PROMOTION OF COUNTER MEASURES AGAINST MARINE PLASTIC LITTER IN SOUTH EAST ASIA AND INDIA

Counter Measures

UN environment programme

Counter MEASURE FOR PLASTIC FREE RIVERS

National Productivity Council

Table of Contents

List of Tables

List of Figures

Executive Summary

The mismanagement of on land plastic waste generation in major urban centres and its subsequent leakage in environment through carriers causes the major environmental impacts such as higher material footprint and GHG emissions. Therefore, it is important to map the material cycle of plastic in a given geography and identify sources and causes of plastic waste generation in the major cities and urban centres. The material cycle of plastic based on life cycle approach (Figure 1) indicates that plastic pollution is generated by the unsustainable use and disposal of plastic products in modern society, threatening economies, ecosystems, and human health.

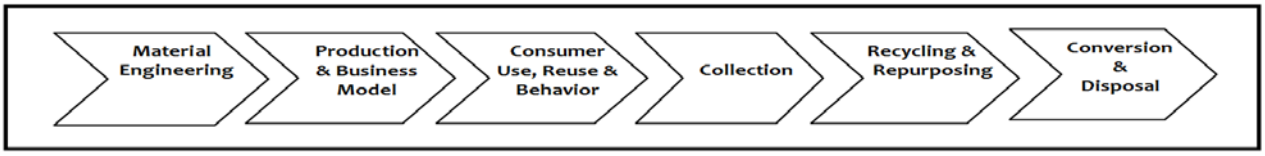


Figure 1: Conceptual Plastic Value Chain

It has been cited that uncontrolled landfilling and open burning have been the most prevalent waste disposal method in India. The current plastic waste disposal practices result in mismanagement of waste leading to their leakage into natural drainage system and finally oceans. About 1.15 and 2.41 million tonnes of plastic currently flows from the global riverine system into the oceans every year. Literature cites that Ganges River catchment, between India and Bangladesh, contributes with a computed input of 0.12 (range 0.10–0.17) million tones of plastics per year. The environmental burden associated with the production, use, and eventual disposal of these plastics will tend to increase in parallel. Reducing these burdens will require greater efficiency of plastics use. Current clean-up strategies have attempted to mitigate the negative effects of plastic pollution but are unable to compete with increasing quantities of plastic entering the environment. Thus, reducing inputs of plastic to the environment must be prioritized through a global multidisciplinary approach. This will require a change in thinking from traditional linear economic models (i.e. manufacture-use-dispose), to more circular economic models, whereby the use of plastics is optimised (e.g. through product redesign and light-weighting), and plastics are kept within the use cycle for longer, through reuse and recycling.

This report provides an insight to the current international market based strategies and policies to minimize plastic litter and also it provide important information and highlights gaps for decisions and policy makers. While measures to reduce plastic pollution have long been established, many countries still lack implementation strategies. Lag times for commencement of plastic bans delays immediate source control, but could provide opportunities to develop appropriate and effective monitoring campaigns. Internationally, all interventions to reduce single-use plastics vary in range and scope. Policies have been developed across a number of nations to ban primarily the use and sale of, but also the manufacturing of plastics. Measures to reduce plastic bag pollution have included bans (including both full and partial) and levies, and these interventions have occurred both regionally and nationally.

A compilation of plastic collection measures adopted in India along with brief feature of regulation adopted in India to prevent plastic litter is made. Different chapters of the report map a different set of actions taken by the public, private sector entities and governments aimed at minimizing the production and use of plastic bags. The objective is to identify the features that lead to the most favorable outcomes, with success stories to be further detailed through the case studies.

By introducing economic incentives, supporting projects which upscale or recycle single-use items and stimulating the creation of micro-enterprises, governments can contribute to the uptake of eco-friendly alternatives to single-use plastics. A number of depository schemes have been initiated in different parts of India towards collection of plastic waste as a part of Swachh Bharat Abhiyaan and other initiatives are discussed in this report. By working together with industry, governments can support the development and promotion of sustainable alternatives in order to phase-out single-use plastics progressively. By introducing economic incentives, supporting projects which upscale or recycle single-use items and stimulating the creation of micro-enterprises, governments can contribute to the uptake of eco-friendly alternatives to single-use plastics. A number of depository schemes have been initiated in different parts of India as well as in other countries towards collection of plastic waste and other initiatives are discussed in this report.

A special reference on how product redesign especially for Multi-layer plastic which creates nuisance in waste management and treatment can make it recyclable. This includes designing and fabricating a product for easy dismantling after end of life, promoting products with modular designs with longer life where different components can be replaced or changed as the need may be so that the product's entry into the waste stream is delayed and controlling use of dyes and additives and looking for non-hazardous substitutes. Also, recyclability of a plastic waste is economically feasible only when it is built into their design. A number of new products have come up having advantages of usage, improved productivity but which challenges their recyclability. Packaging materials have to be such designed that they are fully reusable, recyclable or compostable. This report describes requirement of a much more concerted, global, systemic and collaborative approach with fundamental redesign, new reuse models, and radically improved recycling.

A number of other technological and treatment options have been highlighted in report. Plastic recycling is approached in the report by mainly two recycling methods which are chemical recycling and the other recovery and disposal operations include waste to energy and pyrolysis. Each of these plastic waste treatment methods includes different technological approaches on treating plastic waste based on the type of polymers with different advantages and disadvantages. While recycling is the most suited model for tackling plastic waste as per the waste hierarchy, the implementation of the same is faced with challenges, such as a lack of source segregation and recovery.

Challenges for recycling plastic industry has been discussed ranging from mixed plastics to hard-to-remove residues. The cost-effective and efficient recycling of the mixed plastic stream is perhaps the biggest challenge facing the recycling industry. Experts believe that designing plastic packaging and other plastic products with recycling in mind can play a significant role in facing this challenge.

The report also aims to provide a better picture and understanding of the plastic issues in each of the four cities so that it assists the relevant stakeholders to formulate a long-term activity to monitor, assess and provide policy recommendations, using results from the national reviews and Counter-measure project.

This report also focuses on region wide policies to regulate the plastic pollution. The following section discussed about countermeasures already in implementation and to develop policy interventions related proposed countermeasure in the study areas viz, Agra, Haridwar, Allahabad and Mumbai. Based on the observation on primary waste management, plastic leakage routes into the river, countermeasures specific to study areas which can be applied locally is proposed. The plastic waste litter comprises mainly flexible plastic packaging. Out of the total waste littered, plastic poly bag is around 50-60% as observed in NPC's macroplastic assessment studies undertaken in four study areas viz, Agra, Allahabad, Haridwar, and Mumbai. This is also the case in many developing as well as developed countries.

Finally, the report provides gaps assessment in institutional roles and actions, technological and economic issues. The most important inferences drawn is that the following countermeasures will be required to be implemented in the four study areas to prevent plastic pollution are: Policy level countermeasures to prevent manufacture and sale of certain plastic products which generate waste that are difficult to treat. Alternatively; Effective waste collection and management system; Planning of Depository schemes such as Garbage Café, Kiosk (providing mobile recharge, etc); Availability of Adequate plastic treatment facility within reasonable distance from collection point for reducing transportation cost; and Regular inspection of the probable hotspots and cleaning them.

Chapter 1: Material Cycle of Plastic & Counter Measures

1.0 Introduction

The mismanagement of on land plastic waste generation in major urban centres and its subsequent leakage in environment through carriers causes the major environmental impacts such as higher material footprint and GHG emissions. Therefore, it is important to map the material cycle of plastic in a given geography and identify sources and causes of plastic waste generation in the major cities and urban centres. The following sections describe material cycle of plastic based on life cycle approach. This is followed by description of plastic production and consumption trends in India as well as waste generation. The major focus of this chapter is on resource intensity and related aspects of plastic consumption and production, waste generation and summary of leakage pathways in four cities in India Finally, approach related to resource efficiency and the potential for circular economy have been described.

1.1 Material Cycle of Plastic

Material cycle of plastic has been described considering life cycle approach. Conceptually, life cycle approach considers the range of impacts throughout the life of a product by taking the entire life cycle into account i.e. from the extraction of natural resources to material processing, manufacturing, distribution and use and finally to the reuse, recycling, recovery and disposal of any remaining waste. Life cycle assessments (LCA) quantify these steps by assessing the emissions, resources consumed and pressures on environment, health and safety that can be attributed to a product or service. A conceptual plastic value chain in the context of India has been described in **Figure 1.1**. It starts from material engineering for plastic and leads to its production followed by its consumption, collection, recycling and repurposing and finally its conversion and disposal. The material / product input versus output at each stage determine the sources of plastic waste along the plastic value chain. Stage wise description of plastic value chain is given below [1].

Material Engineering (Stage 1): Different raw materials e.g. petroleum, non petroleum and other resources are identified to develop plastic product for a particular use. This may consist of virgin raw materials or their combination. At this stage, the formulation of plastic product determines extraction of raw materials from finite natural resource e.g. petroleum or secondary materials such as plastic waste. **Production and Business Model (Stage 2):** At this stage, raw materials are converted into products using physical or chemical processes based on technology, economics and business model (export or domestic consumption). The efficiency of conversion determines plastic waste generation at this stage. Further, the formulation at stage 1 determines reuse or recycling of plastic waste generated at this stage or stage 5**. Consumer Use, Reuse and Behavior (Stage 3):** Consumer behavior determines consumption of plastic products, whether consumer wants to use brand new or used product. **End of life product is discarded as plastic waste Collection (Stage 4):** Waste plastic is collected using formal and informal collection system. At this stage efficiency of collection system determines plastic leakage into the environment**.** Uncollected plastic waste leaks into drainage and sewer system or directly into waterways or seas**. Recycling and Repurposing (Stage 5):** Collected plastic waste is segregated for reuse, recycling, energy recovery (non recyclable) and disposal. The efficiency of segregation in both formal and informal plastic waste management system determines leakage into the environment. **Conversion and Disposal (Stage 6):** Plastic waste after recycling and repurposing is meant for disposal. The disposal mechanism includes disposal on land or water such as organized dumping into sanitary landfill site, unorganized burying / dumping, wild dumping close to waterways and directly into waterways. **Last Chance Capture (Stage 7):** Plastic waste dumped on land can be captured at landfill or dump sites through manual or mechanical mechanism used for waste segregation. Plastic waste dumped into waterways can be captured through retention

mechanism.

Figure 1.3 describes cause, problem and effect of plastic waste generation. Further, it depicts stage wise sources of plastic waste generation and its leakage into the environment.

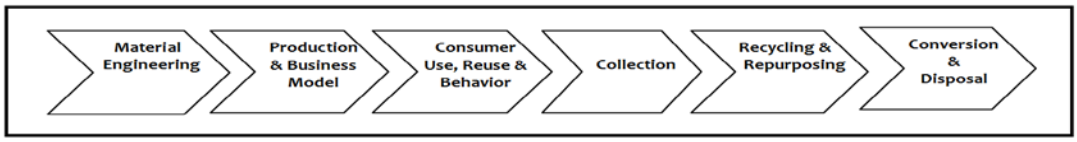


Figure 1.1: Conceptual Plastic Value Chain in Asia and the Pacific[2]

Source: UN Environment (2017) - Reducing Marine Litter by Addressing the Management of the Plastic Value Chain in Southeast Asia

It has been cited that uncontrolled landfilling and open burning have been the most prevalent waste disposal method in India. The current plastic waste disposal practices result in mismanagement of waste leading to their leakage into natural drainage system and finally oceans.[3] **Figure 1.1** shows conceptually how the plastic waste enters the waterways, oceans and seas. About 1.15 and 2.41 million tonnes of plastic currently flows from the global riverine system into the oceans every year.[3] Literature cites that Ganges River catchment, between India and Bangladesh, contributes with a computed input of 0.12 (range 0.10–0.17) million tones of plastics per year.[3]

1.2 Plastic Production, Consumption, Disposal and Leakage Trends

India produced 17 MMT of plastics and consumed an estimated 18.45 Million Tonnes of plastic annually during FY 2018-19. In all, 80% of total plastic produced in India is discarded. Plastic demand in India is 5.7% of global demand (2018-19). Per capita consumption of plastic in India is 13.6 kg (virgin plastic), which is half of global consumption. Polymer consumption is expected to grow at a rate of 10% from 2017 till 2022. About 8.6 MMT is the plastic waste generated in India out of which 6.02 MMT (70%) is getting recycled. There are 100+ recycling units in organized sector, while 10000+ units in unorganized sector. Delhi being the highest generator of plastic waste in India accounts for 9,600 mt per day among the top ten cities, followed by Chennai, Kolkata, Mumbai, Bangalore and few others.

According to Central Pollution Control Board has estimated for the year 2017-18 Plastic Waste in India: 26,000 TPD: 9.4 Million Tonne per Annum. Based on the secondary data collection from Urban Local Bodies, plastic waste generation and that is expected to be uncollected/littered in four cities viz; Haridwar, Allahabad, Agra and Mumbai is as given below in **Table 1.1.**

Table 1.1: City wise total plastic waste generation and littered plastic

Name of City	Name of the Basin / Coastal	Total Plastic waste generation in MTD	Plastic waste littered in MTD
Haridwar, Uttarakhand	Ganga	33-62 (normal) 46-75 (festive)	3.3 - 11
Allahabad, Uttar Pradesh	Ganga	45-60	7-8
Agra	Yamuna	100 - 120	20-30
Mumbai	Coastal	84 - 433	50 - 178

Further, based on the primary observation and interview with various stakeholder, macroplastic / microplastic assessment studies (Plastic leakage scenario report), most prevalent plastic waste found in the litter and their leakage pathway into the environment is as given below in **Table 1.2**.

Table 1.2: City wise plastic leakage route

Sr. No.	Name of the City	Dominant Plastic Waste Generated*					Plastic Leakage Route
		Household	Market	Commercial	Industrial	Ghats / Beach	
1.	Agra	MLP, Poly bags, Milk pouches, Monopolymer packets (Maggi Pouches, Atta packet, Detergent packet, etc), Shampoo bottles, tooth paste tubes, beverage bottles	Petha packaging material; Disposable cutlery, Tobacco sachets, beverage bottles	Packaging material, Disposable cutlery, shampoos, tooth paste, etc bottle, housekeeping materials such harpic, phenol, etc	Footwear waste, Synthetic Textile rejects, Foam, Thermocol, Tobacco sachets	Plastic garlands, camphor sachets, poly bags	• Littering on accumulation points (Household) ➔ nearby open drain through wind blown ➔ river • Littering on accumulation points (Household) ➔ burning-> ashes/unburnt remains through wind blown to drains ➔ river • Littering on road (Market places /Industrial places/Commercial like Bus stands, Railway stations, Auto/Taxi stands ➔ nearby open drain through wind blown ➔ river • Littering in Slum along open drains ➔ river • Littering around Transfer stations ➔ nearby open

Sr. No.	Name of the City	Dominant Plastic Waste Generated*					Plastic Leakage Route
		Household	Market	Commercial	Industrial	Ghats / Beach	
							drain through wind blown ➔ river • Rituals performed (Daily as well as during festivals ➔ Ghats (Bank of river) ➔ River
2.	Allahabad		Poly bags Food take away containers, Disposable cutlery			Poly bags, plastic, disposable cutlery, god sculpture, Agarbatti packets	• Littering on accumulation points (Household) ➔ nearby open drain through wind blown ➔ river • Littering on accumulation points (Household) ➔ burning-> ashes/unburnt remains through wind blown to drains ➔ river • Littering on road (Market places/ Industrial places/Commercial like Bus stands, Railway stations, Auto/Taxi stands ➔ nearby open drain through wind blown
3.	Haridwar		Poly bags Food take away containers, Disposable cutlery, silver with plastic laminated paper plates		Not in the study area	Plastic bottles, poly bags, synthetic textile	

Sr. No.	Name of the City	Dominant Plastic Waste Generated*					Plastic Leakage Route
		Household	Market	Commercial	Industrial	Ghats / Beach	
							➔ river • Littering in Slum along open drains ➔ river • Littering around Transfer stations ➔ nearby open drain through wind blown ➔ river • Waste from festive period ➔ street littering-> drain ➔ Ganga channel • Plastic waste accumulated in Barriers in Ganga Canal/ Barrage - ➔ during monsoon or during heavy flows in the river by opening of sluice gate ➔ river
4.	Mumbai		Poly bags, Blue colored large plastic bags, packaging material, Food		Not in the study area		• Littering on accumulation points ➔ nearby open drain through wind blown ➔ river ➔ ocean • Littering on

Sr. No.	Name of the City	Dominant Plastic Waste Generated*					Plastic Leakage Route
		Household	Market	Commercial	Industrial	Ghats / Beach	
			take away containers, Disposable cutlery				road (Market places / Commercial like Bus stands, Railway stations, Auto/ Taxi stands ➔ nearby open drain through wind blown ➔ river ➔ ocean • Littering in Slum along open drains or directly river ➔ river ➔ ocean • Littering around Transfer stations ➔ nearby open drain through wind blown ➔ river ➔ ocean • Littering along railway tracks ➔ nearby open drain through wind blown ➔ river ➔ ocean

*High value plastic waste like milk pouches; shampoo bottle and beverage bottles, etc are mostly picked up from litter by the rag picker

1.3 Resource Efficiency, Circularity and Loosing Opportunity

The environmental burden associated with the production, use, and eventual disposal of these plastics will tend to increase in parallel. Reducing these burdens will require greater efficiency of

plastics use. This will require a change in thinking from traditional linear economic models (i.e. manufacture-use-dispose), to more circular economic models **(Figure 1.3)**, whereby the use of plastics is optimised (e.g. through product redesign and light-weighting), and plastics are kept within the use cycle for longer, through reuse and recycling.

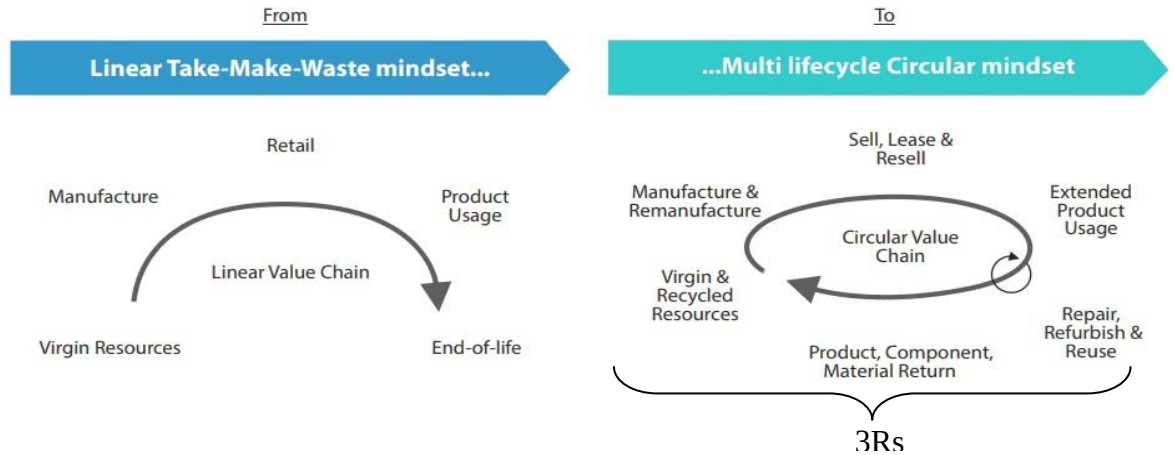


Figure 1.2: Adopting circular business models - a shift in mindset

Use of secondary raw material produced through recycling is an important pillar of circular mindset. An example of environmental implication of this mindset can be demonstrated through GHG reduction which can be achieved on account of energy conservation by recycling of plastics. Major GHG emissions associated with the plastics lifecycle results from the production of virgin polymer. Large amounts of energy are required to refine the fossil fuel like crude oil, crack the distilled constituents into monomers, and then synthesise the base starting materials. This process is highly energy-intensive, and was estimated to account for 400 million tonnes of greenhouse gas emissions (around 1% of the global total) in 2012. The fossil fuel feedstock used in plastics production accounts for an additional 4% of global oil and gas production.[4] Recycling of plastics avoids 80% of use energy.[5] Conceptually, 3Rs being an integral part of circular mindset **(Figure 1.2)** offers a viable policy option to reduce material intensity. The evaluation of the intermediate waste treatment approaches will establish main linkages between economic activity, materials use and environmental pressures. For example, a case study of India indicates that annual plastic waste generation in India is about 5.6 million tonnes. About 60% of this waste is collected by both formal and informal sector. About 46% of this waste is treated while 11% is used for energy recovery. Therefore, 40% of the uncollected waste, which is dumped into landfills offers huge opportunity for achieving environmental and socio-economic benefits. One ton of plastic recycling is expected to save about 1.7 km^2 of landfill area. Further, it can also create 1.39 million incremental jobs in plastic recycling industry.[6]Therefore, a granular approach is needed to understand which 3R policy intervention may improve resource efficiency at the sectoral level, and how major environmental consequences may be avoided in India. In this context, countermeasures across the plastic value chain have been assessed both in terms of current as well as proposed in future. **In this context, India is losing an opportunity of bringing back 30% of the waste plastic back into recycling route. Considering 10-25% being littered plastic enters into leakage pathways in urban centres, this waste plastic enters into riverine ecosystem.**

1.4 Format of the Report

This chapter provides insight to the existing countermeasures measures adopted in India along with brief feature of regulation adopted in India to prevent plastic litter. A special reference on how product redesign especially for Multi layer plastic which creates nuisance in waste management and treatment can make it recyclable. Various countermeasures for stopping plastic litter in the country are proposed. Finally based on the observation

on primary waste management, plastic leakage routes into the river, countermeasures specific to study areas which can be applied locally is proposed being used elsewhere in the world to stop plastic litter. The entire report is organized in seven chapters as given below.

Chapter 1: Introduction and Background
Chapter 2: Policy and Regulatory Regime
Chapter 3: Plastic Waste Collection Mechanism
Chapter4: Treatment Options. This chapter describes the existing treatment options, which are being used globally.
Chapter 5: Existing Counter measures in each city
Chapter6: Proposed Counter Measures in each city.
Chapter7: Conclusions

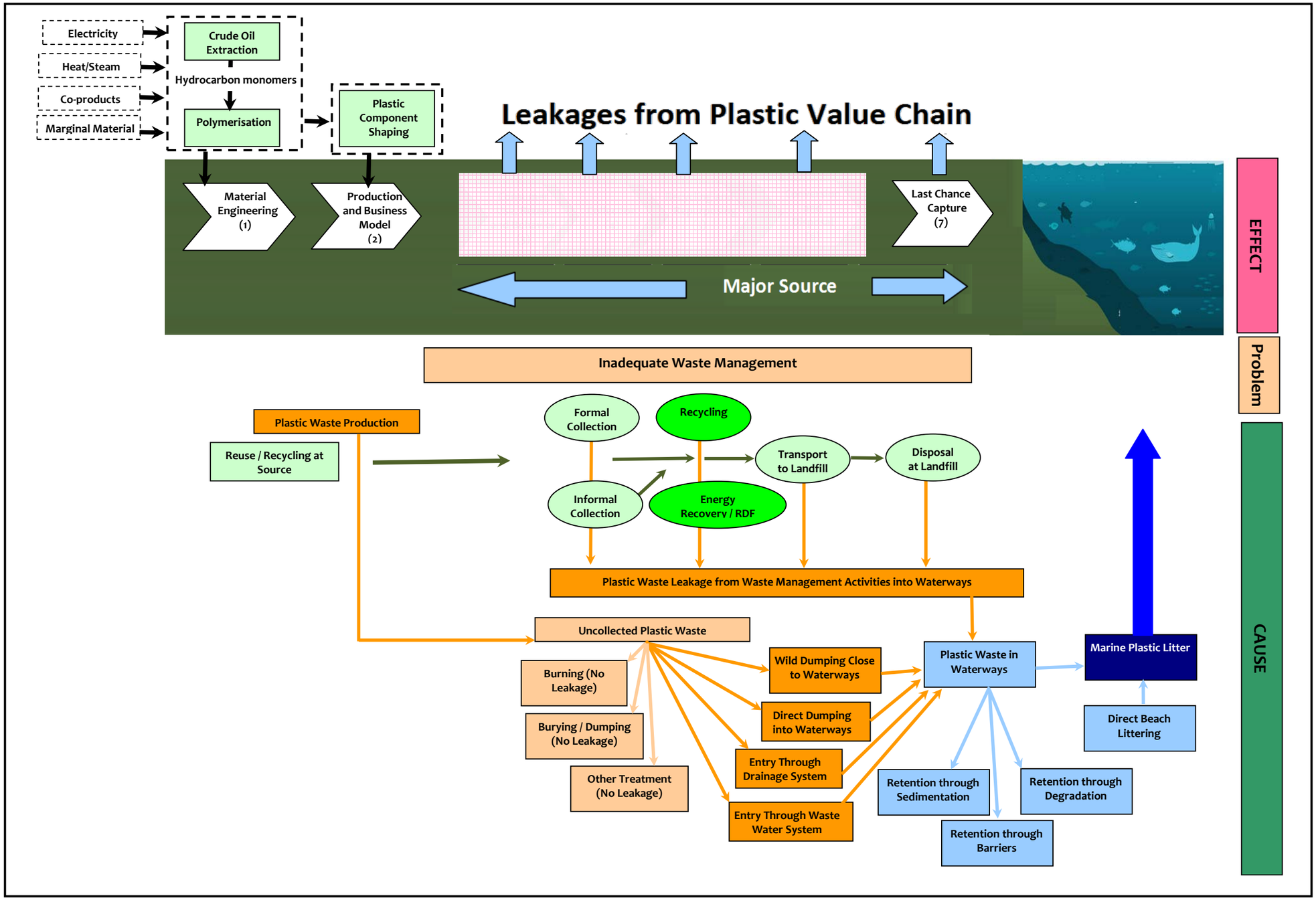


Figure 1.3: Sources of Plastic Waste Leakage into Environment[2][3][7]

Source: Prepared by Amit Jain (2019); From UN Environment (2017) - Reducing Marine Litter by Addressing the Management of the Plastic Value Chain in Southeast Asia; OECD (2018) – Improving Markets for Recycled Plastics – Trends, Prospects and Policy Responses; GIZ (2018) – Marine Litter Prevention (Reducing Plastic Leakage into Waterways and Oceans through Circular Economy and Sustainable Waste Management

Chapter 2: Counter Measures against Marine plastic litter

2.1 Brief Glance at the Chapter

This chapter provides insight to the existing countermeasures measures adopted in India along with brief feature of regulation adopted in India to prevent plastic litter is made. A special reference on how product redesign especially for Multi layer plastic which creates nuisance in waste management and treatment can make it recyclable. Various countermeasures for stopping plastic litter in the country is proposed. Finally based on the observation on primary waste management, plastic leakage routes into the river, countermeasures specific to study areas which can b e applied locally is proposed being used elsewhere in the world to stop plastic litter. A compilation of plastic collection.

2.2 Introduction

As per the latest estimate (Tadinada Sri Sasi Jyothsna and Bandari Chakradhar, 2020), India generates around 56 lakh tonnes of plastic waste annually and Delhi being the highest generator of plastic waste in India accounts for 9,600 mt per day among the top ten cities, followed by Chennai, Kolkata, Mumbai, Bangalore and few others.

According to Central Pollution Control Board has estimated for the ye ar2017-18 Plastic Waste in India: 26,000 TPD: 9.4 Million Tonne per Annum

Plastic Waste Recycled: 15,600 TPD: 5.6 Million Tonne per Annum

Uncollected and littered: 9,400 TPD: 3.8 Million Tonne per Annum
(Source: Dr. Smita Mohanty, CIPET).

Based on the secondary data collection from Urban Local Bodies, plastic waste generation and that is expected to be uncollected/littered in four cities viz; Haridwar, Allahabad, Agra and Mumbai is as given below:

Table 2.1: City wise total plastic waste generation and littered plastic

Name of City	Name of the Basin / Coastal	Total Plastic waste generation in MTD	Plastic waste littered in MTD
Haridwar, Uttarakhand	Ganga	33-62 (normal) 46-75 (festive)	3.3 - 11
Allahabad, Uttar Pradesh	Ganga	45-60	7-8
Agra	Yamuna	100 - 120	20-30
Mumbai	Coastal	84 - 433	50 - 178

(Refer Plastic leakage Scenario report for the basis of estimation) in MTD

Further, based on the primary observation and interview with various stakeholder, macroplastic/microplastic assessment studies (Plastic leakage scenario report), most prevalent plastic waste found in the litter and their leakage pathway into the environment is as given below:

Leakage pathway of dominant plastic litter in each study area is briefly tabulated as given below:

Table 2.2: City wise plastic leakage route

Sr. No.	Name of the City	Dominant Plastic Waste Generated*					Plastic Leakage Route
		Household	Market	Commercial	Industrial	Ghats / Beach	
5.	Agra	MLP, Poly bags, Milk pouches, Monopolymer packets (Maggi Pouches, Atta packet, Detergent packet, etc), Shampoo bottles, tooth paste tubes, beverage bottles	Petha packaging material; Disposable cutlery, Tobacco sachets, beverage bottles	Packaging material, Disposable cutlery, shampoos, tooth paste, etc bottle, housekeeping material's such harpic, phenol, etc	Footwear waste, Synthetic Textile rejects, Foam, Thermocool, Tobacco sachets	Plastic garlands, camphor sachets, poly bags	• Littering on accumulation points (Household) nearby open drain through wind blown river • Littering on accumulation points (Household) burning-> ashes/unburnt remains through wind blown to drains river • Littering on road (Market places/Industrial places/Commercial like Bus stands, Railway stations, Auto/Taxi stands nearby open drain through wind blown river • Littering in Slum along open drains river • Littering around Transfer stations nearby open drain through wind blown river • Rituals performed (Daily as well as

Sr. No.	Name of the City	Dominant Plastic Waste Generated*					Plastic Leakage Route
		Household	Market	Commercial	Industrial	Ghats / Beach	
							during festivals Ghats (Bank of river) River
6.	Allahabad		Poly bags Food take away containers, Disposable cutlery			Poly bags, plastic, disposable cutlery, god sculpture, Agarbatti packets	• Littering on accumulation points (Household) nearby open drain through wind blown river
7.	Haridwar		Poly bags Food take away containers, Disposable cutlery, silver with plastic laminated paper plates		Not in the study area	Plastic bottles, poly bags, synthetic textile	• Littering on accumulation points (Household) burning-> ashes/unburnt remains through wind blown to drains river • Littering on road (Market places/Industrial places/Commercial like Bus stands, Railway stations, Auto/Taxi stands nearby open drain through wind blown river • Littering in Slum along open drains river • Littering around Transfer stations nearby open drain through wind blown river • Waste from festive period street littering-> drain Ganga channel • Plastic waste accumulated in Barriers in Ganga Canal/Barrage - during monsoon or during heavy flows in the river by opening of sluice gate river
8.	Mumbai		Poly bags, Blue colored		Not in the study area		• Littering on accumulation points

Sr. No.	Name of the City	Dominant Plastic Waste Generated*					Plastic Leakage Route
		Household	Market	Commercial	Industrial	Ghats / Beach	
			large plastic bags, packaging material, Food take away containers, Disposable cutlery				• nearby open drain through wind blown, river, ocean • Littering on road (Market places /Commercial like Bus stands, Railway stations, Auto/Taxi stands, nearby open drain through wind blown, river ocean • Littering in Slum along open drains or directly river, river, ocean • Littering around Transfer stations, nearby open drain through wind blown, river, ocean • Littering along railway tracks nearby open drain through wind blown, river, ocean

*High value plastic waste like milk pouches; shampoo bottle and beverage bottles, etc are mostly picked up from litter by the rag picker

2.3 Regulations in India to manage plastic waste -Plastic Waste Management (PWM Rules), 2016 and Hazardous Waste (Management and Handling) Rules, 2016 and its amendment

The Government of India provided a regulatory frame work for management of plastic waste generated in the country and has notified

- Plastic Waste Management (PWM) Rules, 2016 and its amendments
- Hazardous Waste (Management, Handling and Transboundary movement) 2016 and its amendment

2.3.1 Plastic Waste Management (PWM) Rules, 2016 and its amendments

These rules shall apply to every Waste Generator, Local Body, Gram Panchayat, Manufacturer, Importer, Producer and Brand Owner.

- Carry bags made of virgin or recycled plastic, shall not be less than fifty microns in thickness. The provision of thickness shall not be applicable to carry bags made up of

Compostable plastic, complying IS/ISO: 17088.

- Waste Generators including institutional generators, event organizers shall not litter the plastic waste, shall segregate waste and handover to authorized agency and shall pay user fee as prescribed by ULB and spot fine in case of violation.
- Local Bodies shall encourage use of plastic waste for road construction or energy recovery or waste to oil or co-processing in cement kilns etc. It shall be responsible for development and setting up of infrastructure for segregation, collection, storage, transportation, processing and disposal of the plastic waste either on its own or by engaging agencies or producers.
- Gram Panchayat either on its own or by engaging an agency shall set up, operationalize and coordinate for waste management in the rural area under their control and for performing the associated functions, namely, ensuring segregation, collection, storage, transportation, plastic waste and channelization of recyclable plastic waste fraction to recyclers having valid registration; ensuring that no damage is caused to the environment during this process; creating awareness among.
- all stakeholders about their responsibilities; and ensuring that open burning of plastic waste does not take place.

Producer, Importers and Brand Owners need to work out modalities for waste collection system for collecting back the plastic waste within a period of six months in consultation with local authority/State Urban Development Department and implement with two years thereafter.

- State Pollution Control Board (SPCB)/ Pollution Control Committee (PCC) shall be the authority for enforcement of the provisions of PWM Rules, 2016, relating to registration, manufacture of plastic products and multi-layered packaging, processing and disposal of plastic wastes.
- Concerned Secretary-in-charge of Urban Development of the State or a Union Territory and concerned Gram Panchayat in the rural area of the State or a Union Territory shall be the authority for enforcement of the provisions of PWM Rules, Rules relating to waste management by waste generator, use of plastic carry bags, plastic sheets or like, covers made of plastic sheets and multilayered packaging.
- District Magistrate or Deputy Commissioner shall provide the assistance to SPCBs/PCCs, Secretary-in- Charge, Urban Development Department and Gram Panchayat under his jurisdiction, whenever required for enforcement of reprovision of PWM Rules, 2016.

The amended rules, 2018 emphasizes on phasing out of Multilayered Plastic (MLP) is now applicable to MLP, which are "non-recyclable, or non-energy recoverable, or with no alternate use."

The amended Rules also prescribe a central registration system for the registration of the producer/importer/brand owner. The centralised registration system will be evolved by Central Pollution Control Board (CPCB) for the registration of the producer/importer/brand

owner. While a national registry has been prescribed for producers with presence in more than two states, a state-level registration has been prescribed for smaller producers/brand owners operating within one or two states.

In addition, Rule 15 of the Plastic Waste Management (Amendment) Rules 2018 on "explicit pricing of carry bags" has been omitted.

2.3.2 Hazardous Waste (Management & Trans-boundary Movement) Amended Rule, 2019

This rule completely prohibits the import of solid plastic waste.

2.4 Literature review on Countermeasures/options available for preventing Plastic Pollution

Countermeasures can be classified into:

I. Policy ban on Plastic poly bags and other plastic items
II. New innovations in product design
III. Treatment Technologies
IV. Waste Management Companies
V. Plastic waste depository schemes at regional/city level

2.4.1 Review of Policies on plastic bag bans have been applied in several countries

Packaging is emerging as the most important and fast growing sector of Indian Plastic industry. This growth is primarily driven by end-user segments such as personal care, pharmaceuticals, food products including post harvest management etc.

The plastic waste litter comprises mainly flexible plastic packaging. Out of the total waste littered, plastic poly bag is around 50-60% as observed in NPC's macroplastic assessment studies undertaken in four study areas viz, Agra, Allahabad, Haridwar and Mumbai. This is also the case in many developing as well as developed countries.

2.4.2 Review of Policies enacted in various countries

A new report from UN Environment and WRI indicates that at least 127 countries (of 192 reviewed) have adopted some form of legislation to regulate plastic bags as of July 2018.

As of July 2018, one hundred and twenty-seven (127) out of 192 countries reviewed (about 66%) have adopted some form of legislation to regulate plastic bags.

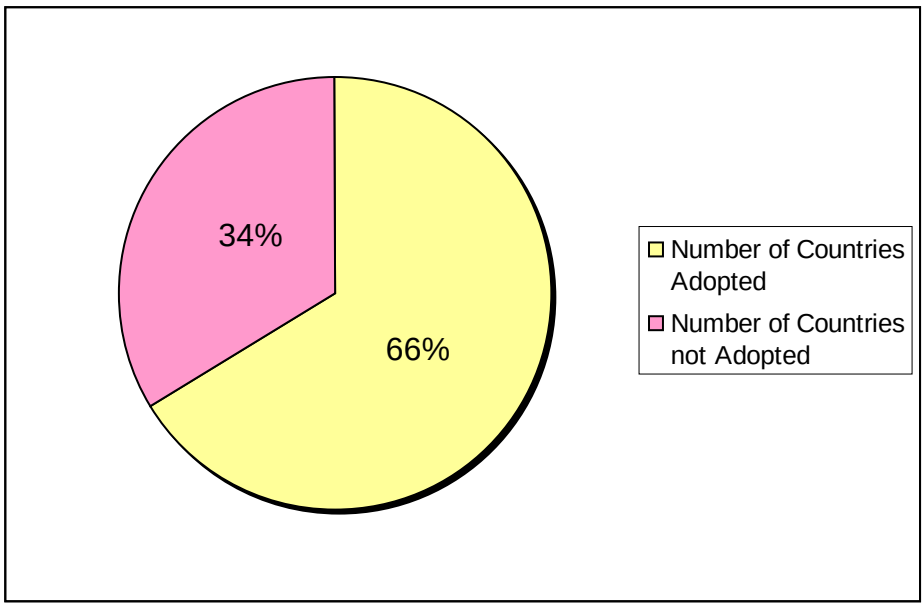


Figure 2.1: Countries adopted legislation to regulate plastic bags out of total 192 countries
Source: Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations, UNEP

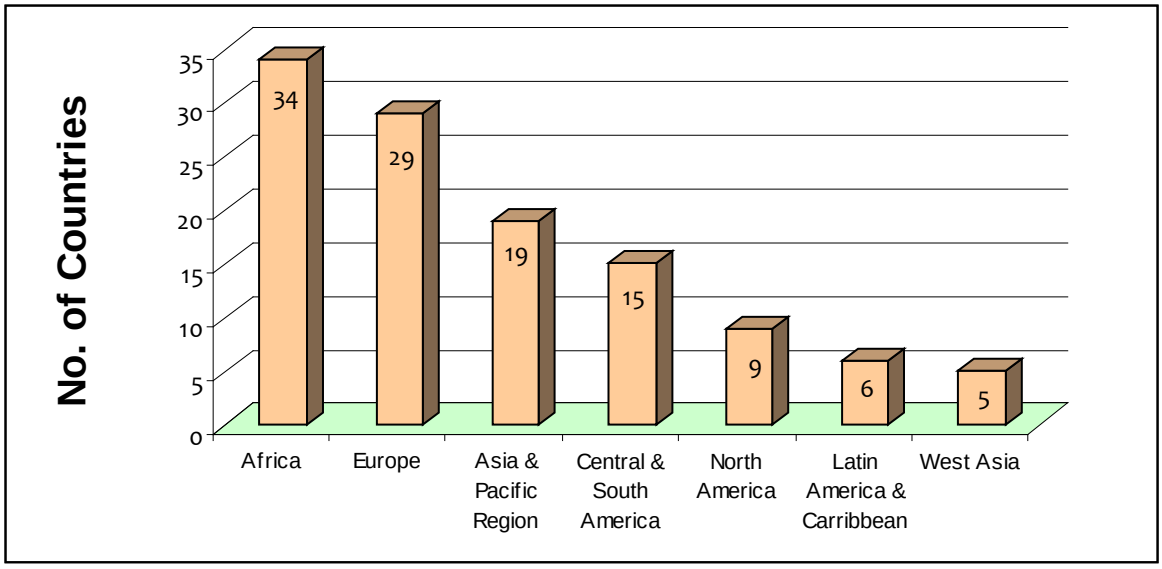


Figure 2.2: Plastic Bag Ban

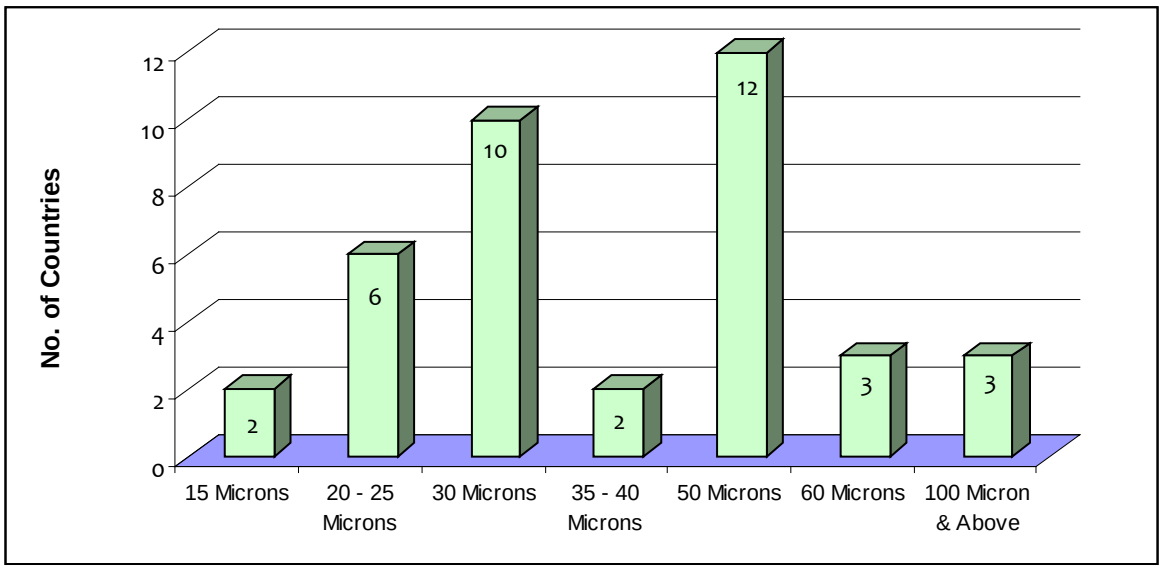


Figure 2.3: Countries with Thickness Thresholds for Plastic Bags

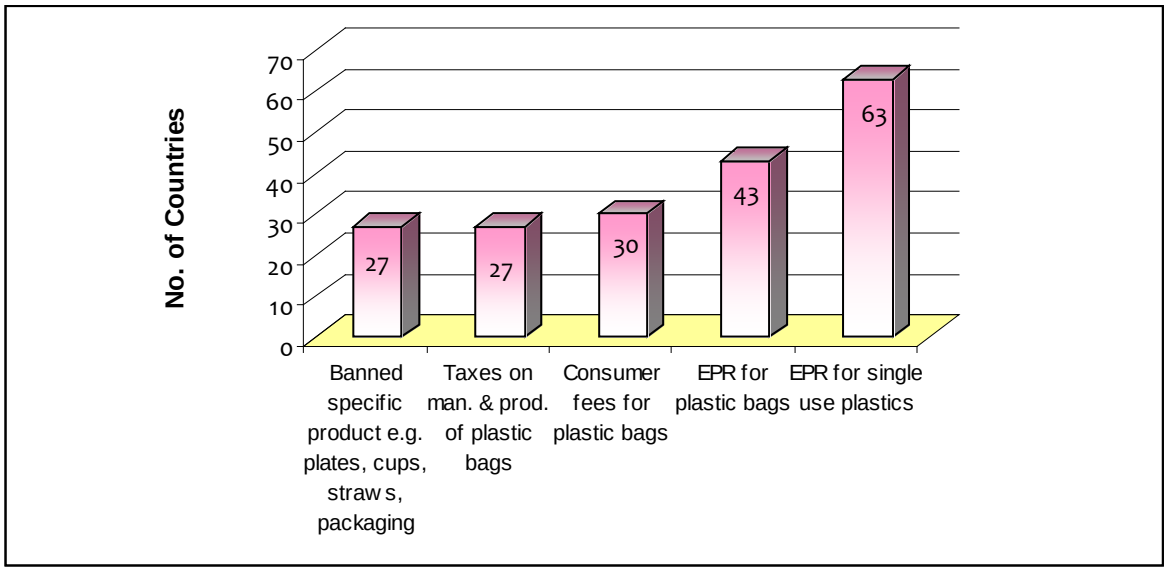


Figure 2.4: Plastic Bag Regulatory Measures

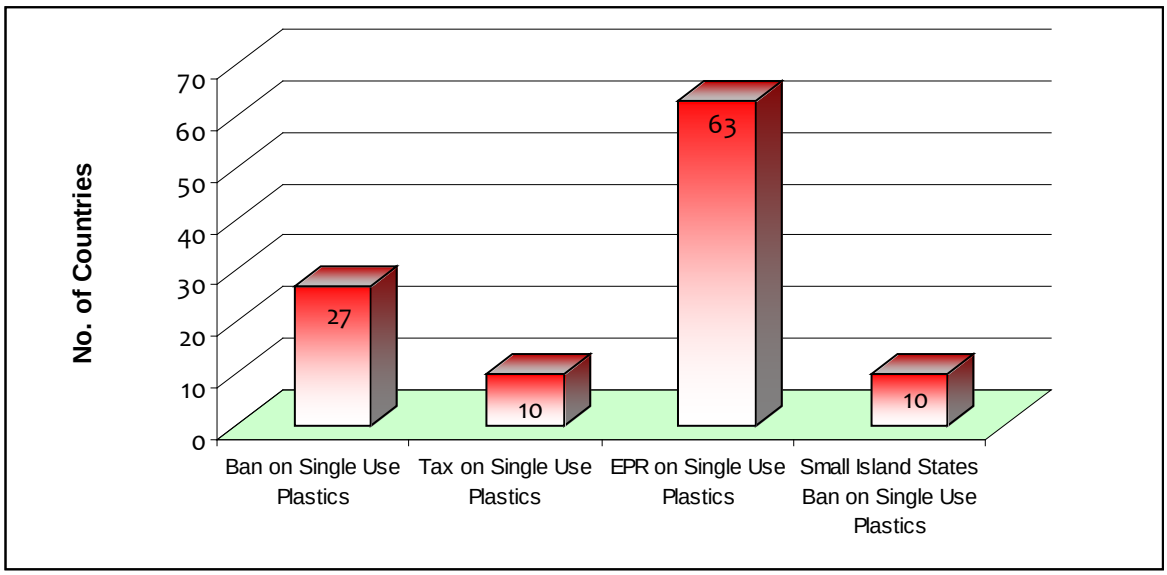


Figure 2.5: Regulatory Measures on Single use plastics

Some of the success stories in the world are briefly given here

1. **Case Study of Plastic Bag Ban in Kenya** (NEMA, 2020)

- Ban on making, selling, of importing" plastic bags, enacted in 2017
- One of the most strict ban enacted in world
- exceptions to the law: certain kinds of single-use plastic bags are still allowed for garbage bin liners, medical waste, construction and for packaging foods like bread, as well as the use of cling film (like Saran wrap)
- Non compliance Penalties- fines of up to $19,000, and 4 years in jail
- more than 500 arrests — mostly traders, small-scale businesses and citizens found with banned bags, about 300 people have been prosecuted
- As a result of the ban, 80% of the population has stopped using plastic carrier bags
- Alternative thicker, recyclable, polypropolyene woven bags were made available
- Many of those targeted by officials patrolling the streets were manufacturers and sellers of banned bags, rather than users.

Source:https://www.ncsl.org/research/environment-and-natural-resources/plastic-bag- legislation.aspx
https://www.reusethisbag.com/articles/where-are-plastic-bags-banned-around-the-world/

2. Case studies from Europe

- a 22c plastic bag tax was introduced in Ireland brought reduction in usage by 90%
- In Portugal, drop is in excess of 85%
- Denmark is lowest in plastic usage in Europe, 4 plastic bags per person per year

3. Case study from China

- Coined plastic pollution as white pollution
- A full ban was adopted in 2008
- Plastic bag waste generation dropped by 60% to 80%, an effective reduction of some 40 billion bags
- However, complete enforcement is still issue

2.4.3 Policy ban on plastic bags and other single use plastic item in India

A review of plastic ban in India as a part of Swachh Bharat Mission of Govt. of India is tabulated below:

States in India with complete, partial and no ban on plastic items is as given below in Table 2.3 and is depicted in Figure 2.6.

Table 2.3: Plastic ban scenario in India with list of states/ UTs

Complete Ban	Partial Ban	No Ban
Bihar Chandigarh Chhattisgarh Daman, Diu & Dadra Nagar Haveli Haryana Himachal Pradesh Jharkhand Karnataka Madhya Pradesh Maharashtra Nagaland Punjab Rajasthan Sikkim Tamil Nadu Tripura Uttarakhand Uttar Pradesh	Andhra Pradesh Arunachal Pradesh Assam Gujarat Kerala Lakshadweep Mizoram Odhisa West Bengal	Goa Jammu & Kashmir Manipur Meghalaya

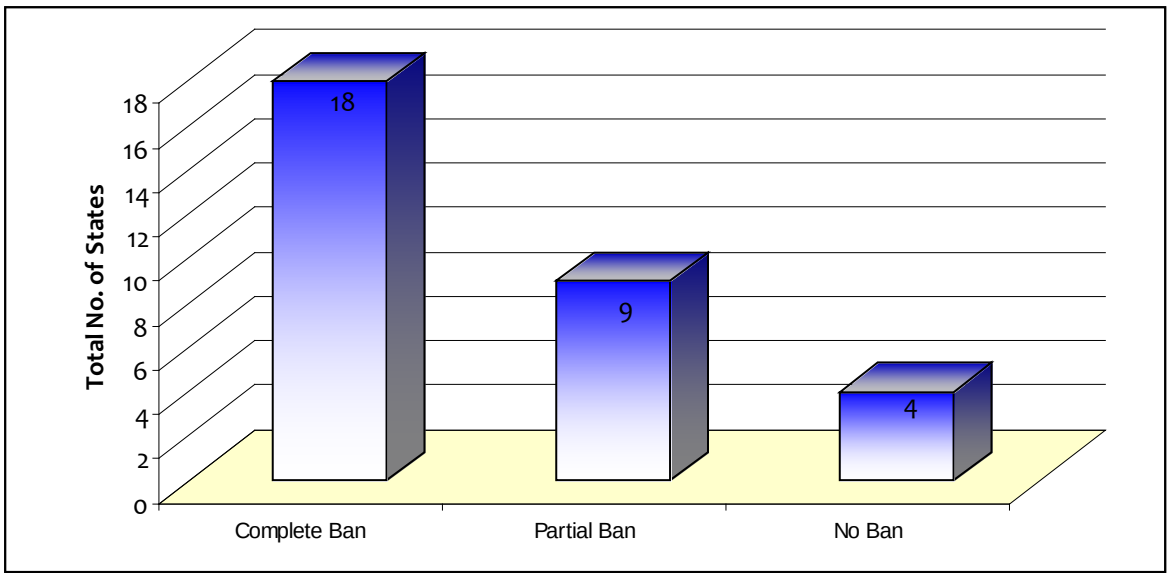


Figure 2.6: Plastic Ban Scenario in India

Some successful case studies of plastic ban in India are briefly explained below:

Table 2.4: Successful case studies

Successful case studies			
1.	Sikkim	• A northeast state with hilly terrain launched the plastic ban in 1998 • State officials took the action after heavy rain caused several major landslides in the area. Experts partly blamed plastic waste for blocking systems that carry away rainwater. • People shopping at the city's main vegetable market bring their own cloth bags to collect their goods. • Restaurants in the area serve food on plates made of paper or plant material instead of plastic. • Ban on plastic bags is successful	 Use of plastic alternative (leaf) for serving food by street vendors Source: Pasricha/VOA
2	Indian Railways	Railway Catering and Tourism Corporation (IRCTC) to set up plastic bottle crushing machines in major railway stations and increase the use of reusable products to reduce plastic footprints. Planned in 2018 to install plastic bottle crushing machines at 2,000 stations across the country. Enforced a ban on single-use plastic, with less than 50-micron thickness, from October 2, 2019 onwards in its premises and trains. Directed the Railway Catering and Tourism Corporation (IRCTC) to	 Source: Tweet by Honourable Minister of Railways Photoplate depicting bottle crushing machines installed in stations

		implement the return of plastic drinking water bottles as a part of Extended Producer Responsibility. Introduced in 2018, bio-degradable cutlery made from sugarcane in eight select Shatabdi and Rajdhani trains originating from New Delhi	 Source: Tweet by Honourable Minister of Railways Photoplate depicting biodegradable cutlery used for serving food in some selected trains  Photoplate depicting terracotta glasses and bowls replacing plastic
3	Indian Airports	• 55 Indian airports are single-use plastic free now banning of single-use plastic items like straws, plastic cutleries, plastic plates, etc. • Quality Council of India has undertaken third party assessment and declared them single use plastic free • Installed waste recycling machines that help in crushing plastic PET (polyethylene terephthalate) bottles, steel/aluminium cans and plastic bags in an eco-friendly way. • At some airports, The plastic straws and cups have been replaced by paper straws and paper cups, plastic spoons, forks, and plates have been replaced by 100 per cent biodegradable and compostable tableware from a company called 'Ecoware'. Along with this, the widely used plastic bags have been replaced by cloth bags, paper bags and traditional brown paper bags. • Installed incinerators for safe disposable of plastic wastes such as sanitary napkins/diapers	Source: Tweet of Airport Authority of India

4	Pilgrimage Places	• Imposing Complete plastic ban in Puri's Jagannath temple from April 1, 2020. • The majestic Jagannath Temple is located in Puri in the state of Oddisha is a major pilgrimage destination for Hindus. About 1 Lakh people visit the temple everyday and more on festive season (Puri Municipal corporation) • Devotees will be provided 'prasad' (religious offering) on leaves • Initiative by Shree Jagannath Temple Administration (SJTA)	 Source: https://economictimes.indiatimes.com/news/politics-and-nation/complete-plastic-ban- in-puris-jagannath-temple-from-april-1/articleshow/74487153.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
5	Reducing plastic pollution		
a.	Gurugram,	**Crockery Bank' for Steel Utensils to reduce plastic waste**	
	Haryana	Sameera Satija, a resident of Sector 14 in Gurugram, has opened a steel crockery bank, which lends citizens steel utensils for functions and occasions free of charge, in an effort to reduce the usage of single-use plastic cutlery. The idea for the bank came from observing charity drives, such as 'chabeels' (organised by devout Sikhs to serve water) and 'bhandaras' (community banquets). Many of the groups she observed were serving water and food in disposable glasses/plates, even though the effort itself was selfless. Through a company manufacturing disposable plastic glasses and plates, Sameera has created a Facebook page named 'Crockery Bank for Everyone' to promote the project. One may get in touch with them, share programme date and contact number. All that is required is a written letter for the requirement from respective Resident Welfare Association functionary or ward councillor. If none of this is possible, two members who require the crockery have to submit ID and address proofs. After this, the utensils may be used, washed and returned. *Source – The Better India website,* (taken from compilation of success stories from Swachh Bharat Abhiyan (Cleaniliness drive of Government of India) Story copied as such from Swachh Bharat Newsletter  *Source – The Better India website*	
	Bangalore, Karnataka	Lakshmi Sankaran and Rishita Sharma also run a Rent-A-Cutlery which they started in Whitefield, Bangalore in 2016 to replace plastic and disposable cutlery used in parties to limit the waste generated. they began with a hundred and fifty sets of plates, glasses, bowls and spoons that they bought. They were sceptical of the initiative picking up traction but today they have regular customers all over Whitefield. Hygiene was something they had to ensure because customers were	

		initially not willing to clean the cutlery themselves but this slowly changed.  Source:https://bengaluru.citizenmatters.in/citizens-in-whitefield- reinvent-recycling-and-find-new-ways-to-go-green-27859

2.5 Product Design

Recyclability of a plastic waste is economically feasible only when it is built into their design. A number of new products have come up having advantages of usage, improved productivity but which challenges their recyclability. Packaging materials have to be such designed that they are fully reusable, recyclable or compostable.
(https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/)

Recycling, reuse packaging efforts in three areas: reducing our use of materials, using more recycled content and ensuring our packaging is reusable, recyclable or compostable. And when it comes to plastic, we're looking at where we can use less plastic, where we can use better plastic – and where we can use no plastic at all.
(https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/)

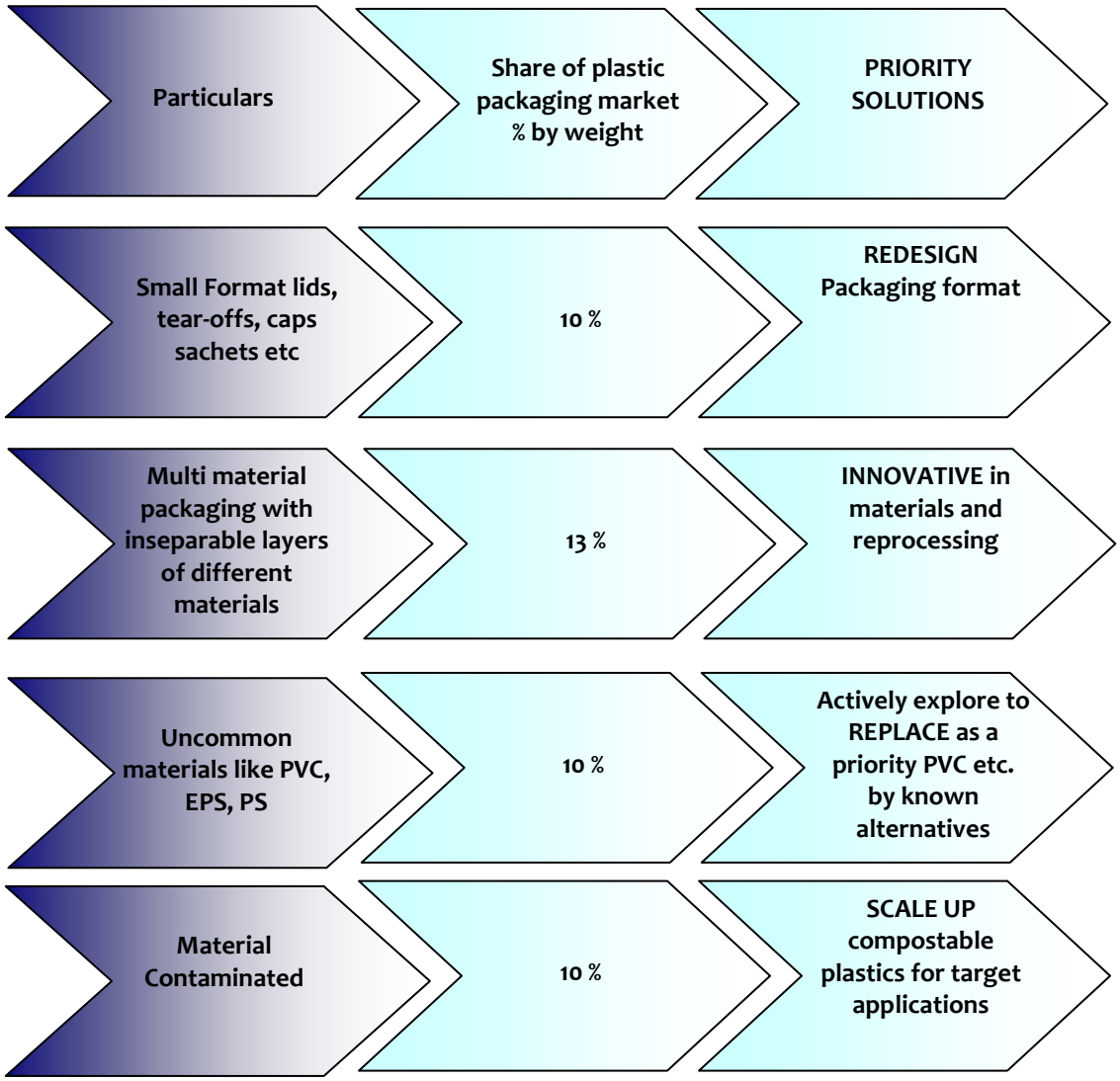


Figure 2.7: Plastic Packaging Segments That Need Fundamental Redesign And Innovation

Major MNC players in the world have committed to reduce packaging waste:

- In January 2017 Unilever committed to ensuring that 100 percent of their plastic packaging would be designed to be fully reusable, recyclable or compostable by 2025. Their new target builds on their previous goals to have the waste associated with the disposal of their products and increase the recycled plastic content in their packaging to 25 percent by 2025.
- Colgate-Palmolive and AB InBev have demonstrated similar 2025 ambitions with commitments of 100 percent recyclability or returnability across various product categories.
  (https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/)

The flexible packaging market is segmented on the basis of application in industries of:

• food and beverage

- cleaning products
- pharmaceutical
- medical and personal care
- construction and building, and
- others

There are two types of flexible packaging:

(i) Monolayer packaging

Monolayer single material flexible packaging is commonly found in plastic bags, produce bags, and self sealed food storage bags. Monolayer, single material flexible packaging constitutes about half of flexible packaging waste. It is easy to recycle such wastes.

(ii) Multilayer Packaging

Multilayer packaging comprises of layers (ranging from 3 up to 20 layers) of a variety of plastic films, adhesives, inks, and metals. These layers are firmly adhered together by either the inherent bonding action of the polymers themselves or adhesives. A multilayer packaging film can be coextruded or laminated. There is, currently, no practical method of disposing of or recycling this heterogeneous, multi-ply packaging material after use. This is because in the combined form certain layers melt at different process temperatures than other polymer layers and some layers such as an aluminum coating do not melt at all at polymer processing temperatures.

LLDPE is widely used in food packaging, is sometimes combined with HDPE which is stiffer, harder, and has higher tensile and bursting strength but lower impact and tear strength than LLDPE.

Some of innovations in product design are listed below:

1.	**Redesigning multilayer pouches**
a.	Food and beverage is the largest application market segments of flexible plastic packaging. Multi layer packaging is commonly used. Multi layer packaging comprises of following: • aluminum foil • polyolelins, such as polyethylene, polypropylene or condensation polymers, such as PET or polyamide (nylon) films • polyolefin films are coated with barrier coatings such as EVOH/PVDC to improve oxygen barrier properties • a heat sealing material such as wax or hot melt adhesive Further, single-use plastic sachets allow low-income consumers in developing countries like India to buy small amounts of quality products that would otherwise be unaffordable to them. These products lend to provide hygiene or nutrition benefits. It has observed during our primary survey in the study areas as well as during macroplastic assessment studies, that these material are found to be mostly littered everywhere and also in the barriers and drains leading to river and contaminating our river water as found from microplastic assessment in the river. This is because these multilayer flexible packaging materials are not currently recycled and have little or no economic value and so they leak into the environment.

There are number of efforts being taken by various packaging industries worldwide towards making these multilayer pouches recyclable without impact on their properties in preserving the food and maintaining hygiene, etc. Efforts are being made (Michael Niaounakis, 2019) towards manufacturing pouches made from monocomponent material, namely polyethylene that will allow recycling.

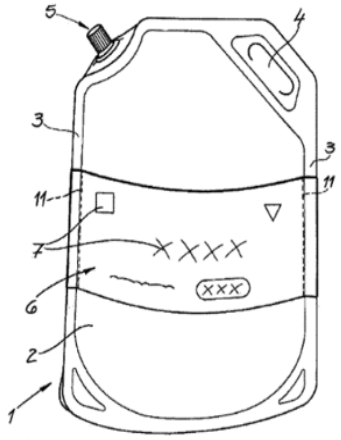
HDPE provides the stiffness but the physical and optical properties of HDPE (such as haze and gloss) are comparatively poor.	LLDPE provides very good physical and optical properties but poor stiffness.
physical and optical properties of medium density polyethylene (MLDPE) generally fall in between those of HDPE and LLDPE	

Innovation 1

According to (Michael Niaounakis, 2020), a 100% recyclable pouch made of polyethylene monomaterial, with detachable decorative panels has been developed.

Patent details are as given below:

Mondi and Werner & Mertz developed a 100% recyclable pouch made of polyethylene monomaterial, with detachable decorative panels. The pouch is free of glue or adhesive. Spout and cap are also made of polyethylene.



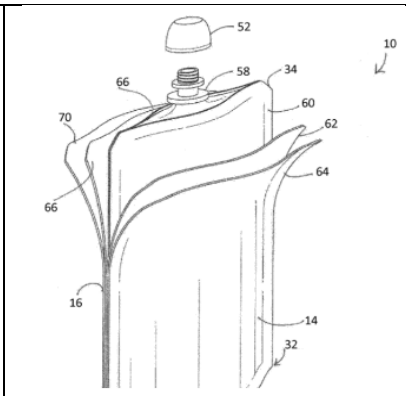


Figure above shows the design of new recyclable pouch which can be separated into layers for recycling (Michael Niaounakis, 2019).

Innovation 2

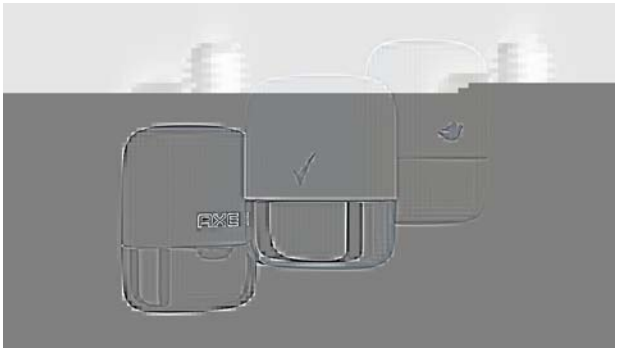
Avantium's business unit Synvina produced pouches from biaxially oriented poly(ethylene furanoate) (BOPlF), which is a biobased polyester. The pouches consist of a two-layer laminate of a BOPEF layer and commercial 55% biobased polyethylene (bio-PE) scaling layer. BOPEF/ bio-PE's inherent oxygen permeability of about 10 cm^2/m^2day atm fits well with oxygen-sensitive products such as cheese and dairy. dry snacks, sauces, and cosmetics, which, today. employ more complex multilayer Structures such as PVDC-coated BOPET or EVOH-containing sealant layer.

Besides the reduced complexity, BOPEF/bio-PE pouches offer excellent toughness and clarity and are suitable for dry and liquid products (Michael Niaounakis, 2019).

b. Replacing EVOH in Multilayer packaging

Multi-layer systems are being used in the packaging industry to add various functionalities to the application. Standard in the market is a 5-layer film set up, but the trend is to go to 7 (and more) layer systems. The excellent oxygen barrier performance of this 5-layer EVOH concept can be attributed to the fact that the oxygen molecules are trapped in the free volume by the hydrogen bonds in the

	EVOH structure. This way shelf life of the food is enhanced. The use of carbohydrates (natural materials consisting of crystalline amylose and branched amylopectin) like starch do have the potential to have similar functionality as EVOH to have excellent oxygen barrier performance. Therefore, replacing EVOH by natural materials having similar functionality can be step towards reducing the challenge of recyclability of these materials.
c.	Bio-based plastic products
	• These are material which undergoes decomposition in a specified period of time under composting conditions in industrial facilities. This type of plastic is made from biomass and can degrade naturally in a matter of years. • These plastics are significantly made of renewable materials like bio mass and save up to 40% energy in production as compared to their petrochemical counterparts. • Many polymers like PLA (Poly Lactic Acid), PHA (Poly Hydroxyalkanoates), Bio PTT (Poly Trimethyl Terephthalate), Bio PDO (Propanediol) etc. form the upcoming trends. • A decade ago, Coca-Cola introduced a fully recyclable package made from up to 30 percent plant-based materials but made the announcement in 2018 that they were ready to take things further, plan named "World Without Waste".
d.	Alternative materials
	Milk pouches are 100 per cent virgin LDPE (low-density polyethylene) monolayer ones which are recyclable if sent to recycling industries. To make them reusable, the industry in India is mulling to manufacture pouches and bags made from polyester filament yarn (PFY) which could be used 45-50 times thicker and are also recyclable as well as reusable. Consumers would be able to send these pouches back to milk suppliers, resulting in savings in the cost of packaging. (https://packaging360.in/news/single-use-plastic-ban--industry-mulls-polyester-yarn-for-milk-packaging/)
e.	Making shopping system circular –Initiatives of MNCs
	• An innovative waste-free shopping and delivery model for reusable packaging innovations and refillable product formats. Products are shipped directly to consumers and are then returned and refilled. The system brings together major brands and retailers with the idea of shifting from a model that is 'disposable' (where packaging is thrown away or recycled after use) to one that is 'durable' (where packaging is reused and any leftover product is either recycled or reused). • Nine of Unilever brands are participating in the pilot in New York, New Jersey and Pennsylvania in the US and in Paris, France: Axe, Dove, Hellmann's, Love Beauty and Planet, Love Home and Planet, REN Clean Skincare, Rexona, Seventh Generation and Signal. Dove, Rexona and Axe will test a premium, refillable deodorant stick called minim™. Made from stainless steel, the design is minimal, compact and sustainable. Depending on use, the product will last on average one month, with the packaging designed to last at least 100 cycles, around eight years in total. • Another innovation from Unilever is refillable toothpaste tablets, which require less water than normal toothpaste, but are designed to be used in the same way. You chew, brush as usual and rinse. They come in a recyclable, refillable jar which means there's no packaging or product waste.

	• Loop™ is formed by Unilever through coalition of large companies including other manufacturers, as well as the retailer Carrefour, courier UPS and resource management company SUEZ, along with TerraCycle, a leader in recycling. All partners have the same goal: to develop supply chains that are more 'circular' from design through to consumer use. The materials differ for each product, but most use glass or aluminium and all are fully recyclable. The initial lifecycle analysis (LCA) showed that Loop™ has the potential to substantially reduce consumer waste and GHG emissions and we will use the pilot to update the LCA. (https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/)
f.	Use of recycled materials in plastic products
	• • Unilever has sought to use 'better plastic', using recycled materials in their plastic bottles – which they began in 2013. In 2017, they committed to increase the recycled plastic content in their packaging to at least 25% by 2025. • • In 2018, they used around 4,845 tonnes of post-consumer recycled (PCR) plastic in their packaging, such as high-density polyethylene (HDPE) and polyethylene terephthalate (PET) in their plastic bottles. They expect their use of PCR materials to accelerate rapidly over the next few years as the design processes begin to deliver at scale. This will help to achieve their global commitment to include at least 25% recycled content in their plastic packaging by 2025. • They took some big steps forward in 2018, introducing post-consumer recycled waste materials into more of their products. For example, they launched their REN Clean Skincare packaging with 100% recycled PET (rPET) bottles. Working with TerraCycle, a US recycling company, they created the bottles from 80% recycled plastic bottles, and 20% reclaimed ocean plastic. In 2018, they also launched 100% rPET packaging for their Sunlight hand dish wash bottles in South Africa, Vietnam and Thailand, Comfort Intense in the UK and in their CIF Naturals bottles in France.  • Another product range (Love Beauty and Planet range) – launched in 2018 – has put packaging at the centre of its consumer proposition. Its packaging is made from 100% recycled PET (rPET) and is also 100% recyclable. A special adhesive makes it easier to remove labels cleanly at the recycling facility. • The caps and pumps are not yet made from recycled content but they have a commitment to use at least 50% recycled plastic in pumps and caps by 2020. The brand also contributes $40 per tonne of carbon to a carbon tax fund which helps to reduce carbon emissions, and to fund initiatives that encourage higher recycling rates and set up recycling communities. (https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/)

g.	Reduction by redesign of consumer product: using less packaging
	In this respect Unilever optimised materials through redesigning their packaging or developing concentrated or compressed versions of their products. This required significant investment and ingenuity to reduce the amount of material in a pack, even by just one gram. However, the return on investment is worth it when their innovations successfully reduced the packaging and waste impact in the value chain, result in material cost savings and which are more attractive to consumers. Recent innovations to optimise our packaging include: • During 2018 we launched a three litre bottle for our Omo laundry detergent brand in Brazil, with a formula at six times the concentration of the original, so it can be diluted in people's homes. This has reduced the volume of plastic used by 75%. • Combining the technology of a thinner polyethylene layer with a stronger polymer and smart polyethylene design in our Home Care brands' flexible packaging, such as sachets and pouches, meant we could reduce polymer use by 1,400 tonnes in 2017. • Innovations such as the foamed plastic layer in the middle of plastic bottle walls using MuCell™ technology – which we developed in collaboration with MuCell and Alpla in 2014 – reduced plastic use by up to 15% per bottle. In 2017, we launched our Dove hand wash bottles with MuCell™ technology, avoiding the use of 304 tonnes of plastic. • Lightweighting initiatives in their skin care product packaging across Vaseline, Dove, Pond's, St. Ives and Simple among others, reduced plastic content by around 1,100 tonnes in 2018. Lightweighting projects have led to avoiding the use of more than 1,000 tonnes in their hair product packaging – including Dove and TRESemmé – in Brazil and Argentina during 2018. • In China, as in most countries, the majority of ice cream cartons are laminated to survive freezer temperatures. This means that the cartons have a low recycling rate. So, we worked with an ink supplier and carton converter to develop a matt UV varnish to replace the film. This could cut packaging waste in China by around 300 tonnes per year. • In Israel, they removed the aluminium wrappers around the individual Crembo ice creams in the eight-pack. Additionally, they optimised the rest of the packaging. In total, this has cut the need for over 13 tonnes of aluminium, around three tonnes of polyethylene terephthalate (PET), over one tonne of polypropylene (PP) and over three tonnes of paper through this single product. • Refills also visibly reduce the volume of plastic used in packaging, and have the added benefit of being more affordable for people. (https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/)
h.	Eliminating Extra or Unnecessary Packaging
	For both retail and e-commerce consumers, it's a common experience to find newly purchased products wrapped in several different materials, most of which end up in the trash can. As brands have shifted from shelves to shipments, over packaging to ensure safe delivery has become common. To overcome the waste associated with this type of non-critical packaging, brands are also committing to eliminating extra or unnecessary packaging. Examples are: • Amazon designed to reduce waste, keep products safe and provide a great packaging experience to their customers. As a result, in 2017 alone, they reduced packaging waste by 16 percent and avoided 305 million shipping boxes. • A new type of retail: zero-waste grocery stores. In this type of environment, goods are stored in dispensers that are collected into "packaging" that consumers bring from home. This concept began in Europe more than a decade ago, according to Smithsonian Magazine, it's been

	spreading globally. Still, these types of stores have their own set of challenges (think food waste) but provide an alternative to over packaging. (https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/)

Changes in final consumers' demands and behaviors can also lead manufacturers to include more recycled plastic in their products. This is a phenomenon seen in the food industry. Pressure from consumers and civil society may push brands to increase the amount of recycled plastic in their packaging.

Chapter 3: Plastic Waste Collection

3.1 Organised Plastic Waste Collection other than that by Municipal Corporation

3.1.1 Through Waste Management Companies

On one hand, there is huge amount of MLP and other plastic waste which needs recycling and on the other hand, waste treatment providers such as cement kilns, waste to energy plants, pyrolysis plants or road construction companies do not get desired quantity and quality of waste. Therefore, there is a necessity of setting of waste management companies which collects, segregates and clean waste and provides to the waste treatment service providers like cement plants, WTE, pyrolysis plants, etc. Few waste companies working in India are listed below:

Table 3.1: List of companies working in India for waste management

Sl. No.	Name of the waste company	Location	Source of Funding
1	Lets recycle	Ahmadabad, Gujarat	funded by impact investors such as Aavishkaar and Asha impact.
2	Waste Ventures	Hyderabad, Telangana	Funded by Vilcap investments.
3	GEM enviro	Delhi	plastic waste PRO for Bislery, Pepsi, Coco Cola, etc.
4	Raddi Connect	Mumbai, Maharashtra	
5	Thekabadiwala.com	Bhopal, Madhya Pradesh	Angel funding.
6	Saahas zero waste	Bangalore, Karnataka	Funds through India Angels network.
7	Rudra Environmental Solutions	Pune, Maharashtra	Own pyrolysis plant acquired by Blue Planet environmental solutions Pte Ltd., Singapore.

Multi Nationals Companies such as ITC, Hindustan Lever, Pepsi Co, Coco cola, etc as part of their EPR have also initiated plans toward collection of packaging waste and channallising to appropriate recycling facility. A case study of ITC's initiative is placed below:

Another corporate who is undertaking waste collection and recycling is ITC. A case study of ITC is placed below:

Fast-moving consumer goods (FMCG) major ITC has introduced the country's first MLP collection and recycling initiative in Pune, tying up with a waste-pickers co-operative (Swach) at one end and recyclers such as Shakti Plastic at the other to ensure sustainable plastic waste management. Further, ITC has invested in technology to help convert the MLP waste into pellets, used for making everyday items such as plastic chairs, stools, files, clips, buckets, mugs etc. photoplate depicts collection of Multi layered Plastics by ITC with the help of waste picker group called SWACH in Pune near Mumbai

(Source: https://www.business-standard.com/article/companies/itc-launches-first-multilayered- plastic-collection-recycling-drive-in-pune-119100201010 1.html)

Such initiatives are also required in other parts of the country including study areas.

3.1.2 Depository schemes in India

A number of depository schemes have been initiated in different parts of India towards collection of plastic waste as a part of Swachh Bharat Abhiyaan and other initiatives. A review of these schemes is listed below.

Waste Depository Schemes in India

Table 3.2: List Waste Depository Schemes in India

S. No.	State	City	Scheme Details
1	Chhattisgarh	Ambikapur	• First Garbage café in India • Inaugurated on 10 October, 2019 • Initiative by Municipal Corporation • Budget of Rs. 0.6 million to start the scheme • Earning of Rs. 1.2 million per month from selling of plastic granules and paper waste • 1.5 km road constructed with plastic granules Scheme • 1 kg of plastic waste: full meal in return • 500 gm plastic waste: breakfast in return. • Collected plastic waste is sent to corporation run recycling unit that turns it into granules

S. No.	State	City	Scheme Details
			 Source: (Photo: Twitter/@TS Singh Deo)
2	Delhi	Delhi	• Located at the City Centre mall in Dwarka Sector 21 • Opened by South Delhi Municipal Corporation in December 2019 • Around 8-10 kg of plastic waste collected at the cafe every day which is sent to the processing plant for recycling purposes Scheme • 250 gms of plastic waste: snacks in return • 1 kg of plastic: full meal in return. • Discounts at other food outlets in the mall in return for plastic waste  Source: https:// zeenews.india.c om/delhis-first- garbage-cafe- opens-in- dwarka-get-
3	Odhisa	Kotpad Notified Area Council (NAC) in Koraput district	• Rs 5-meal in exchange for a kilogram of plastic waste • Waste collected and brought in by residents includes polythene bags, plastic bottles and cups
4	Odhisa	Bhubaneswar	• Initiative by Bhubaneswar Municipal Corporation • Facility available at State government run 11 Aahar Centres in Bhubaneswar city • Waste collected and brought in by residents includes polythene bags, plastic bottles and cups Scheme • A meal in exchange for a half kilogram plastic waste

S. No.	State	City	Scheme Details
			 Source: https://www.india times.com/
5	Gujarat	Dahod district	• "Unique Café" located in tribal-dominated Dahod district • Main purpose to take government led Swachh Bharat Abhiyan scheme to rural areas and encourage people to keep their surroundings clean Scheme • For 1 Kg plastic waste: Snacks • For ½ kg plastic waste: cup tea  https://yourstory.com/socialstory/2020/02/sustainable-cafes-environmentalism-waste-management-plastic https://www.shortpedia.com/en-in/amp/miscellaneous-news/cafe-in- gujarats-dahod-provides-free-snacks-and-tea-in-exchange-for- plastic-waste-1581336868
6.	Assam	Pamohi	• Unusual school— "Akshar" • Located in remote area in woods • Prior to setting up of this school, it was usual in area to burn waste plastic to keep warm Scheme • Students bring polythene bags full of plastic waste as the only form of "Fee" that this school accepts • Each child brings in at least 25 items of plastic waste per week, as their "fee" and their contribution to community and environment • Waste deposited by students is regularly segregated and recycled • Older kids tutor the younger ones and in return get small things like snacks, toys, chocolates etc. • The school, through their students, educates the community about the health hazards due to burning of plastic

S. No.	State	City	Scheme Details
			 Source: *#IndiansAgainstPl astic series. The Better India* and *Karnival. com*
7	Uttar Pradesh	Meerut	• Swachhta Meerut's Waste to Food Café • Poor and homeless families of rag-pickers as the silent warriors of Swachhata mission • Café solving two big problems of nation, i.e. Waste Management and Hunger • It supports both "Swachh Bharat Mission" and "Fight Against Hunger" schemes Scheme • Half kg of waste like plastic, glass, tin cans to get one meal • One kg of waste like plastic, paper, glass tin cans to get two meals
8	Maharashtra	Pune	• M/s. ITC Ltd and SWaCH working with Pune Municipal Corporation to incentivize collection of Multi-Layered-Plastic (MLP) waste and channelize it for recycling • In first phase, waste processing facility with capacity to manage 200 metric tons per month • Program to create an additional income for around 3,500 waste collectors involved in collection and sorting of MLP
9	West Bengal	Siliguri	• Started by alumni of Goethals Memorial School and Nishkam Khalsa Sewa in West Bengal's Siliguri district • Barter system gives free food to anyone who brings 500 gram of plastic • Exchange system takes place every Saturday • Helping to save environment
10	Uttar Pradesh	Prayagraj	• Aim to cut down on menace of littering during "Magh Mela" and "Kumbh Mela" in Prayagraj • Mela association and a popular tea brand installed multiple kiosks in several areas of Mela • Each kiosk dispensed a "free cup of tea" every time recyclable waste items like wrappers, plastic bottles, tetra packs were fed into the kiosk • Kiosk worked like a vending machine except that a person did not have to pay money • Prayagraj Nagar Nigam collected the waste every evening and gave it to recycling companies
11	India	Indian Railways	• Deposit plastic bottles and get your phone recharged • 160 plastic bottle crushing machines at 128 railway stations across India • Installed machines will recharge phone in exchange of a

S. No.	State	City	Scheme Details
			plastic bottle • Commuter to feed the mobile number and deposit the plastic bottle, the phone number to act as a key to charge the phone  https://www.thebetterindia.com/195194/indian-railways-plastic-barter-system-garbage-cafe- assam-school-india/

3.1.3 Waste Depository Schemes in Countries other than India

Some literature review of schemes initiated in other countries is listed below:

Table 3.3: Waste Depository Schemes in other Countries

S. No.	Country	City	Scheme Details
1	Columbia	Main cities of Bogota, Cali, Medellin and Barranquill a	• Colombia's municipalities produce around 28,800 tonnes of solid waste per day, with 10,000 tonnes of this waste being generated by the main cities of Bogotá, Cali, Medellín and Barranquilla. • To overcome their serious waste problem, Colombia came up with the idea of ECOBOT – A recycling initiative that promotes the culture of recycling across the country. • By incentivizing and giving rewards for every recycled item. ECOBOT is basically Reverse Vending Machine which is located in shopping malls, institutions, and public spaces and encourages the process of recycling the PET bottles. • Every time plastic bottles (PET) or the caps are deposited, a coupon is offered by associated companies called Ecopartners. From restaurant coupons to movie, tickets to shopping dollars this machine covers it all. • As for all the plastic that is collected, it is sent to recycling plants instead of landfills. 

			Source: https://swachhindi a.ndtv.com/5- countries- revolutionised- way- tackle-trash- waste-5013/
2	Indonesia	Malang	• Malang generated more than 55,000 tonnes of waste every day. It was also a city where a majority of people did not have health insurance. These two issues may seem unconnected, but it proved to be as a huge social opportunity. • "Garbage Clinical Insurance" was set up which let people trade garbage for medical services and medicines. • This scheme aims to tackle both poverty and waste in Indonesia and inspires low-income households to recycle their trash because by doing so they are able to finance their health micro-insurance. • The clinic takes in the trash from people and sells it to recyclers for recycling. The money collected from recyclers is then spent on giving people basic health insurance  Source: https://swachhindia.ndtv.com/5-countries-revolutionised- way-tackle-trash-waste-5013/
3	Philippines, Haiti and Indonesia		• "The Plastic Bank" is a "*chain of stores for the ultra- poor, where everything in the store is available to be purchased using plastic garbage*." • The block chain-based app is free to download and offers a way for locals to get paid outside of traditional currency. • Beyond food and goods, the stores launched by a Canadian start-up also offer mobile services such as Wi-Fi and solar power phone charging. • The plastic waste collected is recycled and sold to global brands for packaging use under the name of *Social Plastic* – as an ethical alternative to *virgin plastics*. • The Plastic Bank has stores in the Philippines, Haiti and Indonesia and plans to expand in Ethiopia and India.  Source: https://www.gsma.com/mobilefordevelopment/blog/plastic-waste-a-new-currency-in-low-income- countries/
4	South Africa	"Mobile" recycling units	• "Packa-Ching" are local mobile recycling units travelling across low income communities and schools in South Africa to buy recyclable waste from residents on specific days. • The initiative addresses logistical and security-related challenges by taking the recycling facility to the doorstep of remote communities and using a cashless e-wallet payment system that eliminates the risk of dealing with hard cash. • Community members bring their bags of recyclable packaging

			material, including plastic, paper, metal cans and glass, to the truck to be checked, weighed and exchanged for a monetary value. The money earned is paid in real time into a cashless e- wallet payment system called eVoucher-Mobi. • The funds are immediately available to spend at participating merchants to purchase airtime or to transfer to anyone in South Africa, all via a mobile phone.  Source: https://www.gsma.com/mobilefordevelopment /blog/plastic-waste-a-new-currency-in-low-

Chapter 4: Treatment Options

4.1 Treatment options

Plastic packaging wastes can be classified into four categories based on the barriers they create towards effective treatment and disposal. Accordingly, counter measures needs to be implemented to overcome these barriers. Table 4.1 depicts the four categories of plastic packaging waste.

Table 4.1: Categories of plastic packaging waste based on their barriers in treatment and disposal

Category	*Small-format* plastic packaging	*Multi-layer* packaging	*Uncommon* plastic packaging materials	*Nutrient-contaminated* packaging
Market share	(about 10% of the market, by weight, and up to 35%-50% by number of items),	(about 13% of the market, by weight) currently cannot be economically, and often not even technically, recycled.	(about 10% of the market, by weight), while often technically recyclable, are not economically viable to sort and recycle because their small volumes prevent effective economies of scale.	
Examples	sachets, tear-offs, lids, straw packages, sweet wrappers and small pots, tend to escape collection or sorting systems and have no economic reuse or recycling pathway.	Chips Packet, Biscuit Wrappers, etc.	PVC, PS, and EPS are uncommon Plastic packaging materials. Less than 5% of PVC Packaging is generally recycled. Further, PS and EPS are rarely sorted from household waste.	*Take away containers, disposable cutlery* often difficult to sort and clean for high quality recycling.
Barriers	The small size of these items means they are likely to leak out of the system into the natural environment. This can be witnessed in emerging countries where their low after- use value makes them less likely to be collected by the informal sector (i.e. waste management activities carried out by waste pickers)11 and in advanced economies, where items like lids,	By combining the properties of materials, multi-material packaging can often offer enhanced performance versus its mono-material alternatives and resulting functional benefits, such as providing oxygen and moisture barriers at reduced weight	The economics of plastics sorting, which is a critical step in the recycling process, are highly dependent on scale. Their low volumes lead to poor outcomes recycling potential. Also, these materials frequently contaminate streams of other	This segment includes applications that are prone to be mixed with Organic contents during or after use. such as food packaging for events, Fast food restaurants and canteens. Either way, when

Category	*Small-format* plastic packaging	*Multi-layer* packaging	*Uncommon* plastic packaging materials	*Nutrient-contaminated* packaging
	caps, straws and sweet wrappers are consistently mentioned as some of the plastic packaging items most found in litter.12 Even when they are collected, small- format items are hardly ever recycled due to significant technical and economic barriers.	and costs. However, this combination of multiple materials means that many of these applications, like those combining plastic and aluminium layers, are economically, and in some cases even technically, unrecyclable.	plastics and harm their recycling economics. For example, even very small concentrations of PVC (0.005% by weight) lead to significant quality reductions in recycled polyethylene terephthalate (PET) and EPS is a known contaminant for polyolefin recyclers as it is not removed during the float-sink separation process. In addition, there are safety concerns about PVC.	there is high contamination with organic nutrients, recycling becomes problematic, as organic residues and odours might be hard to separate from the packaging in the recycling process.
Countermeasure				
1	There is no solution for such waste other than putting a ban on their manufacture and sale. Simultaneous, there is a need towards creating awareness regarding impact of such waste among customers.	Replacing layers of different materials by one material, while maintaining the same functionalities, could lead to packaging which is more suitable for recycling. Such a innovative product has been developed by Dow Chemical, together with Printpack and TysonFoods. They have developed a mono-material, stand-up pouch with improved recyclability versus the existing multi-material	Replacing the *uncommon* materials PVC, EPS, and PS in packaging with known alternatives would need to be actively explored. This would enhance recycling economics and reduce the potential negative impact of substances of concern.	compostable multi-material packaging, which combines enhanced performance due to the use of multiple layers of different materials, with an effective after use pathway (such as composting or anaerobic digestion).

Category	*Small-format* plastic packaging	*Multi-layer* packaging	*Uncommon* plastic packaging materials	*Nutrient-contaminated* packaging
		alternatives, suitable for a specific set of applications (e.g., certain frozen food segments).		
2		Disassembly of multi-material laminates could provide another alternative. Companies like Saperatec (delaminating), Cadel Deinking (delaminating) and APK (dissolving) are developing or scaling up technologies that separate material after use.		
3		Thermochemical recycling technologies, such as pyrolysis, could, in theory, provide a closed-material loop for currently unrecyclable packaging items.		

4.1.1 Recycling of Plastic

4.1.1.1 Challenges

Plastic Recycling industry in India is facing a number of challenges such as:

- Lack of critical infrastructure and support from small players involved in recycling.
- Small recyclers are involved in cleaning process which results in the release of effluent, dust and debris. But due to poor financials, these recyclers are unable to set up and operate large effluent treatment plants or even use dust filters.
- Non availability of segregated and clean plastic waste in appropriate quantity
- Further, no guideline is available towards monitoring of quality of recycled plastic products

Government is considering to create polymer clusters in various parts of country which would include small and medium sized entrepreneurs (SMEs) and recyclers.

Furthermore, there is a growing need for public awareness and discipline towards plastic waste recycling. Maximum participation of all stakeholders is critical to tackle the issue of Plastics Waste Management.

Towards overcoming the challenges, following is required

- Implementation of design changes in plastic packaging to improve recycling quality and economics (e.g., choices of materials, additives and formats).
- Harmonising and adopting best practices for collection and sorting systems.
- Scaling up high-quality recycling processes: Increasing the share of high-quality recycling for plastic packaging would enable more high-value applications for the recycled material, with a corresponding increase in sales prices for recycled plastic. This approach has been adopted for PET bottle-to-bottle recycling facilities and is starting to be developed for other segments of the packaging market, particularly PE and PP.85 While these two plastic types, compared with PET, might present additional challenges to achieving high-quality recycling (e.g., absorption of chemicals or odours), several companies have proven the feasibility of recycling these materials into high-quality applications including packaging (e.g., through the use of hot-washing and degassing). Assuming that 25% of PE and PP recycling would shift to higher-quality recycling.
- Explore the potential of material markers to increase sorting yields and quality.
- Developing and deploying innovative sorting mechanisms for post-consumer flexible films.
- Boosting demand for recycled plastics through voluntary commitments or policy instruments, and explore other policy measures to support recycling.
- Deploying adequate collection and sorting infrastructure where it is not yet in place.
- Developing appropriate Guidelines for recycling and for Recycled plastic products and quality assurance.

4.1.1.2 Innovative Technologies and Approaches in the Area of Plastic Recycling

- Material markers, such as chemical tracers or digital watermarks, are currently researched and piloted but industry views vary widely on their importance, feasibility and cost effectiveness.87 such markers could provide new sorting possibilities in regions where automatic sorting is available, resulting, for example, in an increasing opportunity to supply higher-value food grade plastics.
- Global convergence on marking standards would be required to maximise the impact.
- Depolymerisation (a chemical recycling process breaking down polymers into their monomer building blocks) could offer additional opportunities for high quality recycling – a technology currently most advanced for polyesters like PET.
  (Source: ELLEN MACARTHUR FOUNDATION, 2017)

4.1.1.3 Case Example of a Revolutionary Recycling Process

In Israel, a start up called UBQ has developed a revolutionary solution that converts Residual Municipal Solid Waste (RMSW) that is destined for landfills into patented UBQT^{M} material. Through a proprietary process, the mixed waste stream – containing organic elements like food waste, garden trimmings, paper, cardboard, diapers, dirty plastics, and packaging materials – is converted into an entirely homogeneous composite material (UBQT^{M}) that can be utilized by industry. UBQT^{M} material is thermoplastic and climate-positive. It is compatible as a raw material in many industrial applications and helps create products with a reduced carbon footprint.
(Source: http://www.ubqmaterials.com/materials/)

4.1.2 Recycling process of clean mono-polymer plastic waste

Recycling of Mono-polymer plastic waste recycling processes comprise of:

I. Clean and segregated Mono-polymer such as poly-ethylene or polypropylene undergoes Physical recycling through extrusion and granulation to produce plastic granules. These plastic granules can be used for manufacturing new plastic products.
II. Waste water-bottles are made of PET (polyethene terephthalate). PET is recycled by using de-polymerisation based chemical recycling to make polyester fiber. The polyester fiber is used for making new plastic granules of PET.

4.1.3 Recycling of Multi-polymer and Multi-material plastic waste

These can be recycled physically using 20% plasticiser to manufacture substandard plastic granules. The role of plasticiser is to bind mixed and brittle plastic into a solid block to make plastic granules. These plastic granules do not possess much strength and can only be used for limited Low-Quality Applications like thick benches and thick tables. High-quality plastics like carry-bags cannot be manufactured from these granules.

Major limitations of Low-Quality Application of physical recycling using plasticizer are:

a) Extended Producer Responsibility (EPR) is attached to this activity because new plastics are being manufactured.
b) These plastic products have a limited life. The plastic products with 20% plasticiser cannot be further recycled using physical recycling.

4.1.4 Other Treatment/Disposal solutions for Multilayered Plastics (MLP)

MLP waste can be converted into power or fuel through a number of processes as enumerated below. Additionally, it can also be used as filler for laying roads

4.2 Co processing in cement kilns

This is most environment friendly option. MLPs are burnt in the cement kiln along with other combustible waste. Around 54 cement plants in India have made investments in co

processing facilities that allow them to use alternate furl in the kiln (CPCB, 2017). According to cement manufacturers association (CMA), cement plants currently have a thermal substitution rate (TSR) of 4% indicating that they meet 4% of their fuel requirements from alternate fuels including plastic waste. Cement industry has proposed to increase their TSR of 4% to 25% by 2025. For cement plants, MLP waste can be contaminated but it has to be moisture free.

Feeding conditions (CPCB guideline)

Different feed points that can be used to feed the plastic waste materials into the cement production process are given below.

- The main burner at the rotary kiln outlet end
- The rotary kiln inlet end
- The pre-calciner
- The mid kiln (for long dry and wet kilns)

Appropriate feed points amongst the above will have to be selected for the environmentally sound co-processing of the plastic waste. Usually, plastic wastes that are contaminated with toxic components such as pesticides etc, should be fed to the main burner to ensure its complete combustion in the high temperature and long retention time. For this, the plastics may need to be shredded to less than 20 mm size. The non-recyclable plastic wastes that is not contaminated with toxic components, can be fed at the other feed points such as calciner, kiln inlet or mid kiln depending upon its size.

4.3 Waste to energy plants

MLPs are burnt in Waste to Energy Plants along with unsegregated municipal solid waste. They can treat both dry as well as wet waste. Currently, there are around 7 operational waste to energy plants and 40 under different stages of construction. Environmental compliance by these plants is still a issue. However, they are largely preferred by the municipal corporations

4.4 Pyrolysis

MLPs along with other unrecyclable plastics are converted into oil. Economic viability and pollution compliance is an issue. This process needs clean/moisture free waste. Pyrolysis is yet to take off largely due to non availability of clean waste and also due to pollution compliance requirements. For economic viability of such plants, 2-3 tonnes of clean waste is the minimum requirement. Several municipal corporations in India are now looking for this option. Haridwar Municipal Corporation has already floated tender towards this.

4.5 Plastic to road

Clean and shredded plastic except PVC is mixed with bitumen to lay the road. Collecting large quantities of clean plastics has been a challenge. Plastic has been used to build roads

in Chennai, Indore, Pune, Meghalaya, and Kolkata. The challenge is availability of required amount of clean plastic. Maharashtra State Government has made it mandatory to use plastic waste to lay roads (Swachh Bharat Newsletter June 2018).

4.6 Technological Interventions

Policy and regulatory initiatives are implemented by using applicable technology interventions in a country's context. Therefore, a number of technological interventions for addressing plastic waste have been initiated in Asia and the Pacific region. These include plastic waste conversion into different products by physical and chemical processes. **Table 4.2** describes technology matrix in Asia and the Pacific region. Majority of these interventions result into textile, bottles, sheets and solid and solid liquid fuels. A snapshot of the processes used to convert waste plastic into useful products is shown in **Figure 4.1**. Generally solid fuels (RDF and RPF) and liquid gaseous hydrocarbons are produced from waste plastics. [18]

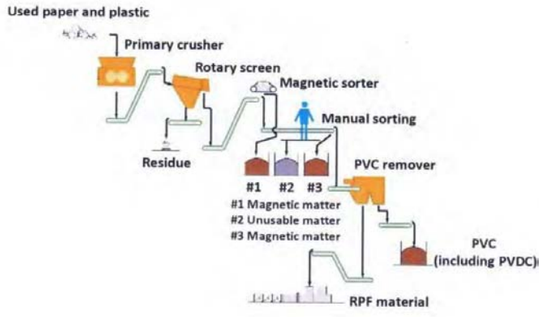
Table 4.2: Plastic Waste Technology Matrix in Asia and the Pacific Region

Issues	Application	Process / Technology	Equipment	Capacity Range	Selection			Remarks
					R	P	C	
1. PET waste as major component of MSW	Value addition ot raw material generation for PET	Shredding / Monomerization Plant	1. Shredding Plants 2. Monomerization Plant	1. Shredding 3600 t/year – 36000 t/year 2. Monomerization 3.25000 t/year – 60,000 t/year			√	Scale and cost of the plant will be major factor for its implementation
2. Mixed plastic waste as major component of MSW	Value addition as fuel for waste heat and energy recovery	1. Coke oven chemical feedstock recycling 2. Gasification 3. Gasification and melting furnace power generation	1. Coke oven chemical feedstock recycling 2. Gasification 3. Gasification and melting furnace power generation	30000 tons to 50000 tons per year of waste plastic			√	Technology absent in Mongolia. Scale and cost of the plant will be major factor for its implementation
3. Mixed plastic waste as major component of MSW	Vlue addition to road construction	Size reduction and melting Shredding, crushing, melting and mixing	Plant Shredding, crushing, melting and mixing	20 – 350 t/hour			√	Technology absent in Mongolia. Scale and cost of the plant will be major factor for its implementation

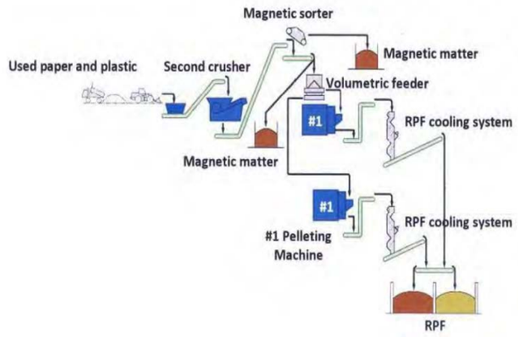
Note: R – Research and Development / P – Pilot Stage / C – Commercial Stage

Source: UNEP (2012); Application of the Sustainability Assessment of Technologies Methodology: Guidance Manual

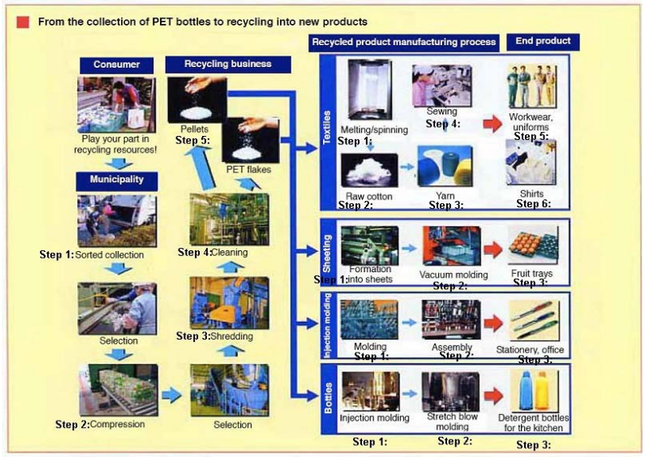
Table 4.3 describes polymer used as feedstock for fuel productions. Pyrolysis and gasification processes and their products are described in **Table 4.4** and **Table 4.5**. The successful demonstration of these technologies as well as implementation of policy and regulation has been described in two case studies of India and Japan.



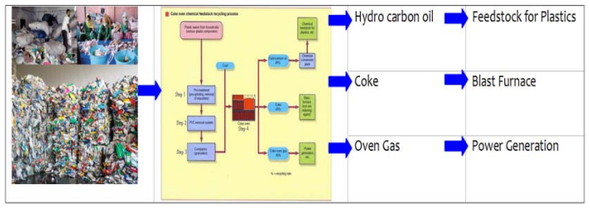
Schematic diagram of pretreatment process



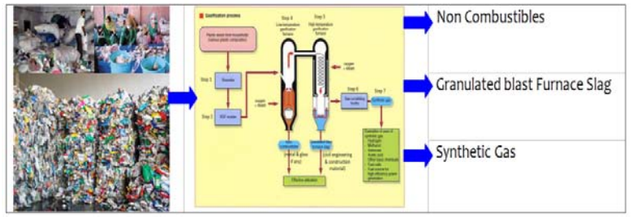
Schematic diagram of a pelletizing process



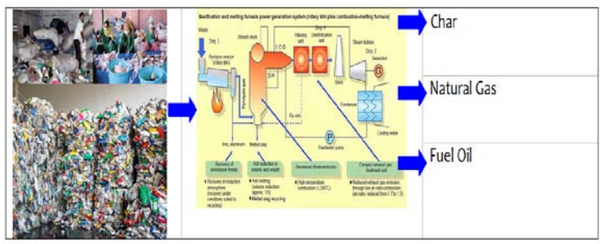
Source: Council for PET Bottle Recycling



Coke oven chemical feedstock recycling
Step 1: Pre-treatment (pre-grinding, removal of impurities)
Step 2: PVC removal system Step 3: Compactor (granulator) (20 to 30 mm)
Step 4: Granulated plastic is charged into coke ovens with coal for thermal decomposition.
Step 5: Production of 20% coke, 40% coke oven gas and 40% hydrocarbon oil.



Coke oven chemical feedstock recycling
Step 1: Pre-treatment (pre-grinding, removal of impurities)
Step 2: PVC removal system
Step 3: Compactor (granulator) (20 to 30 mm)
Step 4: Granulated plastic is charged into coke ovens with coal for thermal decomposition.
Step 5: Production of 20% coke, 40% coke oven gas and 40% hydrocarbon oil.



Step 1: Conversion of plastic waste into gas through pyrolysis in rotary kiln
Step 2: Combustion of pyrolysis gas at 1300°C and removal of melted slag.
Step 3: Use pyrolysis gas and char as fuel to drive steam turbine and generate power.
Step 4: Emission cleaning system for stack emissions.

Different Steps Involved
Step 1: Plastic waste collection, segregation and storage
Step 2: Cleaning and drying of plastic wastes
Step 3: Shredding plastic wastes into required sizes (2 to 4 mm) Step 4: Stone aggregate (granite, ceramic) heated to around 160° - 170°C
Step 5: Shredded polymer waste (5-10% w/w) is added to heated stone aggregate for 30-40 sec and mixed for uniform coating at surface of aggregate
Step 6: The coated aggregate is mixed with hot bitumen at temperature ranges from 155°C – 163°C
Step 7: The mix (composite) known as waste plastic aggregate bitumen mix (130°C – 140°C). This composite used for road laying at temperature between 110°C – 130°C

Figure 4.1: Snapshot of Plastic Recycling Technology in Asia and the Pacific Region
Source: Amit Jain (2018)

Table 4.3: Polymer as feedstock for fuel production

Types of polymer	Descriptions	Examples
Polymers consisting of carbon and hydrogen	Typical feedstock for fuel production due to high heat value and clean exhaust gas.	Polyethylene, polypropylene, polystyrene. Thermoplastics melt to form solid fuel mixed with other combustible wastes and decompose to produce liquid fuel.
Polymers containing oxygen	Lower heat value than above plastics.	PET, phenolic resin, polyvinyl alcohol, polyoxymethylene.
Polymers containing nitrogen or sulfur	Fuel from this type of plastic is a source of hazardous components such as NO_x or SO_x in flue gas. Flue gas cleaning is required to avoid emission of hazardous components in exhaust gas.	Nitrogen: polyamide, polyurethane Sulfur: polyphenylene sulfide.
Polymers containing halogens of chlorine, bromine and fluorine.	Source of hazardous and corrosive flue gas upon thermal treatment and combustion.	Polyvinyl chloride, polyvinylidene chloride, bromine-containing flame retardants and fluorocarbon polymers.

Source: UNEP (2009): Converting Waste Plastics into a Resource

Table 4.4: Product types of some plastics pyrolysis

Main products	Type of plastics	As a feedstock of liquid fuel
Liquid hydrocarbons	Polyethylene (PE)	Allowed.
	Polypropylene (PP)	Allowed.
	Polystyrene (PS)	Allowed.
	Polymethyl metacrylate (PMMA)	Allowed.
Liquid hydrocarbons	Acrylonitrile-Butadiene-Styrene copolymer (ABS)	Allowed. But not suitable. Nitrogen-containing fuel is obtained. Special attention required to cyanide in oil.
No hydrocarbons suitable for fuel	Polyvinyl alcohol (PVA) Polyoxymethylene (POM)	Not suitable. Formation of water and alcohol. Not suitable. Formation of formaldehyde.
Solid products	Polyethylene terephthalate (PET)	Not suitable. Formation of terephthalic acid and benzoic acid.
Carbonous products	Polyurethane (PUR) Phenol resin (PF)	Not suitable. Not suitable.
Hydrogen chloride and carbonous products	Polyvinyl chloride (PVC) Polyvinylidene chloride (PVDC)	Not allowed. Not allowed.

Source: UNEP (2009): Converting Waste Plastics into a Resource

Table 4.5: List of various gasification methods

Type of gasification	Conditions	Typical products
Pyrolysis	>700 °C under inert atmosphere	Gaseous hydrocarbons from aliphatic hydrocarbons including polyethylene and polypropylene.
Partial oxidation	>1000 °C under oxygen or air	Carbon monoxide from carbon, hydrocarbons and carbohydrates including wood. Hydrogen also forms from hydrocarbons and carbohydrates.
Steam gasification	>800 °C under oxygen or air	Methane, carbon monoxide and hydrogen.
Hydrogasification	Around 500 – 600 °C under hydrogen	Methane, carbon monoxide and water.

Source: UNEP (2009): Converting Waste Plastics into a Resource

Box 1: Waste Plastics to Construct Roads

India generates about 5.6 million tonnes of plastic waste is generated in country. Thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total post-consumer plastics waste generated in India. Plastic garbage that litters the country like carry bags, chip bags, chocolate bar wrappers, plastic bags, bottles, lids, etc. can be shredded and added as a limited substitute for bitumen in road construction. This method makes plastic waste a useful substitute in construction.

"Constructing roads from polythene" is a new project that the Himachal Pradesh government has embarked on to rid the state of polythene menace. After the use of polythene was banned in the state last year, there have been huge stocks in the state, which the government decided to utilize for metaling the roads. The Himachal Pradesh State Pollution Control Board in collaboration with the Public Works Department (PWD) has built three road stretches on a pilot basis by using shredded plastic waste on the outskirts of Shimla. "The results have been good as there has been no stripping or any other major damage to the roads laid by using plastic-asphalt mix. The plastic blend not only helps lowering the cost of tarring but also enhances the durability of roads because of higher binding strength of plastic,".

Process: At first plastic waste is cut into a size between 2.36 mm and 4.75mm using shredding machine. Bitumen is heated to 160°C, to prevent weak bonding. At the mixing chamber the shredded plastic waste is added to the hot aggregate. It gets coated uniformly within 30 seconds. Hot bitumen is then added over the plastic-coated aggregate and the resulting mix is used for road construction. The road-laying temperature is between 110°C and 120 °C.

Cost Benefit Analysis: "The plastic waste replaces 10 to 15% of the bitumen and thus saves approximately Rs. 35,000 to Rs. 45,000 per km of a road stretch. The state under the scheme would purchase plastic waste at Rs3/- per kg with an additional rupee as handling charges. The use of plastic in roads has also become a source of earning for rag pickers: Rs. 12/- per kg per day. This can go up to Rs. 14/- per kg for 5-10 kg and Rs.16/- per kg for quantity exceeding Rs. 10/- kg of plastic. The PWD would bill Rs. 2/- extra, Re. 1/- as handling charges and another rupee to be utilized for the welfare of rag pickers and waste workers by providing them boots, masks, gloves, free medicines and an insurance cover of Rs. 200,000 in case of any eventuality.

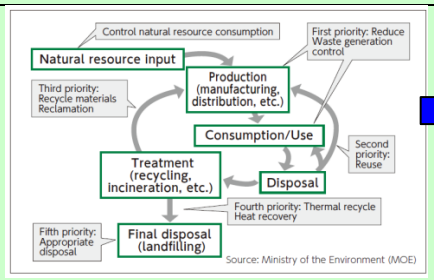
Source: Ministry of Housing and Urban Affairs, Government of India (2017); Waste to Wealth – A Ready Reckoner for Selection of Technologies for Management of Municipal Waste

Box 2: Sound Material Cycle Society and 3R Implementation: A Case Study of Japan

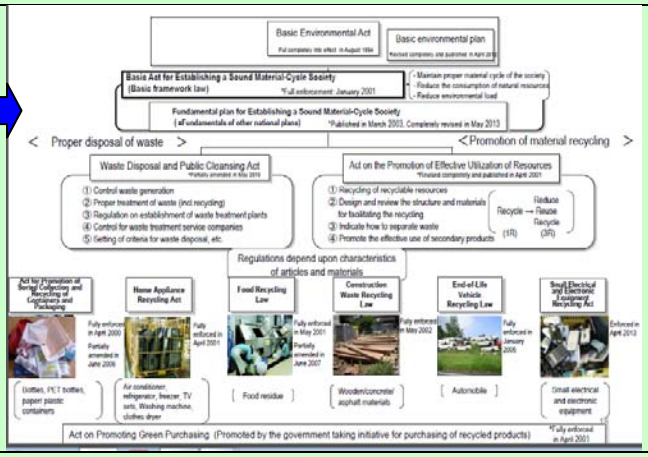
Japan has established a sound material cycle society in Asia and the Pacific region. It is based on the spirit **"Mottanai"** which encompasses the practice of treasuring and using all things as long as possible. This spirit of Mottainai restrained the generation of waste and motivated the development of technology for reuse, recycling and effective use through heat recovery in the country. Therefore, Japan has developed waste management and recycling technologies, which effectively turn waste into resources or appropriately dispose of it. The vision of sound material cycle society has led to the development of regulatory framework based on EPR **(Figure)**.

In 2000, the Basic Act for Establishing a Sound Material-Cycle Society (Basic Framework Act) was enacted to achieve: move away from the current economic system based on mass production, mass consumption and mass disposal, and to promote the establishment of a sound material-cycle society designed to ensure the implementation of 3R (Reduce, Reuse, and Recycle) and the appropriate management of waste. The Basic Recycling Act defines the vision that reduces natural resource consumption and minimizes environmental impact. The law specifies the order of priority in the management of recyclable resources as well as the roles of different entities (national and local governments, business operators, and consumers). The Basic Recycling Act also legally established, for the first time, the basic principle that recyclable resources should be processed in the following order of priority: (1) generation control, (2) reuse, (3) recycling, (4) thermal recovery, and (5) appropriate disposal. In defining the roles of different entities, this law distinguishes between the principle of waste generator responsibility, which places the responsibility for the management and recycling of waste on consumers and business operators that dispose of waste, and the principle of extended producer responsibility (EPR), which places the responsibility for the manufacture, design and post-use management of products on their manufacturers. The Containers and Packaging Recycling Act specified the respective roles of consumers, municipalities, and business operators (container manufacturers and business operators that sell products using containers and packaging). The act placed the responsibility for sorted waste disposal on consumers, the responsibility for sorted waste collection on municipalities, and the responsibility for recycling on business operators, in order for these three entities to work together to promote the recycling of containers and packaging.

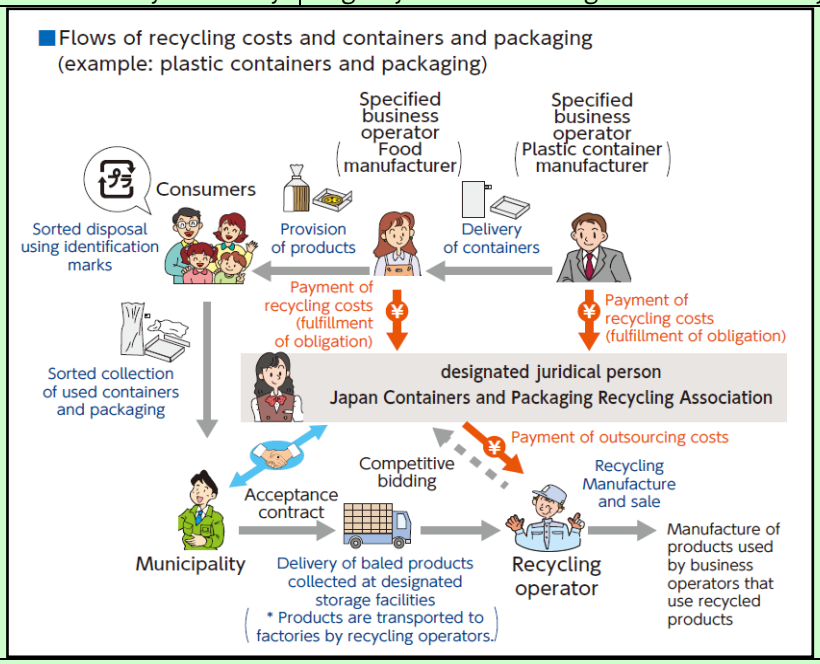
Japan intends to achieve approximately double resource productivity (GDP/input natural resources) by 2025 in comparison to 2000 by achieving 30% increase of cyclical use rate (waste base) and 77% reduction of final disposal amount during the same period. As per MOEJ, Government of Japan about 9400 kilo tons of plastic waste was generated in Japan in 2016, out of which 4260 kilo tonnes was packaging and container (PET bottles) waste. About 1040 kilo tonnes of packaging and PET Bottles waste was collected by municipal collection system. 60% of this waste underwent chemical processing (coke ovens, syngas and reducing agent) while 40% went for material recycling (PP resin, Palette, others). PET bottles were converted into shed, fibre and bottle. Japan has already provided technology transfer to a number of developing countries in the region (Thailand, Singapore and China).



Vision of Sound Material Cycle Society



Legal System for Building a Sound Material Cycle Society



Source: Ministry of Environment, Ministers Secretariat, Waste Management and Recycling Department Policy Planning Division, Office of Sound Material – Cycle Society (2014); Solid Waste Management and Recycling Technology of Japan – Towards a Sustainable Society and History and Current State of Waste Management in Japan

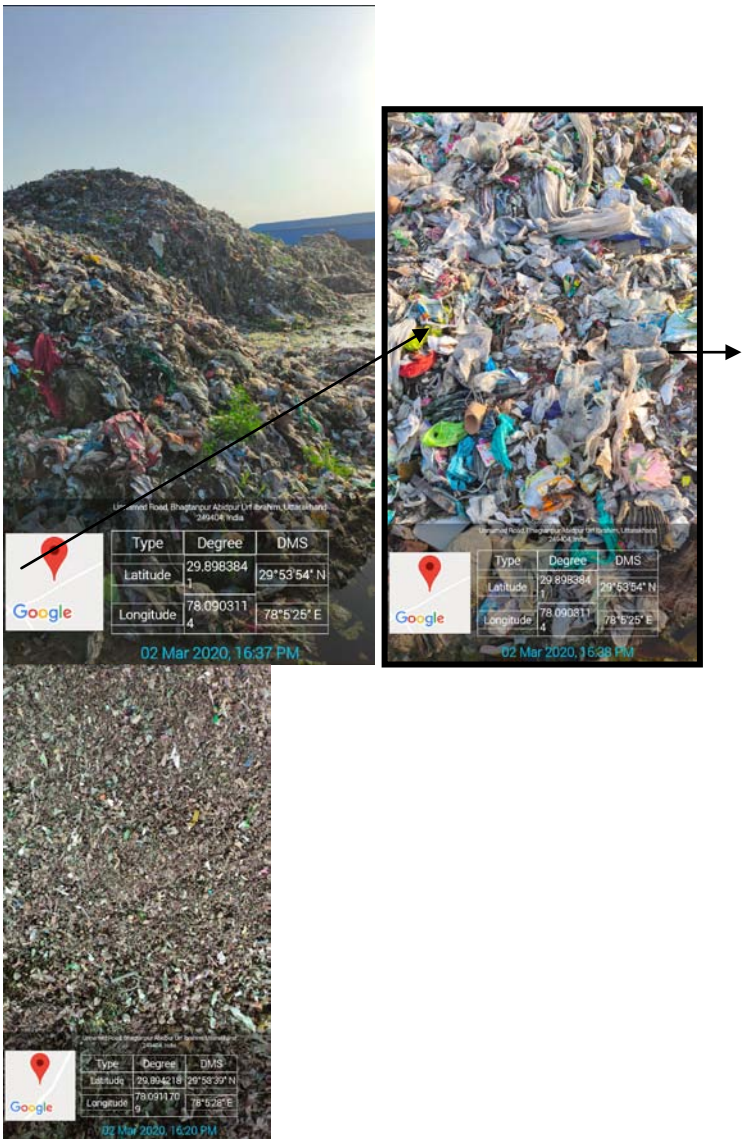
Chapter 5: Implementation of Counter Measures

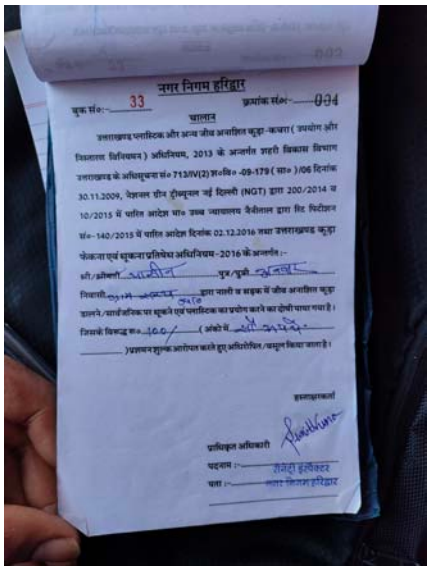
5.1 Countermeasures already in implementation in the study areas viz., Haridwar, Agra, Prayagraj and Mumbai

5.1.1 Haridwar

As part of Swachh Bharat Abhiyan (Cleanliness drive), Haridwar Municpal Corporation has initiated some countermeasures as listed below:

Table 5.2: List of Countermeasures which is already in implementation in Haridwar

Conversion of all Multilayer plastic(MLP) to RDF	All MLP at the dumping site is segregated and shredded and converted to RDF which is sent to cement plants as fuel  Photoplate depicting mixed waste containing MLP and polybags in landfill facility

	being segregated and then shredded which is being sent to cement plant nearby. Around 200-250 Tonnes per Month is being sent to cement Plant (in the month of February, 2020)
Plan to set plastic recycling facility	The Department of Panchayati Raj is setting up a 3 ton per day capacity, Common Waste Plastic Recycling Plant in Haridwar of Uttarakhand. The facility when ready would be able to treat all recyclable plastic waste collected from village (Source: Govt. website: https://sbmgramin.wordpress.com/2020/02/11/haridwar-to-get-3-ton-day-plastic-waste-recycling-facility/)
Fines levied on usage of polybags less than 50 micron	19 fines were imposed for littering amounting to Rs. 28,800/- an amount of Rs. 27,900 is collected as fines towards illegal possession of polybags having thickness less than 50 micron in the month of February, 2020.   Photoplates depicting fines collected for illegal possession of polybags having thickness less than 50 microns
Disposal options for plastic waste proposed by Haridwar Municipal Corporation	Municipal Corporation Haridwar has proposed to convert plastic waste to fuel oil. and has invited bids from interested parties in this regard. Photoplate depicts the advertisement calling for bids.

Nagar Nigam Haridwar

Letter No: 2707 **Re-TENDER NOTICE** Date: 29.02.2020

Nagar Nigam Haridwar (NNH) invites tenders from interested eligible bidder to set up plant for conversion of postconsumer mixed waste plastics from Municipal Solid Waste into fuel/ Hydrocarbons derivatives of capacity 10 TPD by using an innovative Patented Environmentally clean technology (with zero pollution) through Public Private Partnership (PPP) mode based on Design, Built, Finance, operate and Transfer (DBFOT) basis. The Tender will be published on dated 03-03-2020. The detail tender notice and Tender Document can be seen on website: https://uktenders.gov.in and www.haridwarnagarnigam.com by the Firms / Individual registered on the Portal.

(Narender Singh Bhandari)
IAS
MC, NNH

UJVN LTD.

H.O.: 'UJJWAL', Maharani Bagh, G.M.S. Road, Dehradun-248006
Telephones : 0135-2763508, 2763808 & Fax : 0135-2763507
CIN No. U40101UR2001SGC025866 Website : www.ujvnl.com

In addition, many countermeasures related with use of traditional eco friendly materials instead of single use plastic is prevalent in the city as depicted in the city.

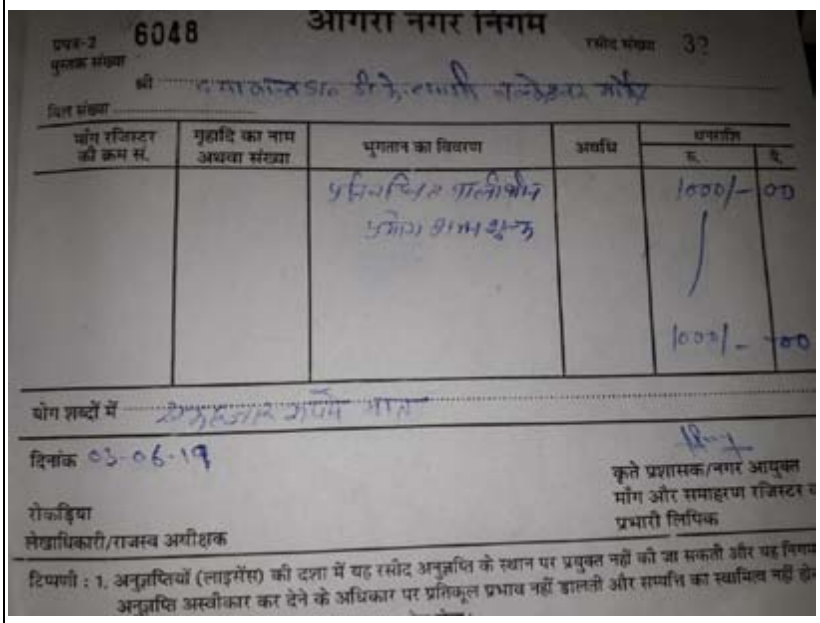
Photoplate depicting street vendor serving food in leaf to customers

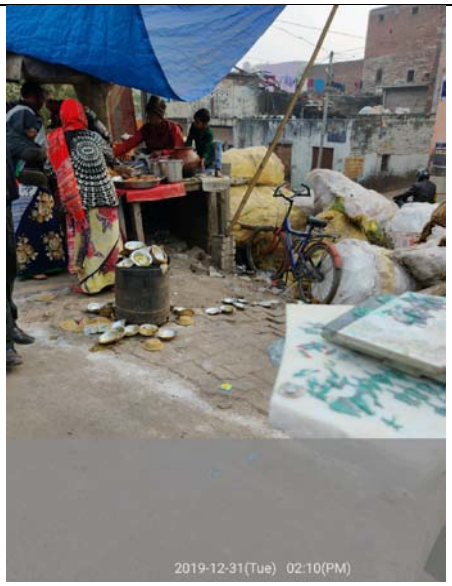
5.1.2 Agra

In 2018, plastic-free campaign was launched in Agra and the Taj Mahal Declaration "To beat Plastic Pollution" was released. Several counter measure have been implemented by Agra Municipal corporations in this regard. Some of them are briefly listed:

Table 5.1: List of Countermeasures which is already in implementation in Agra

A. Fines levied on usage of polybags less than 50 micron	Plastic ban have been completely enforced in the city of Agra. Based on the DO from GoUP received on 15 July 2018, AMC prepared its action plan which has been successfully implemented on ground. Mechanism adopted by the city has been explained in Solid Waste Action Plan document developed by Agra Municipal Corporation

	 Photoplate: depicting receipt of fine of Rs. 1000/- each taken from shopkeepers towards possession banned polyethene bags
	 Photoplate: depicting squad of Agra Municipal Corporation officials visiting shops/street vendors for monitoring illegal possession of banned polythene bags
	For the period between 15 July, 2018 – 6 February, 2020, Agra municipal Corporation has confiscated 15913.55 Kgs of plastics which comprises of : • 3367.07 Kgs of banned plastic items • 550.75 Kg of thermocol glass 10659.17 Kgs of polyethene bags less than 50 micron thickness
B. Fines collected for littering By Agra Municipal Corporation	

	  Photoplate: depicting fine of Rs. 500/- collected for littering from shops/street vendors
C. Segregation of Dry waste collected through door to door collection and sent to Material Recovery facility	Dry waste segregated from landfill site is sent to Material recovery Facility from where plastic which is 40% is segregated and is sent to a plant in Gajraula, Uttar Pradesh where it is converted into polymer beads. The non recyclable plastic waste mixed with other dry waste from landfill facility is being sent to Waste to Energy Plant in Okhla

In addition to above, Agra's famous sweat meat manufacturing industry locally known as Petha manufacturing and selling industry is doing EPR for its packaging waste which is generated in huge quantity. Many Petha sellers are offering additional quantity of peta in return of their packaging waste to customers.

Similarly, many small tea/snack vendors are using terracot cups for serving tea to their customers.

5.1.3 Prayagraj

Some of countermeasures implemented in Allahabad are listed below:

Table 5.3: List of Countermeasures which is already in implementation in Allahabad

Depository scheme for plastic waste	Ardh **Kumbha Mela** is a major pilgrimage and festival in Hinduism held at Triveni Sangam in Allahabad, celebrated for over a stretch of two long months and is celebrated in a cycle of 6 years. During Ardh Kumb Mela 2019, The mela (Fair) administration, in association with a leading tea brand installed multiple kiosks across the mela premises which gave free cups of tea in exchange of recyclable plastic

	waste 
Treatment option for plastic waste	Plastic waste is segregated in the landfill facility and is converted into pellets (RDF) for use as fuel for cement plant 
Restaurants using cutlery made of eco friendly materials	 The photoplate is of a restaurant in Allahabad serving traditional food called Dal Bhatti Choka. People love the food served here as well as the ambience which is completely plastic free. Food is served in leaf plates and clay/terracotta pots. There are number of such restaurants in Allahabad. Similarly, lot street vendors were found to be serving food in leaf plates in the city.

5.1.4 Mumbai

A number of countermeasures have already been implemented in Mumbai. Some of them are listed below:

Table 5.4: List of Countermeasures which is already in implementation in Mumbai

Policy ban on use of single use plastics	Govt. of Maharashtra has published guideline for ban of single use plastic • Notification on Plastic Ban -23rd March 2018 • System for collection of plastic voluntarily disposed by citizens put in place. • Bins of 1.1 cu.m. Capacity, painted in black and having stickers stating "For the collection of banned plastic", placed at 65 locations all over Mumbai • Awareness created in public regarding ban on Plastic and Thermacol products • A dedicated team has been formed from the staff of Shop & Establishment. • Action carried out at: ✓ All Shop & Establishments,Public Places, All Seashores, Bus Stops ✓ Railway Station, All places where plastic storage use is prohibited ✓ Banned Plastic seized from 23.06.2018 is 76,000 Kgs and is auctioned to authorized  According to the Municipal Corporation, a fine of *Rs.* 5,000 is imposed on a person found using the prohibited plastic for the first time, and if caught for the second time, the person have to pay *Rs.* 10,000 as penalty. Anyone caught for the third time will have to pay a fine of *Rs.* 25,000 and can also be jailed for three months. M/s. Shakti Plastic is appointed for 1 year to take banned plastic. Since the Government of Maharashtra first banned the single-use plastic in 2018, Brihanmumbai Municipal Corporation has seized 86,000 kilogram of plastic and

<table>
<tr><td></td><td>recovered a fine of Rs. 4.65 cr. between June 2018 and February 2020.</td></tr>
<tr><td>Door to door collection of dry waste from household</td><td>Dry waste collected is sent to Material recovery Facility where plastics are segregated and sent to recycling facilities</td></tr>
<tr><td>Beach cleaning activities</td><td>A number of NGOs, individuals are involved in beach cleaning activities in Mumbai. Plastic waste collected during these clean up activities is sent to recycling facilities.

 
Mahim Beach Image courtesy @ Indrani Sen Gupta

Juhu Chowpatty Image courtesy SHUDDHI, a NGO</td></tr>
<tr><td>Cleaning of barriers</td><td>During Monsoon, plastics caught in various barriers such major drains leading to rivers such as Mithi river and than to ocean are cleaned regularly using motorised machines and plastic is segregated and sent to recycling facilities.

 
Image courtesy @ Brihanmumbai Municipal Corporation (BMC)

• Trash Booms have been installed and operated for preventing the pollution of sea and mangroves from floating trash.

• Clean up Marshals are deployed on major drains along the slum areas to fine defaulters and arrest the choking of drains because of garbage dumped into drains.

• Banners are displayed along major drains, appealing citizens, not to throw garbage into drains.</td></tr>
<tr><td>EPR in Mumbai</td><td><u>M/s Bisleri India Ltd.</u></td></tr>
</table>

	• 1 Centre in K/East ward. Space by MCGM, Cap-ex and Op-ex by Bisleri. • Collection and Transportation through dedicated vehicle. • Output: By-products will be sold by Bisleri. • Mobile App will be developed for Collection & transportation of Bottles, from citizens. **<u>M/s Hindustan Unilever Ltd.</u>** • 1 Centre in K/East ward. Space and Shed by MCGM, Cap-ex and Op-ex by HUL • Collection and Transportation through dedicated vehicle. • Output: Multilayer Packaging (MLP) benches. Company is also willing to share technical knowhow to deal with MLP. • Mobile App will be developed for Collection & transportation of dry waste, from citizens.
Muck trains to clean railway tracks	Muck trains have been launched in January 2019. improved version of Muck Trains runs daily from Virar to Churchgate in Mumbai and collect garbage lying on the railway tracks. The Muck train halts at every station through the excavator machines, the muck or liquid waste is lifted and dropped in the train. Meanwhile, the railway staff collects dry waste like plastic items and puts it in a sack. The sacks are then deposited in the train. While the dry garbage is sent to recycling facilities, the wet garbage is processed at the waste treatment plant at Deonar landfill. 

	 Image Source: official twitter account of Honourable Minister of Railways, Govt. of India https://twitter.com/i/status/1041156022537256965
Incinerators for safe disposal of plastic wastes	Incinerators for safe disposal of plastic wastes such as sanitary napkins, diapers have been installed at selected railways stations in Mumbai (Churchgate) and cities in other states (Vadodara, Ahmedabad, Ratlam, Rajkot and Bhavnagar) by Western Railways (Swachh Bharath/ndtv)

Chapter 6: Proposed Counter Measures

6.1 Proposed Countermeasures against marine plastic litter

6.1.1 Policy interventions

To develop policy interventions related countermeasure following needs to be considered:

A. Policies jointly address the challenges – market failures, policy misalignments, and status quo biases – on both the supply and demand sides of recycled plastics markets. Put differently, an effective policy framework would address challenges across the entire plastics life cycle, from plastics and product design through to end- of-life management and recycled plastic production.
B. To create demand for recycled products, pricing of virgin plastic products have to be increased through no government support for hydrocarbon inputs to plastics production
C. Policy interventions that aim to level the playing field between virgin and recycled plastics or support the market for recycled plastics. They include: • Taxes on the use of virgin plastics or differentiated value added taxes for recycled plastics or plastic products; • Reform of support for fossil fuel production and consumption; • Introduction of recycled content standards, targeted public procurement requirements, or recycled content labelling; and • Creation of consumer education and awareness campaigns (concerning the environmental benefits of recycled plastics) in order to stimulate demand for products containing recycled plastics.
D. Policy interventions towards Maintaining right quality of recycled plastics through the following • Creation of certification standards for recycled plastics; • Creation of requirements to collect and recycle all types of plastic products; • Facilitation of better coordination and communication across the plastics value chain, including through the promotion of chemical information systems; and • Restrictions on the use of hazardous additives in plastics manufacturing.
E. Policy interventions to meet the challenge of making recycled plastic economical and comparable to virgin plastic • Introduction of multiple stream collection systems allowing separated collection of recyclables; • Creation of incentives for better product and plastics design (e.g. design for reuse and recycling), such as through better designed extended producer responsibility, product stewardship and deposit-refund systems; • Support for R&D for improved plastics management systems and the sustainable design of plastics (more easily recyclable or more easily biodegradable for example), working in close partnership with industry; • Introduction of more ambitious recycling rate targets and harmonisation of the methods used to calculate these rates; and • Increased stringency of landfill and incineration fees to better reflect the full social cost of these activities.
F. Promotion of Circular economy in Plastics management through suitable interventions, such as emphasis on product composition declarations reflecting the plastics contents in addition to other materials for a wide spectrum of products across sectors, wherein plastics are used as part of the products as well as with regard to packaging aspects and their consumption on product unit basis as well as manufacturing technologies aspects and arriving at suitable benchmarks for Circular Economy promotion. Suitable indicative aspects also reflected by FICCI as per a report on Circular Economy promotion for plastics management
G. Making mandatory and ensuring compliance by all manufacturers and recyclers of plastics to label correctly and effectively the polymer types amongst the 7 cases as well as reflecting additional details such as fillers and chemical additives utilized in the said plastics based products manufactured for

	the market. This shall enable efficiency in recycling systems and suitable guidelines be prepared as well
H.	Encouraging development of financing instruments to take forward Extended Producer Responsibility as well as in a contextual sense Extended Consumer Responsibility (whereby atleast 7 category level segregations be enabled via consumer efforts and separate recycling value chains are strengthened and made efficient), all of which to parallelly enable both formal and informal systems to gel well and achieve mutually symbiotic efficiencies in plastics production, reuse and recycling arrangements. The financial instruments could include different incentives built into various initiatives, be it R&D and stock market and material exchange arrangements for the plastics moved

6.2 Strengthening of enforcement of PWM Rules, 2016

Enforcement of existing Rules is more important than developing new policy interventions. Towards these, following countermeasures are proposed

- Towards enforcement of the rule, more number of monitors for ensuring enforcement of rules has to be developed. This group of people will be assigned this specific task of ensuring plastic ban in the city. Monitors such as being formed by BMC as stated in section 7.4 can ensure enforcement of policies. These monitors shall be reporting to State pollution Control Boards. Learning from Kenya's Plastic bag ban implementation case study (Refer section 4.1.1), strict penalties, and punishment has to be enforced towards, manufacture, sale or trading of thin plastic bags (less than 50 micron). Awareness among traders towards this ban has to be made among market association/trader associations/street vendors, etc
- Segregated waste collection from household/slum areas has to be ensured through door to door collection system in all cities of India
- Opening of Garbage Café in Maket areas, Bus stands, Railway station
- Installing of Kiosk for plastic exchange with some form of incentives to customers

6.3 Technology options

6.3.1 Recycling of Monolayer Plastic

Quality of Recycled plastic products has to be inspected. Guidelines for recycled products to be developed and monitored strictly. Further, market for use of recycled plastic in different plastic products to be encouraged.

New entrepreneurs for recycling industries to be encouraged. Inventory of recycling industries to be prepared. Financing schemes for modernisation of recycling industries with all pollution control equipment linked to creating products with higher recycled plastic content and their market development.

Further a common web portal for recycling and other treatment options for plastic may be developed which can be maintained by a private party.

6.3.2 Treatment/Disposal solutions for Multilayered Plastics (MLP) and other Plastics

MLP waste can be converted into power or fuel through a number of processes as enumerated below. Additionally, it can also be used as filler for laying roads

- A detailed study involving total available capacities of cement plant and waste to Energy plants to be undertaken. Economics including transportation cost for treatment and disposal of MLPs in cement and Waste to Energy plants have to be worked

- State Governments have to develop regional level plan for treatment and disposal of plastic waste

- Strict enforcement of usage of plastic waste generated in cement plant, waste to energy plants and in road construction as per the Plastic Waste (Handling & Management) Rules, 2016 and its amendment has to be made

- Many plastic waste collection centres have to be developed, In order to do this, Plastic depository schemes such as installation of Kiosk (where customer is given some kind of incentive such as Tea or mobile recharge, etc in exchange of plastic wastes which can be made specific for segregated collection of waste) in plastic leakage prone areas such as markets, park, residential (slum) areas, etc. Garbage cafes can be the other option to encourage rag pickers to collect maximum plastic litter

- Encouraging new start ups for waste collection and incentivising them.

6.3.3 Outreach/Awareness programs against Plastic litter in cities

A number of outreach/awareness programs are already being undertaken as a part of Swachh Bharat Abhiyan (Cleanliness drive) of Government of India. Citywide monitoring of outreach/awareness programs sensitising citizen, waste collectors, etc has to be made. Impact of these programs to be assessed and accordingly more programs to be tailor-made for specific category of stakeholders/section of society, etc.

6.3.4 Monitoring of microplastic in rivers

From the microplastic studies in Ganga and Yamuna basin, it is inferred that microplastic analysis of river water samples clearly gives an idea regarding the plastic waste generated and littered and also enables tracking sources of plastic litter. Based on substantive India based research in rivers, appropriate plastic leakage models can emerge.

6.3.5 Improving collection of plastic materials, strengthening segregation and recycling in inaccessible areas

- Strengthening of Waste collection in Slums through daily lifting of waste from Waste Bin placed near Slum areas

- Slum clean up groups /committee to be formed by ULB
- paying people a small fee to reward them for returning their plastic bags for recycling.
- Deposit scheme-Garbage cafe scheme, Kiosks to be concentrated around the slums
- Slum centric Award: To create competition for transformation within state and interstate for recognition.

6.3.6 Fixing recycling targets of each city

- Designated large scale producers (base line for different industry segment) of plastic waste to be identified
- Based on the baseline fixed for different producer segment, provisions may be made for incentivising the leaders vis-a vis laggers
- Buying of recycling credits by other cities like carbon trading

Note: Similar scheme like Perform Achieve and Trade (PAT) is being successfully implemented by Ministry of Power, Govt. of India which identifies the baseline for different Designated Consumers (DCs) of energy.

6.3.7 Steel Utensil Bank establishment

In India, there have been cases reported towards forming Steel Utensil Banks, one found in Gurgaon near Delhi which supplies steel utensil to big festivity gatherings, marriages, etc free of cost to customers to avoid use of single use plastic cutlery.

6.3.8 Guidelines for establishment of recycling/waste to energy/pyrolysis plant

As per the Biomedical Waste Management Rules, there is a criteria for establishment of common biomedical waste treatment facility to cater to specific number of beds and at a specific distance from the waste generators. Similarly there should be recycling/waste to energy/pyrolysis plant availability at a certain distance from the waste generation sources.

6.3.9 Extended Consumer Responsibility

As there are seven categories of plastics already notified (However, labelling of the plastic products is lagging which needs enforcement), there is need for citizen to be encouraged to segregate seven categories for efficient recycling.

6.3.10 Monitoring of microplastic in aquatic life such as in fish, higher trophic level etc

Regular monitoring will help check the species that could be at risk. Further, to assess the plastic polymer accumulation in food chain which will need specific attention for production and consumption options.

6.3.11 EPR implementation and online monitoring

The entire value chain from small, medium and large companies to submit in their consent to operate forms to state pollution control board their initiative in reduction of single use plastic consumption and plastic recycling efforts.

6.3.12 Countermeasures for handling festivities, pilgrimages, etc

According to Haridwar Municipal Corporation, between 10 July to, 4 crore Kanwar pilgrims visit Haridwar generating about 2400 metric tonne trash in 10 days period. This trash comprises of plastic bottles (used for carrying Ganga water), polybags, food leftovers, clothing, wilted flowers, etc.

In order to assist Haridwar Municipal Corporation in collection of plastic waste, depository schemes for plastic waste can be installed in the prominent places of plastic waste generation such as Ghats, market places, etc. Depository schemes can be following:

- One installed in Kumb Mela in Allahabad in 2019 –tea dispensers providing tea in place of plastic waste.
- Garbage café providing meals in return to plastic waste
- Mobile recharge in return of plastic waste
- Amount added in Paytm wallet in return of plastic waste

Adequate marking of these schemes have to be done in order to use these schemes fully via announcements through loudspeakers, etc

Similar Festivities happen in Allahabad like Magh Mela during February every year, etc, in Mumbai, Ganesha idols immersion in sea during August every year

6.4 Study area specific Countermeasures based on plastic leakage scenario

Based on the observation of primary survey and results of macroplastic assessment studies in four study areas, microplastic assessment in two cities and leakage scenario, a few local level countermeasures are proposed:

Table 6.1: List of few local level countermeasures

City observation	Countermeasure proposed
Allahabad	
• Most prominent litter is Multi layer packets for food, sachets for Tobacco and thin poly bags, plastic disposable cutlery. • Waste dumping by residents is observed in vacant plots in residential as well as industrial area. • Major Plastic leakage path to river is through drains/barriers leading to river. Most of the open drains are located near slum,	• Waste collection and treatment facility has to be made operational immediately. • 100% door to door segregated waste collection has to be ensured.

City observation	Countermeasure proposed
market places. • There is a practice of direct dumping of waste by residents(living along Yamuna, mostly slum) into the river as observed during our study. • Microplastic study indicates presence of very high concentration of EVOH polymer in both Ganga and Yamuna which is leached from a Multilayer packaging material. • Waste management system is weak at present. Waste collected from the city is just being dumped at the waste treatment facility due to administrative reason. • Segregated plastic waste is being stored at the facility due to refusal by nearby cement plant. No waste to Energy plant is operating in the surrounding. • It is observed that community bins are not covered everywhere. • Transfer station is not properly covered, fenced. Plastic litter was found outside the transfer station. • Ardh Kumbh Mela is celebrated in a six year cycle, Magh Mela is celebrated every year (February) which attract large number of pilgrims leading to huge quantity of waste generation	• Community bins to be appropriately covered to avoid air blown plastic litter. • Transfer stations or locally called Dhalos should be appropriately fenced and waste to be transferred in closed container only. • Ensuring acceptability of plastic waste by nearby cement industry. Additional Waste to Energy plant to be set up towards disposal of plastic waste generated • Towards effective collection of MLP and polybags, Garbage cafes should be opened in Slum areas. • Kiosks similar to that installed during Kumbh Mela or that installed by Railways which provides mobile recharge, etc may installed in market places, Ghats, etc • Awarding restaurant/ hotels/ shops who use ecofriendly cutleries in place of single use plastics may be done • • Ban on single use plastics to be enforced and fines and severe punishment on illegal possession of single use plastic • Provision of steel utensil to various food courts established during Annual festivals like Magh Mela by Mela Administration (where large masses) join at subsidised rates to avoid use of single use plastic cutleries. • Plastic recycling industries to be encouraged to set up their plant in Allahabad. • Plastic pyrolysis plant may also be another option to treat huge

City observation	Countermeasure proposed
	plastic waste generated • EPR from large MNC players may be enforced. • Informal rag pickers to be formalised and to be provided with protective gears. • Informal rag pickers to be formalised and to be provided with protective gears.
AGRA	
• It houses one of the seven wonders of the world, therefore attracts large number of tourist. • Most prominent litter is Multi layer packets for food, thin poly bags, small sachets of different usage for detergents, tomato sauce, tobacco sachets, woven polypropylene bags etc. • Waste dumping by residents is observed in vacant plots in residential as well as industrial area. • Major Plastic leakage path to river is through open drains/barriers leading to river. Most of the open drains are located near slum, market places. • A number of temples, Gurudwaras, Mosque (religious places) are situated along the river banks which are visited by a large number of devotees. • It is observed that there is a practice of direct dumping of religious waste by residents on Ghats (bank) of river by slum residents as well as by devotees. • Microplastic study indicates presence of very EVOH, LDPE, etc. EVOH is from MLP • 100% door to door collection of waste is not there. • It is observed that community bins are not covered everywhere. • Transfer station is open area which is not fenced and waste is placed on the ground. • Burning of waste was observed in industrial areas as well as in residential area where door to door waste collection is not there. And this is more prevalent during winters in slum areas.	• 100% door to door segregated waste collection has to be ensured. • Community bins to be appropriately covered to avoid air blown plastic litter. • Transfer stations or locally called Dhalos should be appropriately fenced and waste to be transferred in closed container only. • Towards effective collection of MLP and polybags, Garbage cafes should be opened in Slum areas. • Kiosks similar to that installed during Kumbh Mela or that installed by Railways which provides mobile recharge, etc may installed in market places, Ghats, etc • Awarding restaurant/ hotels/ shops who use eco friendly cutleries in place of single use plastics • Informal rag pickers to be formalised and to be provided with protective gears.
HARIDWAR	
• Most prominent litter is Multi layer packets for food, thin poly bags, small plastic bottles, plastic laminated metallised paper plates, disposable cutlery • Waste dumping by residents is observed in vacant plots in	• 100% door to door segregated waste collection has to be ensured. • Community bins to be

City observation	Countermeasure proposed
residential as well as industrial area • Major Plastic leakage path to river is through drains/barriers leading to river. • 100% door to door collection of waste is not there. • Lot of plastic waste gets stuck in the barrier and have been found to be settled in the drain and Ganga Channels along the Ghats • Lots of religious materials are found during festive periods • It is observed that community bins are not covered everywhere • Kanwar festival, Ganga Snan, Shahi Snan, Kumbh are major pilgrimage festivals (held during April – July every year) which attracts devotees in a very large number around 50-60 lakhs per year. This gathering lead to generation of 100gm per person per day of waste generation out of which 50% is dry waste comprising mostly plastic, paper, etc • People also come here in large numbers to perform last rites of their family members and during this process; a huge quantity of cloths mostly synthetic is left behind on the bank of the river. • Capacity of waste treatment plant is only 150TPD where as total waste generation is 379 TPD during normal period and additional of 6-7 TPD during peak season and including floating population, total waste is estimated to be 522 TPD. • The waste not being treated because of under capacity of the waste treatment plant is being stored in a dumping yard located near waste treatment plant.	appropriately covered to avoid air blown plastic litter. • Towards effective collection of MLP and polybags, Garbage cafes should be opened in Slum areas. • Kiosks similar to that installed during Kumbh Mela or that installed by Railways which provides mobile recharge, etc may installed in market places, Ghats, etc • Awarding restaurant / hotels/ shops who use eco friendly cutleries in place of single use plastics • Regular cleaning of barriers is must • Small plastic bottles used for carrying Ganga water should be banned. • EPR from large MNC players may be enforced. • Laminated Metallised paper plates in place of single use plastics should be discouraged and instead ecofriendly materials like plates made of leaf, etc should be encouraged and street vendors using such materials may be rewarded or incentivised. • Informal rag pickers to be formalised and to be provided with protective gears.
MUMBAI	
• Mumbai is the financial capital of India. • Ganesha festival which is celebrated during August which attracts large number of tourist (Indian as well as International). • Plastic waste litter is mostly found in slums, along Mithi river, railway track along slum, beach areas. • Plastic litter from beach is because of litter being thrown by the sea during high tide period.	• Waste collection from Slum area to be strengthened through slum committee formulation • Increased awareness on plastic ban among slum dwellers to be made. • Garbage cafe in slum areas to

City observation	Countermeasure proposed
• Beach is cleaned regularly by Municipal Corporation. • Door to door segregated waste collection is being done from 24 wards in Mumbai only. However, no waste collection is happening in Slum areas due to inaccessibility. • Waste collection from some market areas is not on daily basis. • Enforcement of plastic ban is there but needs to be strengthened to achieve 100% coverage. • Major Plastic leakage pathway to ocean is through drains along railway track near Slum leading to Mithi River flowing into the Arabian Sea. • Direct disposal of plastic waste into Mithi river by Slum residents residing along the river is also observed. Mithi river is the major contributor of plastic leakage to Arabian sea (ocean). • Major plastic litter observed in Mumbai comprises of Multi layer plastic, poly bags, disposable cutleries (most likely from event, celebrations, etc), cement bags (polypropylene woven bags). • No litter observed on roads and nearby. Roads are cleaned regularly through mechanised cleansing system. • Open drains were observed only in slum areas. • It is observed that community bins are not covered everywhere (only some are covered). • Plastic waste mostly bottles are collected by a large number of informal rag pickers belonging to slum are mostly from Dharavi slum area (one of the largest slum area in Mumbai) and is recycled at the recycling plant located in the slum.	be opened. • Kiosks (providing mobile recharge in exchange of plastic waste) to be installed in market areas, slum areas. • Muck train is plying beween Virar to Churchgate in Mumbai to collect waste littered along railway tracks. This needs to extend in areas near slums where large quantity of plastic litter was observed during the study. • Community bins to be covered properly to avoid air blown plastic litter from them • Informal rag pickers to be formalised and to be provided with protective gears.

In addition to the above, outreach programs towards sensitising people in all the four study areas have to be planned.

Chapter 7: Conclusions

In this chapter, we have discussed the various countermeasure adopted in the world. Also compilation of various countermeasures being adopted in different parts of the country and also as observed in the study area during our primary survey and through different stakeholder consultation have been listed. The most important inferences we have made from this chapter is that following countermeasures will be required to be implemented in the four study areas to prevent plastic pollution:

- Policy level countermeasures to prevent manufacture and sale of certain plastic products which generate waste that are difficult to treat. Alternatively, use of recycled plastic in them to be encouraged
- Effective waste collection and management system
- Planning of Depository schemes such as Garbage Café, Kiosk (providing mobile recharge, etc)
- Availability of Adequate plastic treatment facility within reasonable distance from collection point for reducing transportation cost
- Regular inspection of the probable hotspots and cleaning them

7.1 Institutional Roles and Actions

Plastic waste is generally covered under the regulation of solid waste in majority of countries in the Asia and the Pacific Region. However, many countries have specific regulations related to packaging, single use plastic, plastic bags and microbeads as described in above sections. It majorly falls under policy and regulatory jurisdiction of nodal ministry of environment and forest in Asia and the Pacific region. However, the regulations are also implemented at the sub-national and city level respectively. A number of other institutions like private sector both formal and informal and civil society organizations are also involved in the implementation of regulations. All the stakeholders are involved at each level of policy, plan / strategy program and projects development and implementation. Therefore, a number of policy, regulatory, technological, economic and institutional issues have been identified in the region. Countries like Australia, New Zealand, Japan, Republic of Korea and Singapore have minimized these issues by institutionalizing policy, regulations, programs and plan to achieve higher recycling rate and circularity of materials. Therefore, the issues summarized below are relevant in the context of developing countries.

Policy Regulatory

- Policy and regulations are unevenly developed and lack effectiveness.
- Definition of waste is very crucial in the regulations, considering the evolution of standards and later enforcement. For example concern over environmental standards for recycling.
- Lack of EPR based policy and regulations for plastic waste. Therefore, EPR based regulatory mechanism is yet to evolve. Currently, there is no specific and comprehensive policy and regulation in place in the region to address the issue of

plastic wastes in coastal and marine environment. These also include local ordinances on the regulation on the use of plastics and study on the life cycle analysis of packaging materials including plastics in relation to the prohibition on the use of Non-environmentally acceptable products and packaging materials.

- Countries lack in addressing significant reduction of MSW, plastic waste and approach for zero waste emissions. Though the countries support 3R concepts, they either lack action plan / strategy, programs and projects for complete implementation as per 3R hierarchy.
- Countries in the Asia and the Pacific also lack in comprehensive policy, program, plan and projects in resource efficiency and productivity, greening of the chain for plastic.
- Some countries have regulation and are preparing for Integrated Solid Waste Management Strategy / Plan for future development of waste management sector, their implementation at national, sub national and city level are a major challenge. Even though waste minimization and collection targets exist at the national level, they are not well adopted within the policy frameworks of local governments.
- Countries also lack better understanding of waste composition to enable the development of a holistic strategy plan for waste management.
- Emerging policy regime particularly green procurement and greening of the value chain need to be implemented through development of projects.
- Poor enforcement of regulations not only leads to uncontrolled dumping and burning of plastic waste but also illegal trafficking of waste plastics.

Box 3: No Plastic Bag Weekend in Brunei Darussalam

Brunei Darussalam launched the *No Plastic Bag Weekend*, a nationwide initiative, on26 thMarch 2011. This initiative promoted the use of reusable and biodegradable bags as one of the ways to minimise plastic wastes. This initiative engaged a few big departmental stores, as the key players to impact the change of minimising the use of plastic bags. The No *Plastic Bag Weekend* initiative was received well by the public at large. On17th February 2012, this initiative was therefore extended to include Fridays, in addition to Saturdays and Sundays.

Source: UN Environment (2017); Waste Management in ASEAN Countries; https://www.unenvironment.org/resources/report/waste-management-asean-countries-summary-report

7.2 Technology Issues

- Lack of segregation of waste at source exists in each country. Further, waste collection system is not adequate in terms of geographical coverage of population.
- There is a lack of waste reduction technologies like incineration and recycling infrastructure for treatment of plastic waste. Therefore, recyclable wastes are being exported to other countries for recycling due to lack of local facilities.
- Only small recycling facilities exist in major cities within majority of countries.
- Need for capacity building exists for choosing the most adequate technologies.
- Mixed discarding of recyclable materials with other non recyclable waste makes it difficult to collect and properly utilize recyclable materials. For example plastics

contaminated and mixed with other materials; biodegradable plastics mixed with other plastics and mixing of problematic additives.

- Recycling infrastructure lacks upgradation and coverage as well as linkage to upstream supply. For example limited collection schemes and treatment technologies for thermosets plastics.
- Pilot level technology demonstration existing in the country needs to be scaled up and replicated.
- Competition between recycling and energy from waste.

7.3 Economic and Institutional Issues

- There is lack of capacity in design, implementation and monitoring of policies, program and projects.
- There has been no major initiative related to development of financial mechanism or institutional framework for developing recycling industry in the country though examples of private sector involvement exist in treatment and disposal mechanism.
- Private sector does not find it lucrative to invest in plastic recycling infrastructure due to lack of incentive and unstable prices of the product. The long term of PPP mechanism is yet to be determined.
- Cost of collecting, sorting and processing waste plastics is significant.
- There is a considerable lack of funding at the regulatory level, causing insufficient monitoring, controlling and enforcement of plastic waste treatment and disposal.
- Global markets for recycled plastics are concentrated in small number of countries.
- Due to price volatility of virgin plastics versus recycled plastics, recycled plastic sector has limited resilience to market shocks.
- Lack of differentiated demand for recycled plastics.
- Limited awareness and behavior of people related to the concept of sustainable cities /m green cities and management of plastic waste.

Box 4: Community Outreach Program in Singapore

Under the Community 3R Outreach Programme (CROP) all 3R community events and initiatives organised by NEA carry a common tagline: "Reduce, Reuse, Recycle. Care for Our Environment." Other examples of instilling a 3R culture in different settings and through different media are:

- 3R Pre-school Awareness Kits
- 3R information on website
- myENV app
- 3R Video for households
- Community Events
- 3R tips and guidelines
- No Waste Day Challenge

NEA has been actively working with various stakeholders on 3R outreach and to co-develop 3R guide books. Examples of guide books developed so far are for households, condominiums and private apartments, shopping malls, hotels, industries and events.

Source: UN Environment (2017); Waste Management in ASEAN Countries; https://www.unenvironment.org/resources/report/waste-management-asean-countries-summary-report

- Lack of knowledge and skill and lack of human resources for managing plastic waste stream.
- Significant opportunities exist in Asia and the Pacific region for plastic waste management. These include: Opportunity for development integrated policy, regulatory, program and projects based on 3Rs for all plastic waste streams; Opportunity for technology transfer and assimilation for plastic waste management; Opportunity for development of recycling infrastructure in the country; and Opportunity to develop integrated institutional mechanism for all types of waste streams.

Box 5: National Recycling Programme (NRP) in Singapore

The NRP was launched in 2001 to provide a convenient means for residents living in public high-rise apartments and private landed housing estates to recycle their source segregated waste streams. It started off with the provision of recycling bags to households, with fortnightly door-to-door collection. The participation rate by households in NRP was 15 % at the start in 2001 and had increased to 71% in 2012. To further improve recycling infrastructure for residents, a recycling bin is provided for every HDB block from 2014 in place of the fortnightly door-to-door collection services. Residents find it more convenient in terms of space for storage of recyclables and they are able to deposit recyclables at any time of the day. The NRP has also been enhanced to provide private landed estates with more frequent collection as well as garden waste collection, and incentive schemes such as "Cash-for-Trash" was implemented to further encourage recycling. In addition, NEA has been promoting the adoption of dual-chute system for recyclables and residual waste. In light of the encouraging results of the trial projects, all new public high-rise residential developments will be fitted with Centralised Chutes for Recyclables (CCR) from 2014.

Source: UN Environment (2017); Waste Management in ASEAN Countries;
https://www.unenvironment.org/resources/report/waste-management-asean-countries-summary-report

References

1. UN Environment (2018); Exploring the Potential for Adopting Alternative Materials to Reduce Marine Plastic Litter; https://www.unenvironment.org/resources/report/exploring-potential-adopting-alternative-materials-reduce-marine-plastic-litter

2. UN Environment (2017); Reducing Marine Litter by Addressing the Plastic Value Chain in South East Asia; http://upload.openaid.se/document/thailand/project-document-reducing-marine-litter-july2018.pdf

3. GIZ (2018); Marine Litter Prevention Reducing Plastic Leakage into Waterways and Oceans through Circular Economy and Sustainable Waste Management

4. Hopewell Jefferson, Dvorak Robert and Kosior Edward, Plastics recycling: challenges and opportunities, Philos Trans R Soc Lond B Biol Sci. 2009 Jul 27; 364(1526): 2115–2126. doi: 10.1098/rstb.2008.0311

5. Francis, Lorraine F.; Stadler, Bethanie J. H.; Roberts, Christine C, Materials Processing - A Unified Approach to Processing of Metals, Ceramics and Polymers, Elsevier 2016, ISBN978-0-12-385132-1
6. FICCI Circular Economy Symposium (2018); Accelerating India's Circular Economy Shift A Half-Trillion USD Opportunity Future-proofing growth in a resource-scarce world

7. **OECD (2018) – Improving Markets for Recycled Plastics – Trends, Prospects and Policy Responses**

8. United Nations Environment Programme, ISWA (2015); Global Waste Management Outlook; https://www.uncclearn.org/sites/default/files/inventory/unep23092015.pdf

9. SPREP (2016); Cleaner Pacific 2025; Pacific Regional Waste and Pollution Management Strategy 2016-2025; http://www.pops.int/; http://www.basel.int/; https://www.sprep.org/convention-secretariat/waigani-convention; http://www.pic.int/; http://www.mercuryconvention.org/; http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

10. UNEP (2012); Application of the Sustainability Assessment of Technologies Methodology: Guidance Manual

11. UNEP (2009): Converting Waste Plastics into a Resource

12. UNEP (2012); Application of the Sustainability Assessment of Technologies Methodology: Guidance Manual; https://wedocs.unep.org/bitstream/handle/20.500.11822/8649/IETC_SAT_Manual_Nov_2012.pdf?sequence=3&isAllowed=y

13. UN Environment (2017); Waste Management in ASEAN Countries; https://www.unenvironment.org/resources/report/waste-management-asean-countries-summary-report

14. AS Yadav, 2019. A Scenario of Plastic Waste Management in India: A Review. Indian Journal of Waste Management, Volume 3 Number 2.

11. Chavan Indrajeet D., D. S. Patil, 2017. International Journal of Engineering Research & Technology (IJERT). Vol. 6 Issue 05

12. CPCB, 2017. Guidelines for Co-processing of Plastic Waste in Cement Kilns. Ellen MacArthur foundation, 2017. The new plastics economy catalysing action
13. European Commission, 2016. Guidance for the identification of polymers in multilayer films used in food contact materials.

14. FICCI, 2016. *A report on* Plastic Industry. 2nd National Conference. Plastic Packaging- Sustainable Choice.

15. Katharina Kaiser, Markus Schmid and Martin Schlummer, 2017. Recycling of Polymer-Based Multilayer Packaging: A Review. Recycling, 3, 1; doi:10.3390/recycling3010001

16. Michael Niaounakis, 2020.Recycling of Flexible packaging. Elsevier Book.

17. Ministry of Housing & Urban Affairs, Government of India, 2018. SBM Coffee Table Book

18. Ministry of Housing & Urban Affairs, Government of India, 2018. Swachhata Sandesh, A monthly newsletter of the Ministry of Housing and Urban Affairs (MoHUA), Government of India. Volume 1, Issue 12.

19. Xiufeng, Xing. (2009). Study on the Ban on Free Plastic Bags in China. Journal of Sustainable Development. 2. 10.5539/jsd.v2n1P156.

20. Michael Niaounakis, 2020.Recycling of Flexible packaging. Elsevier Book.

21. Woldemard'Ambrières, 2019. Plastics recycling worldwide: current overview and desirable changes. Field Actions Science Reports, The journal of field actions, Special Issue 19, Reinventing Plastics.

22. CPCB, 2017. Guidelines for Co-processing of Plastic Waste in Cement Kilns.

23. European Commission, 2016. Guidance for the identification of polymers in multilayer films used in food contact materials.

24. UNEP, 2020. Legal Limits on Single-UsePlastics and Microplastics:A Global Review of National Lawsand Regulations.

25. OECD, 2018. Improving Plastics Management:Trends, policy responses, andthe role of internationalco-operation and trade. OECD ENVIRONMENT POLICY PAPER NO. 12

26. Katharina Kaiser, Markus Schmid and Martin Schlummer, 2017. Recycling of Polymer-Based Multilayer Packaging: A Review. Recycling, 3, 1; doi:10.3390/recycling3010001

27. Ministry of Housing & Urban Affairs, Government of India, 2019. WasteManagementIssues, Solutions& Case Studies. www.mohua.gov.in

28. Ministry of Housing & Urban Affairs, Government of India, 2018. Swachhata Sandesh, A monthly newsletter of the Ministry of Housing and Urban Affairs (MoHUA), Government of India. Volume 1, Issue 12.

29. AS Yadav, 2019. A Scenario of Plastic Waste Management in India: A Review. Indian Journal of Waste Management, Volume 3 Number 2.

30. FICCI, 2016. *A report on* Plastic Industry. 2nd National Conference. Plastic Packaging- Sustainable Choice.

31. Ministry of Housing & Urban Affairs, Government of India, 2018. SBM Coffee Table Book

32. Chavan Indrajeet D., D. S. Patil, 2017. International Journal of Engineering Research & Technology (IJERT). Vol. 6 Issue 05

33. Ellen MacArthur foundation, 2017. The new plastics economy catalysing action

34. Tadinada Sri SasiJyothsna, Bandari Chakradhar, 2020. Current Scenario of Plastic Waste Management in India: Way Forward in Turning Vision to Reality. Urban Mining and Sustainable Waste Management pp 203-218

35. Ministry of Housing & Urban Affairs, Government of India, 2019. Waste Management Issues, Solutions & Case Studies. www.mohua.gov.in
36. OECD, 2018. Improving Plastics Management: Trends, policy responses, and the role of international co-operation and trade. OECD ENVIRONMENT POLICY PAPER NO. 12

37. Tadinada Sri SasiJyothsna, Bandari Chakradhar, 2020. Current Scenario of Plastic Waste Management in India: Way Forward in Turning Vision to Reality. Urban Mining and Sustainable Waste Management pp 203-218

38. UNEP, 2020. Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations.

39. Woldemard'Ambrières, 2019. Plastics recycling worldwide: current overview and desirable changes. Field Actions Science Reports, The journal of field actions, Special Issue 19, Reinventing Plastics.

40. Xiufeng, Xing. (2009). Study on the Ban on Free Plastic Bags in China. Journal of Sustainable Development. 2. 10.5539/jsd.v2n1P156.