plastic waste generated in India 2001-2041.* Retrieved January 8, 2020, from https://www.statista.com/statistics/1009095/india-plastic-waste-generation/: https://www.statista.com/statistics/1009095/india-plastic-waste-generation/

Tang, X.,Chen, E,Y,X. (June 2018) *Toward Infinitely Recyclable Plastics Derived from Renewable Cyclic Esters.* Chem, 5((284-312. Retrieved on July 24, 2020 from https://www.sciencedirect.com/science/article/pii/S2451929418304911

The Organisation for Economic Co-operation and Development. (2018). *Improving Plastics Management:Trends, policy responses, and the role of international co-operation and trade.* OECD. Retrieved December 29, 2019, from https://www.oecd.org/environment/waste/policy-highlights-improving-plastics-management.pdf

THE WORLD BANK. (2018). *GDP growth (annual %) - India.* Retrieved 2019, from https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2018&locations=IN&start=2000&view= chart: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2018&locations=IN&start=2000&view=chart

Tobias, P. H., Vçlker, C., Kramm, J., Landfester, K., & Wurm, F. R. (2019, January 2). Plastics of the Future? The Impact of Biodegradable Polymers on the Environment and on Society. *Angewande Chmie International Edition, 58*(1), 50-62. doi:10. 1002/ anie.201805766

Trade Promotion Council of India. (2019, November). Melting Point. (V. Bahri, Ed.) *India business & trade, 1*(5), pp. 22-27.

United Nations Environment Programme. (2018). *Single-Use Plastics: A Roadmap for Sustainability.* UNEP. doi:2018

United Nations Environment Programme (2020). Single-use plastic bags and their alternatives - Recommendations from Life Cycle Assessments. Retrieved on July 24, 2020 from https://www.lifecycleinitiative.org / wp-content/ uploads/2020/04/ Single-use-plastic-bags-and-alternatives- Recommendations-from-LCA-final.pdf

Verma, R., Vinoda,K,S.,Papireddy,M., Gowda,A,N,S. (2016). Toxic Pollutants from Plastic Waste- A Review. *Procedia Environmental Services, 35, pp 701-708.* Retrieved November 10, 2020 from https:// doi.org/10.1016/j.proenv.2016.07.069

Watkins, Emma; Gionfra, Sussana; Schweitzer, Jien Pirre; Pantzar, Mia; Janssens, Charlotte; Brink, Patrick ten. (2017). *EPR in EU Plastics Strategy and the Circular Economy: A focus on plastic packaging.* Institute for European Environmental Policy. Belgium: MAVA FoundationPour La Nature. doi:09/11/2017

WIKIPEDIA. (n.d.). *Economy of India*. Retrieved from https://en.wikipedia.org/wiki/ Economy_of_India

World Economic Forum. (2016). *The New Plastics Economy: Rethinking the future of plastics.* Retrieved January 4, 2020, from http://www3.weforum.org/ docs/ WEF_The_New_Plastics_Economy.pdf

We are an independent, multi-dimensional organization, with capabilities in research, policy, consultancy and implementation. We are innovators and agents of change in the energy, environment, climate change and sustainability space, having pioneered conversations and action in these areas for over four decades.

We believe that resource efficiency and waste management are the keys to smart, sustainable and inclusive development. Our work across sectors is focused on

1. Promoting efficient use of resources
2. Increasing access and uptake of sustainable inputs and practices
3. Reducing the impact on environment and climate

Headquartered in New Delhi, we have regional centres and campuses in Gurugram, Bengaluru, Guwahati, Mumbai, Panaji, and Nainital. Our 1000-plus team of scientists, sociologists, economists and engineers delivers insightful, high quality action-oriented research and transformative solutions supported by state- of-the-art infrastructure.

teri | The Energy and Resources Institute

Creating Innovative Solutions for a Sustainable Future

TERI, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi 110 003, India
Tel.: +91 11 2468 2100 or 2468 2111 | Fax: +91 11 2468 2144 or 2468 2145
Email: pmc@teri.res.in | Web: www.teriin.org