BASELINE REPORT ON

PLASTIC WASTE MANAGEMENT IN TAMIL NADU, INDIA

PERSPECTIVES AND PATHWAYS

INDIA-NORWAY COOPERATION PROJECT ON CAPACITY BUILDING FOR REDUCING PLASTIC AND CHEMICAL POLLUTION IN INDIA (INOPOL)

Norway | NIVA Norwegian institute for water research | mμ gamma | सिपेट CIPET

Baseline Report on Plastic Waste Management in Tamil Nadu, India: Perspectives and Pathways

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Acknowledgements

This report is a joint effort by the Norwegian Institute for Water Research (NIVA), Norway's leading institute for fundamental and applied research on marine and freshwaters; Mu Gamma Consultants Pvt Ltd (MGC), which works towards environmental-friendly solutions in promoting green development across India; SRM Institute of Science & Technology (SRMIST), a private deemed university at the forefront of breakthrough research and innovation in environmental sciences and other areas; Toxics Link (TL), an NGO dedicated to bringing toxic-related information into the public domain with unique expertise in the areas of hazardous, medical and municipal wastes, and Central Institute of Petrochemicals Engineering and Technology (CIPET), India's leading research institute in petrochemical engineering and technology.

The research was carried out under the scope of the second phase of the India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India (INOPOL), under the Marine Pollution Initiative developed by the two governments and funded through the Norwegian Development Assistance Programme to Combat Marine Litter and Microplastics. The INOPOL group would like to thank the project owner, the Royal Norwegian Embassy in New Delhi, for funding and supporting this study.

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Suggested Citation

INOPOL (2025) Baseline Report on Plastic Waste Management in Tamil Nadu, India: Perspectives and Pathways

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This report is made possible by the support of the Royal Norwegian Embassy in New Delhi. The contents of this report are the sole responsibility of NIVA, MGC, Toxics Link and CIPET and do not necessarily reflect the views of the Royal Norwegian Embassy.

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Foreword

I am very pleased to launch this baseline report on plastic waste management in Tamil Nadu. I believe that this report will pave the way for meaningful action in addressing plastic pollution in the water sources.

Plastic pollution is a global crisis that adversely impacts our environment, human health, and livelihoods across all geographic contexts. To address and prevent pollution from both land-based and offshore activities, Norway and India cooperate under the joint Marine Pollution Initiative. As part of the initiative, Norway supports a project on capacity building for reducing plastic and chemical pollution in India (INOPOL), implemented by the Norwegian Institute for Water Research (NIVA) and several Indian partners.

The launch of the INOPOL project's comprehensive baseline report on Plastic waste management in Tamil Nadu is an important output in this project. This project epitomizes the international commitment needed to tackle this challenge and aims to develop targeted and efficient measures to control and reduce plastics pollution in Tamil Nadu and Uttarakhand, India.

I congratulate the consortium of the Norwegian Institute for Water Research (NIVA), along with Indian partners such as; Mu Gamma Consultants Pvt. Ltd. (MGC), the Central Institute of Petrochemicals Engineering and Technology (CIPET), the SRM Institute of Science and Technology (SRMIST), and Toxics Link, on their cooperation and achievements in this important field.

May-Elin Stener

Ambassador, The Royal Norwegian Embassy in New Delhi

Foreword

Plastic pollution and persistent organic pollutants (POPs) pose a growing threat to ecosystems, human health, and livelihoods. Addressing these interlinked sustainability challenges requires diverse solutions at local and global levels.

To effectively reduce plastic and POPs pollution, we must identify where pollution originates and occurs throughout products lifecycle and how leaked contaminants impact people and environments. Science-based knowledge can contribute strengthening capacities to monitor, manage, and control plastic and POPs pollution and is especially crucial in countries where adequate pollution control systems, technologies and infrastructures are lacking.

At NIVA, we are fortunate to collaborate with leading Indian partners to bridge some of these knowledge needs as part of the India-Norway Cooperation Project on Capacity Building for Reducing Plastic and Chemical Pollution in India (INOPOL). INOPOL aims to provide science-based knowledge that drive solutions to reduce the harmful impacts of plastic and POPs pollution, by developing monitoring and data collection capacity, supporting policy implementation, identifying local challenges and provide science-based advice relevant government bodies.

POPs, a category of toxic chemicals known for their persistence in the environment and harmful health effects, require an integrated approach that spans regulation, research, capacity building, and public awareness. This report identifies gaps in POPs management and synthesises policies and research from national to international levels. With a specific focus on Tamil Nadu, the project facilitates informed decision-making and the development of a targeted strategy for reducing the harmful impacts of these pollutants.

The report emphasises the connection between POPs management and key sustainability targets and highlights how lessons from the Stockholm, Basel, and Rotterdam Conventions can be applied to the Indian context, contributing to a more integrated approach to chemical management and pollution control.

I hope this report will serve as a valuable resource for policymakers, researchers, and all stakeholders working towards a future free of plastic pollution. On behalf of NIVA, I extend my sincere thanks to Royal Norwegian Embassy in New Delhi and the entire project team for their dedicated efforts in preparing this report.

THORJØRN LARSSEN
Deputy Managing Director,
Norwegian Institute for Water Research (NIVA)

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List of ABBREVIATIONS AND ACRONYMS

AMAP	Arctic Monitoring and Assessment Programme
BBMP	Bruhat Bengaluru Mahanagara Palike
BIS	Bureau of Indian Standards
CBDR	Common But Differentiated Responsibilities
CPCB	Central Pollution Control Board
CSR	Corporate Social Responsibility
DST	Department of Science and Technology
DWCC	Decentralized Dry Waste Collection Centre
EC	European Commission
EDCs	Endocrine Disrupting Chemicals
EPR	Extended Producer Responsibility
EU	European Union
FACCyR	Federación Argentina de Cartoneros, Carreros y Recicladores
FAO	Food and Agriculture Organisation
FTIR	Fourier-transform infrared spectroscopy
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GHMC	Greater Hyderabad Municipal Corporation
GPA	Global Programme of Action
GP	Gram Panchayat
GPDP	Gram Panchayat Development Plan
GPML	Global Partnership on Plastic Pollution and Marine Litter
GSM	Grams Per Square Meter
HDPE	High-Density Polyethylene
HELCOM	Baltic Marine Environment Protection Commission
IISD	International Institute for Sustainable Development
ILO	International Labour Organization
ICT	Institute of Chemical Technology
ICES	International Council for the Exploration of the Sea
INC	Intergovernmental Negotiating Committee
INR	Indian Rupee
IIT	Indian Institute of Technology
IS	Indian Standard
IT	Imperial Tobacco Company of India Limited
kg	kilogram
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
MCCs	Micro Composting Centres
MLD	Million Liters per day
MRFs	Material Recovery Facilities
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act

MARPOL	International Convention for the Prevention of Pollution from Ships
MEA	Multilateral Environmental Agreement
MLALAD	Member of Legislative Assembly Local Area Development
MoEFCC	Ministry of Environment, Forests and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoU	Memorandum of Understanding
MPLAD	Member of Parliament Local Area Development
MSL	Mean Sea Level
MSFD	Marine Strategy Framework Directive
MSMEs	Micro Small and Medium Enterprises
MSW	Municipal Solid Waste
MT	Metric Tonnes
NGT	National Green Tribunal
NCT	National Capital Territory
NOWPAP	Northwest Pacific Action Plan
NOAA	National Oceanic and Atmospheric Administration
NWDA	National Water Development Agency
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic, Oslo-Paris Convention
PA	Polyamide
PCB	Pollution Control Board
PCPs	Personal Care Products
PCC	Pollution Control Committee
PET	Polyethylene Terephthalate
PI	Press Information
PIB	Press Information Bureau
PIBO	Producers, Importers, and Brand Owners
PWM	Plastic Waste Management
PU	Polyurethane
PP	Polypropylene
POPs	Persistent Organic Pollutants
RAP	Reproducible Analytical Pipeline
RDF	Refuse-Derived Fuel
SMS	Convention on the Conservation of Migratory Species of Wild Animals
SIPCOT	State Industries Promotion Corporation of Tamil Nadu
SPCB	State Pollution Control Board
SDG	Sustainable Development Goals
SRM IST	SRM Institute of Science and Technology
SUP	Single-Use Plastic
SUPPs	Single-Use Plastic Products
SHG	Self-Help Groups
TB	Tuberculosis
TDS	Total Dissolved Solids
TRL	Technological Readiness Level
TPA	Tonnes Per Annum
TPD	Tonnes Per Day
TN	Tamil Nadu
TNPCB	Tamil Nadu Pollution Control Board
UN	United Nations
UNEP	United Nations Environment Programme
UNEA	United Nations Environment Assembly
UNFCCC	United Nations Framework Convention on Climate Change
UTs	Union Territories
ULBs	Urban Local Bodies
UK	Uttarakhand
WIOMSA	Western Indian Ocean Marine Science Association
WWTPs	Wastewater Treatment Plants
WRIS	Water Resources Information System
XPS	Extruded Polystyrene
μm	Micrometer

Executive SUMMARY

Plastic pollution is rapidly increasing across the globe, adversely affecting the environment, sustainable development, human health, and livelihoods across socio-economic and geographic contexts. This ranges from the extraction of fossil- and bio-based feedstock for primary plastic polymers, to waste management, environmental remediation, and compensation for communities affected by plastic pollution. Simultaneously, the challenge of managing plastic pollution has grown more complex in recent years due to increasing production- and consumption rates, international waste trade, and the growing multitude of pollution sources.

The India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India (INOPOL) is a collaboration project between the Norwegian Institute for Water Research (NIVA), Mu Gamma Consultants Pvt. Ltd. (MGC), the Central Institute of Petrochemicals Engineering and Technology (CIPET), the SRM Institute of Science and Technology (SRMIST) and Toxics Link. INOPOL aims to develop targeted, efficient, mitigative, and solution-oriented measures for the control and reduction of plastics and POPs pollution in Tamil Nadu and Uttarakhand in India through a multidisciplinary, cross-sectoral, and integrated approach.

This baseline report provides an overview of plastic pollution, plastic pollution management, and socio-economic considerations in the South Indian coastal state of Tamil Nadu. It addresses the volume and distribution of plastic pollution in natural environments, corresponding management efforts and limitations, and the socio-economic impacts stemming from the environmental and governance challenges of managing plastic waste and pollution. This baseline provides a starting point for developing monitoring and data collection capacity, supporting the implementation of current policies, assessing local gaps and hurdles, identifying opportunities associated with implementation, and promoting science-based advice to local and national government bodies.

Tamil Nadu is a hub of several industrial clusters contributing to plastic and chemical pollution. Managing pollution from key sources in these areas are key to prevent environmental and health risks to surrounding ecosystems and communities.

The Cauvery River connects people and communities in Tamil Nadu by providing essential water for drinking, agriculture, and industry, supporting local livelihoods, fostering cultural and religious practices, and linking various regions through its extensive basin and tributaries. However, it is considerably polluted by plastic and chemical waste, necessitating action to prevent further contamination. Developing baselines and assessing pollution hotspots and sources along the Cauvery River provides a starting point for building capacities and identifying challenges and opportunities for reducing plastic pollution.

The findings presented in this report draw on the best available scientific knowledge on plastic pollution and plastic waste management in Tamil Nadu and India, including analysis of state and national plastic waste regulations and reports, ongoing regulatory developments and initiatives, scientific sampling and monitoring procedures, and knowledge gained in the first phase of the INOPOL project. This report emphasises various facts about how to mitigate and minimise the adverse and future effects of plastic pollution to ensure a just transition for people and communities across the plastics lifecycle. The report addresses several of these issues in more detail and provides policy advice for the way forward in ten chapters.

Chapter one describes the background for the INOPOL project and its ambition to support the development and implementation of multiple regulatory frameworks for managing pollution in India through a multidisciplinary, cross-sectoral, and integrated approach.

Chapter two focuses on the level of plastic pollution in Tamil Nadu. As a starting point for understanding the cumulative and complex issues of plastic pollution in the state, this chapter provides an overview of the geographical characterisations of the Cauvery River and provides initial insights into key sources of plastic waste and waste management practices, as well as emerging contaminants of concern in Tamil Nadu.

Chapter three provides a summary of national, and state-level regulatory frameworks, policies, and initiatives aimed at tackling plastic pollution in India, with a specific focus on Tamil Nadu. It outlines key elements and changes in the Plastic Waste Management (PWM) Rules, including the nationwide ban on single-use plastic products (SUPPs) and the implementation of Extended Producer Responsibility (EPR) Rules. It also provides insights into regulatory challenges related to plastic waste management.

Chapter four moves from the local and national level to the emergence of plastic pollution on the international regulatory agenda by delving into the ongoing process of developing a legally binding instrument to end plastic pollution. The chapter summarises developments linked to multilateral environmental agreements (MEAs) addressing plastic pollution, such as the attention shift from marine to land-based plastic pollution. It focuses on key debates in the plastics treaty negotiations and their relevance for national and local policy contexts in India. It further discusses challenges to address plastic pollution in the form of global commitments and national implementations across the entire plastics value chain.

Chapter five provides an overview of current methods for detecting macro and microplastics across India and outlines existing programs and guidelines for marine litter at global and regional levels. It highlights established techniques for sampling and detecting both macro-and microplastics, as well as methods for analysing microplastic particles across various matrices (terrestrial, coastal, and aquatic) within established guidelines. The chapter calls for the harmonisation of international monitoring methods for plastic pollution and argues that insights from international strategies and approaches to plastic pollution monitoring can provide useful guidance in establishing effective monitoring in India.

Chapter six outlines the use and management of plastics in the large and important agricultural sector in India. To find best practices for the use and handling of different agriplastics and to minimise potential negative effects, the chapter argues that more research is needed to establish a baseline of plastic contamination in farm soils and to better understand associated impacts on environments and ecosystems. The chapter also identifies a need for more research and data on the use, application, and waste generation of agriplastics at both the local and regional levels. It emphasizes that the benefits of using agriplastic in farming should be measured against potential costs in the Indian context to better understand how to secure long-term sustainability within agricultural production, food and nutrition security, as well as for individual farm economies.

Chapter seven focuses on the health risks associated with plastic pollution, including exposure to nano-, micro- and macroplastics and the interlinkages between plastic pollution and persistent organic pollutants (POPs). These interlinkages underscore the urgent need for a comprehensive approach to address environmental pollution and its consequences for human health. The chapter argues that reducing plastic pollution and limiting exposure to associated hazardous chemicals necessitates a combination of regulatory measures, improved waste management, and sustainable alternatives to plastics, from local to global levels.

Chapter eight focuses on the challenges and opportunities for enabling a just transition for people and communities disproportionately affected by plastic pollution. It elaborates on how the ecological and socio-economic impacts of plastic pollution and corresponding control measures are currently inequitably distributed, often impacting people and communities in low-income and marginalised situations. Providing a snapshot of challenges faced by waste pickers in Tamil Nadu, the chapter identifies and acknowledges the role waste pickers have as key knowledge- and rights-holders, contributing to reducing of plastic pollution by recovering mismanaged waste that diverts significant amounts of waste from landfills and the environment. The chapter also provides insights into ongoing policy developments and initiatives to integrate waste pickers in municipal and privately run waste management systems.

Chapter nine provides examples of different initiatives aimed at reducing plastic pollution in Tamil Nadu and India. The chapter contextualises these within the priorities of the waste hierarchy, indicating that initiatives to date have largely prioritised awareness raising to reduce the use of single-use plastic packaging and to support the implementation of the bans under the PWM Rules. In addition, waste-to-energy solutions are commonly being promoted. The chapter calls for aligning the circular economy with waste hierarchy goals, including waste prevention, production reduction, design for longevity, and reuse systems, to identify long-term sustainable and scalable solutions that avoid the unintended social, economic, and environmental implications of promoted solutions to end plastic pollution.

Chapter ten identifies challenges and ways forward for reducing plastic pollution in Tamil Nadu based on the previous chapters. The chapter underlines the importance of recognising and addressing plastic pollution as a cross-cutting issue that has wide-spread impacts across the full life cycle of plastics. It emphasizes the need for engaging a range of stakeholders to reduce plastic pollution, including households, consumers, businesses, industries, waste workers, including waste pickers and other informal workers, civil society actors, research institutions, local governments, practitioners, and decision makers across states.

CHAPTER 1
BACKGROUND TO THE INOPOL PROJECT

[1]Girija K. Bharat

The *India-Norway cooperation project on capacity building for reducing plastics and chemical pollution (INOPOL)* was established in 2019 under the joint Marine Pollution Initiative, to address the interlinked challenges of marine litter, microplastics and Persistent Organic Pollutants (POPs) in India.

The first phase of the project (2019-2022) focused on developing capacities to manage plastic waste and chemical pollution in the two industrial regions of Surat and Vapi, in the western state of Gujarat. It investigated the land sources, river fluxes, and leakages of plastics and POPs pollution into aquatic environments, as well as socio-economic drivers and impacts of pollution, contributing with policy relevant science-based knowledge that supports ongoing initiatives to reduce plastic pollution from local to national levels.

The INOPOL team has produced several scientific publications and is following the national and international processes related to plastics and POPs regulations closely, while engaging with key stakeholders to identify challenges and opportunities within the current policy environment, to optimise support towards ongoing implementation processes of plastic waste management rules and the Stockholm Convention on POPs.

The Norwegian Institute for Water Research (NIVA) led the project in close collaboration with Indian partners, including Mu Gamma Consultants (MGC), The Energy and Research Institute (TERI), Central Institute of Petrochemicals Engineering and Technology (CIPET), Toxics Link (TL) and SRM Institute of Science and Technology (SRM IST).

Key features of the first phase of INOPOL:

Time frame:	January 2019- June 2022
Funding:	NORAD - The Norwegian Agency for Development Cooperation
Program:	Development Assistance Program Against Marine Litter and Microplastics/India-Norway Marine Pollution Initiative
Project Management:	NIVA, in collaboration with TERI and MGC
Project partners:	NIVA, TERI, MGC, CIPET, SRM and Toxic Links
Case studies:	Surat, river Tapi (Tapti) Vapi, river Daman Ganga
Key outcomes:	■ Establish baselines on use and release ■ Strengthen monitoring capacity and standardisation ■ Assess social drivers and impacts, and identify sustainable solutions ■ Develop sound management tools

Building on INOPOLs established partnerships and identified challenges for reducing plastics and POPs pollution in India, the second phase of the project continues to focus on contributing to solutions to

[1]Mu Gamma Consultants, Gurugram, India

manage and protect the environment and human health from the toxicological impacts of plastics and POPs pollution.

Key features of the second phase of INOPOL:

Time frame:	September 2022 - December 2025
Funding:	The Royal Norwegian Embassy in New Delhi
Program:	Development Assistance Program Against Marine Litter and Microplastics/India-Norway Marine Pollution Initiative
Project Management:	NIVA, in collaboration with MGC
Project partners:	NIVA, MGC, CIPET, SRM and Toxic Links
Case studies:	Tamil Nadu, River Cauvery Uttarakhand
Key outcomes:	▪ Establish baselines on use and release ▪ Strengthen monitoring capacity and standardisation ▪ Assess social drivers and impacts, and identify sustainable solutions ▪ Develop sound modelling and management tools

Building on the first phase of INOPOL, the project applies a multidisciplinary, cross-sectorial, and integrated approach to collect data and develop a coherent system for data collection in two states: Tamil Nadu and Uttarakhand. INOPOL will scale up by establishing baselines in the selected states, develop monitoring and data collection capacity, support the implementation of current policies, assess local gaps and hurdles, identify opportunities associated with implementation, and promote science-based advice to local and national government bodies.

Through regular stakeholder engagement activities, the project will ensure scientific and policy relevant outputs are made available and accessible to key stakeholders and policymakers. INOPOL will develop an online platform to facilitate sharing of knowledge, experiences, and best practices across Indian states, engaging with actors representing state and local governments, scientists, and civil society.

International lab visits, interactive knowledge sharing sessions, and online dissemination activities are organised to accelerate knowledge exchange and enhance synergies between stakeholders across Indian states – including, but not limited to Gujarat, Delhi, Tamil Nadu, and Uttarakhand – as well as between the states and at the national level. The international lab visits will contribute to strengthening collaboration between Indian and Norwegian stakeholders to exchange and share experiences, practices and scientific knowledge used to manage chemicals and plastic waste.

The project will ensure that INOPOL findings feed into national and international policy processes on plastics and chemicals, including into efforts to regulate single use plastics products (SUPPs) and implement Extended Producer Responsibility (EPR) under India's Plastic Waste Management (PWM) Rules, whilst contextualising research findings and activities in relation to the ongoing plastics treaty process.

The aim of INOPOL is to develop targeted, efficient, mitigative, and solution-oriented measures for control and reduction of plastics and POPs pollution in Tamil Nadu and Uttarakhand in India through a multidisciplinary, cross-sectorial and integrated approach.

Planned activities and key outputs

1. **Establishing local monitoring capacity on plastics**
   a. Develop locally adapted monitoring strategy for plastics
2. **Assessing sources of plastics and POPs pollution**
   a. Baseline assessment of plastic pollution sources
   b. POPs inventorisation and toolkit assessment for industrial and other waste sources
   c. Hot-spot assessment and prioritisation
   d. Review of health and environmental impacts

3. **Identifying effective reduction measures in the private sector (plastics)**
   a. Set-up collaboration with local private sector
   b. Develop plan for emission reduction and pollution control
   c. Assessment of specific challenges for micro, small and medium enterprises (MSMEs)
4. **Analysing pollution regulations, management, and impacts**
   a. Analysis of existing regulation and policy
   b. Socio-legal study on regulation and policy enforcement and implementation
   c. Science-based support towards the global plastics treaty process
   d. Assessment of social and economic impacts and benefits of prevention
5. **Identifying societal challenges and opportunities**
   a. Examine the role of informal sector in India under a global plastics treaty
   b. Assess the interface between informal, public and private sectors in reducing pollution
6. **Contributing to education and disseminating findings**
   a. Arrange stakeholder workshops
   b. Local-National integration activities
   c. Build capacities amongst government officials to manage and reduce pollution
   d. Build sector-specific capacities to manage and reduce pollution
   e. Arrange annual knowledge sharing seminars / workshops
   f. Explore synergies with other projects / activities

The expected impact of the project is to contribute to reduced marine pollution in Tamil Nadu (TN) and Uttarakhand (UK). The expected outcome is to improve performance to manage and reduce use and impact of plastic waste pollution in TN and UK states.

The project will engage with key stakeholders in TN and UK to reach the expected impacts and outcomes, including the Ministry of Environment, Forests and Climate Change (MoEFCC), the Central Pollution Control Board (CPCB), and the respective State Pollution Control Boards (SPCBs) and Urban Local Bodies (ULBs), as well as academic and research institutions, industry associations, and other civil society actors.

Through its multidisciplinary, cross-sectorial, and integrated approach, INOPOL supports the development and implementation of multiple regulatory frameworks for managing pollution in India. The project aims to generate of integrated, scientific data and knowledge that informs implementation and is guided by principles of sustainable and circular use of resources to protect the environment and human wellbeing from plastics and POPs pollution. The theory of change of INOPOL is depicted in Figure 1.1.

In this Baseline Report for Plastic Pollution in Tamil Nadu, the INOPOL project provides an overview of key sources, hotspots, regulations, initiatives, and socio-economic considerations of plastic pollution in the State, based on available scientific and grey literature and building on experiences and understandings on the pressing issue of reducing plastic pollution during the first phase of the INOPOL project. The following chapters provide an overview of the status of pollution in Tamil Nadu. This is followed by a summary of frameworks, policies, and programmes relevant for reducing plastic pollution in India, including insights into the relevant international processes and the ongoing global plastics treaty process. Practices for monitoring macro- and micro-plastics across environmental matrixes and contexts are then explored, before delving into the uncertainties and health risks associated with exposure to plastic pollution and associated chemicals of concern and recent advances in plastics research and technology. The following chapters explores the just transition concept and initiatives to reduce plastic pollution in India. Building on these chapters, the final chapters summarises persistent gaps and charts a way forward for reducing plastic and chemical pollution in India and beyond.

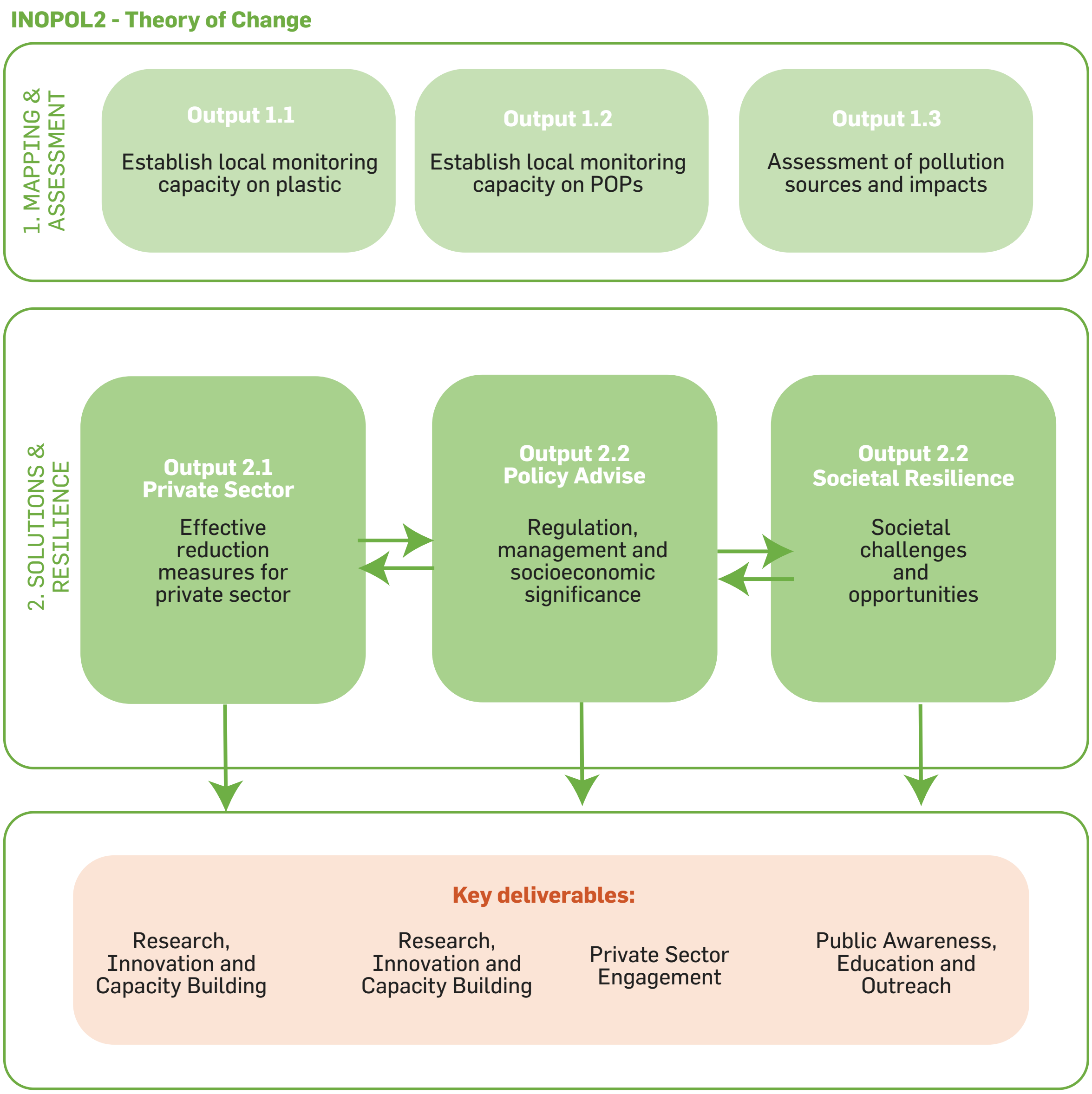


Figure 1.1: Theory of Change: Outcomes, outputs, solutions, and resilience contributing to the four broad categories of deliverables of INOPOL.

CHAPTER 2
BASELINE ASSESSMENT OF PLASTIC POLLUTION AND MANAGEMENT IN TAMIL NADU

[1]Neha Lakhwan, [1]Nathaniel B. Dkhar, [1]Mary Abraham, [1]Anagha Krishnan, [2]Girija Prasad, [2]Smita Mohanty

INOPOL focuses on the Cauvery (known as Kaveri) River stretch [alt. Basin], also known as *Dakshina Ganga* (Figure 2.1). This chapter provides a baseline assessment of plastic pollution and management in Tamil Nadu, including geographical characteristics of the case study sites along the Cauvery River, key sources of pollution and plastic waste management in Tamil Nadu, insights into sources and waste management practices in cities along the Cavuery River, and emerging contaminants of concern.

2.1 Geographical characteristics of the case study sites along Cauvery River

Cauvery, a significant river in the Southern Peninsula, originates from Talacauvery in the Kodagu District of Karnataka. Situated within the Brahmagiri range of the Western Ghats, its elevation is 1341 meters above mean sea level (MSL) (NWDA, 2020). The Cauvery Basin spans Kerala, Karnataka, Tamil Nadu, and the Union Territory of Puducherry, with distribution percentages of 42% in Karnataka, 54% in Tamil Nadu (including the Karaikkal region of Puducherry), and 4% in Kerala (WRIS, 2014). Encompassing a drainage area of 81,155 km^2, the river's geographical coordinates range between 75°27' to 79°54' East longitudes and 10°9' to 13°30' North latitudes. The Cauvery River stretches over a total length of 800 km, bounded by the Western Ghats to the West, the Eastern Ghats to the East and South, and the basins of the Pennar and the Krishna rivers to the North (WRIS, 2014).

The Cauvery River basin exhibits three distinct physiographical divisions, including the Western Ghats, the Plateau of Mysore, and the Delta. The basin's elevation varies from 2 to 3000 meters. The Western Ghats bordering the left side of the basin has the highest elevation (Figure 2.2). As the river flows east, it descends from the South Karnataka plateau to the Tamil Nadu plains through waterfalls. The Western Ghats host a diverse range of flora and fauna, protected by wildlife sanctuaries and national parks. Upon reaching Thanjavur, the Cauvery River divides into two distributaries fanning into a delta as it enters the Bay of Bengal (Ibid).

The alteration in Land Use and Land Cover (LULC) is a significant factor influencing the physical, chemical, and biological characteristics of the river basin (Kumaraswamy, et al., 2021). The Cauvery River basin is predominantly covered by crops, encompassing about half of the area (Figure 2.3). Furthermore, the fertile delta region at the river mouth is acknowledged for its prolific rice production. Over recent years, the urban development pattern in the river basin demonstrates rapid growth of Tier-I and Tier-II cities, primarily driven by improved transportation facilities and waterbodies, leading to habitat fragmentation (Kumaraswamy et al.,

[1]Mu Gamma Consultants, Gurugram, India; [2]Central Institute of Petrochemicals Engineering & Technology (CIPET)

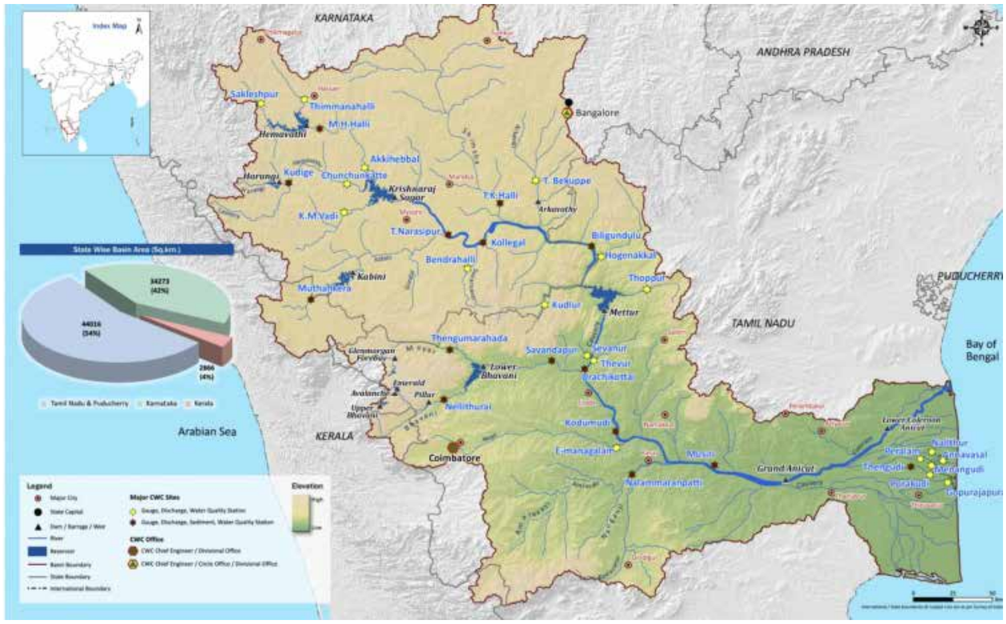


Figure 2.1: Flow of the Cauvery River (Source: WRIS Portal)

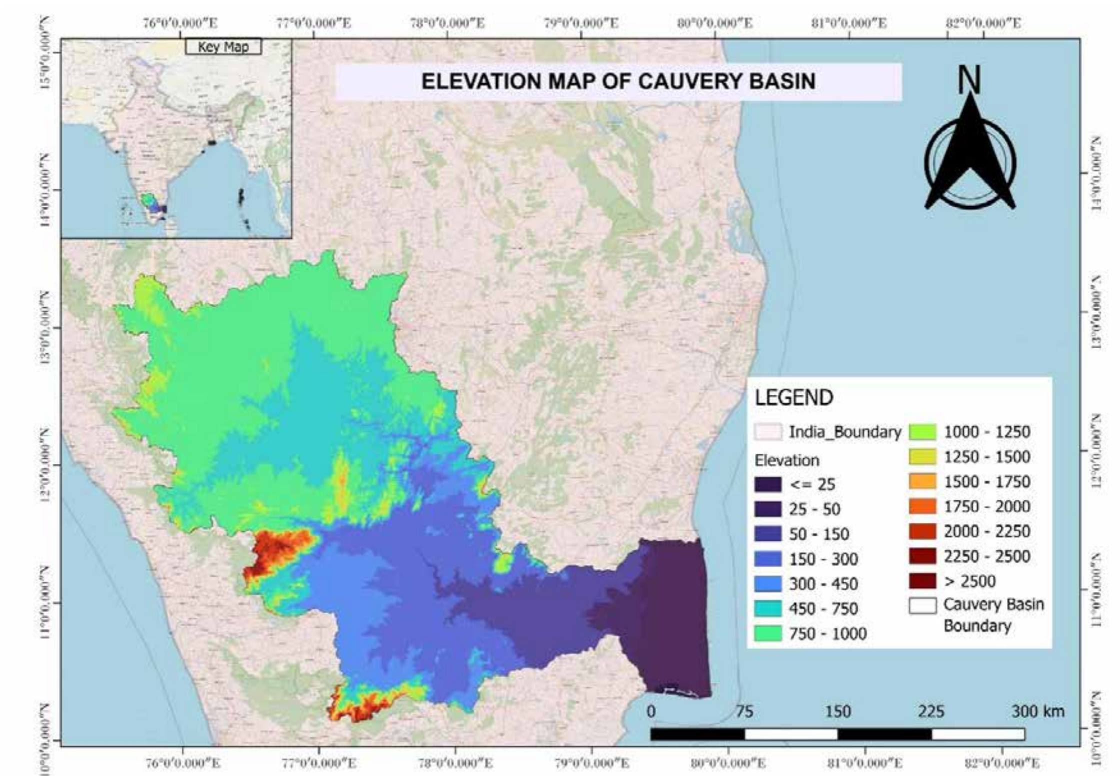


Figure 2.2: Elevation Map of Cauvery Basin 30 m

2021). This has further attributed to the increasing challenge of solid waste management in the region.

Rainfall serves as the primary source of runoff in the Cauvery basin (NWDA, 2020). The basin predominantly receives rainfall from the South-West Monsoon and partially from the North-East Monsoon in both Karnataka and Tamil Nadu (WRIS, n.d.).

The climate in the basin is generally dry, except during the monsoon months. The mean daily

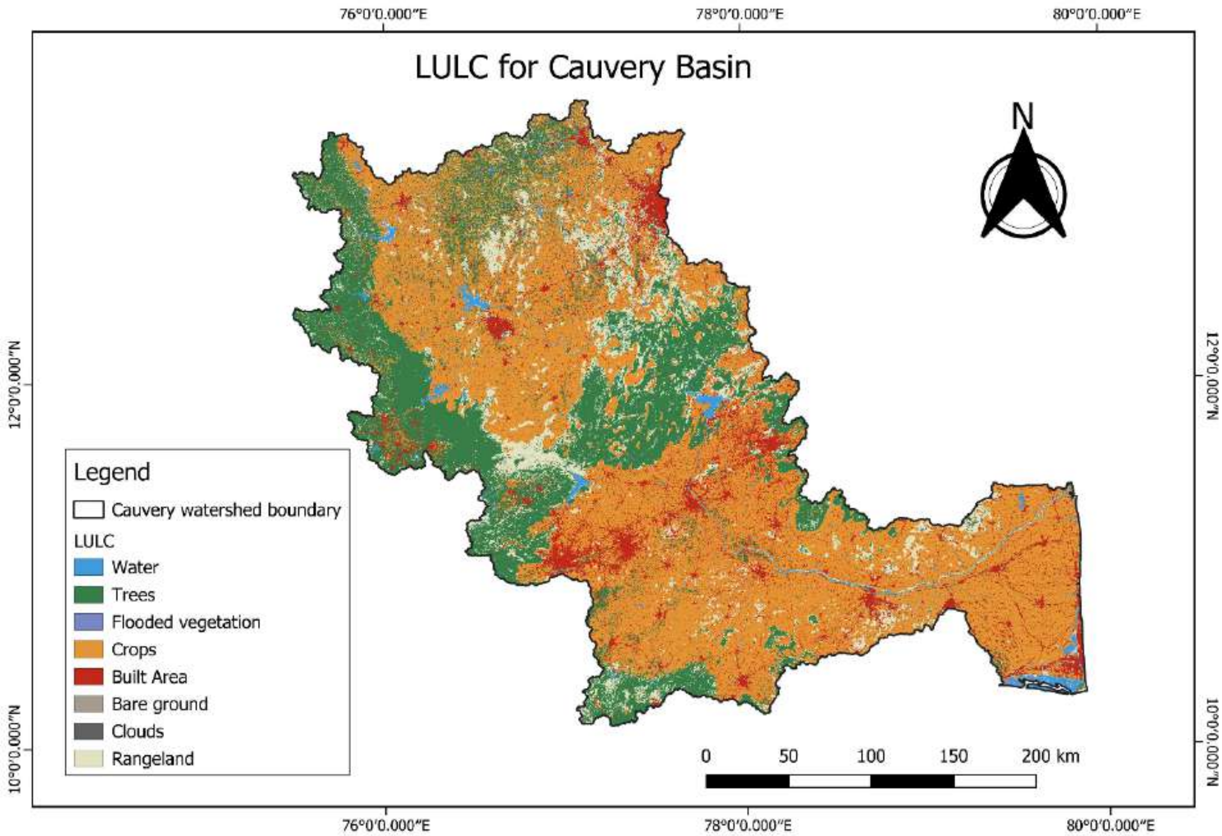


Figure 2.3: Land Use and Land Cover (LULC) for Cauvery basin using ESRI 10 m LULC map.

temperature in the basin fluctuates between 9.10°C to 33.7°C (NWDA, 2020). Monsoon winds dictate the wind direction during the monsoon, while the wind blows from north to east during the rest of the year. The mean wind speed in the basin varies from 5.4 km/hr to 18.9 km/hr (NWDA, 2020). Relative humidity in the basin spans from 49% to 86% (NWDA, 2020).

The Cauvery River plays a vital role in irrigating the fertile lands of Mysuru and Bengaluru. However, it faces pollution challenges as it flows through Karnataka and Tamil Nadu. The most polluted stretches of the river are reported to be from Coimbatore to Tiruppur along the Bhavani River, downstream of Erode, and Thanjavur to Grand Anicut (CPCB, 2019). In Tamil Nadu, prominent industrial areas such as State Industries Promotion Corporation of Tamil Nadu (SIPCOT) and Tamil Nadu Small Industries Development Corporation Limited (TNSIDCO) contribute to this pollution. The river TDS (Total Dissolved Solids) measures 1,750 near Mettur and 1,450 near Erode, primarily due to industrial waste discharge into the river (Jitendra, 2019).

2.2 Key sources of plastic pollution in Tamil Nadu

Sources of plastic waste in Tamil Nadu are diverse, reflecting the widespread use of plastic materials used in various aspects of daily life, industry sectors, and economic activities. Plastic waste generated by households is a significant contributor to the overall plastic waste generation in the state, including items such as plastic bags, packaging materials, bottles, containers, and single-use plastic products (SUPPs). Restaurants, shops, supermarkets, and other commercial establishments have also been identified as key generators of plastic waste, including packaging, disposable cutlery, straws, and takeout containers. As a popular tourist destination, Tamil Nadu's tourism and hospitality industry also contributes to plastic waste generation in the state. Other industrial sectors are also contributing to plastic waste generation. For instance, plastic materials used in agriculture, such as mulching films, pesticide containers, and irrigation pipes, contributes to plastic waste generation in rural areas.

Tamil Nadu is one of India's industrial hubs, being the home to a substantial number of plastics manufacturing units, ranging from small-scale enterprises to large industrial giants. The plastic industries in the state are estimated to employ up to 10 lakh people and the sector is expected to grow exponentially (Business Standard 2017; The Hindu. 2022c).

The state has highly diversified industrial sectors such as automobiles, electronic, hardware, textiles, leather products, chemicals and a range of other industries which uses plastic components. Leading companies in the automotive industry, such as Hyundai Motor India, BMW, and Renault Nissan, have established themselves in the state and contributed to the expansion of the region's automotive and supporting sectors. Rapid adaptations to consumer needs and ongoing technological adaptations in manufacturing are key factors behind the growth in plastic industries. The existence of numerous plastic manufacturing facilities in important industrial areas, such as Chennai, Coimbatore, and Madurai, contributes to economic growth but also to the generation of plastic waste.

The electronics manufacturing sector is expanding in Tamil Nadu, with numerous telecommunications giants choosing Chennai as their production base in South Asia, including Flextronics, Motorola, Sony-Ericsson, Samsung, Cisco, Moser Baer, and Dell. Cellular phone handsets and circuit boards are examples of manufactured goods which uses various plastic products including polycarbonate (PC), Polypropylene (PP), polymethyl methacrylate (PMMA) etc. 20% of India's electronics are produced in Tamil Nadu (Sen Gupta, 2022).

The region around Coimbatore, Tirupur, Karur and Erode is recognised for their textile exports and manufacturing sectors and is as such known as the "Textile Valley of India" (Jagadeeswari, 2015). Rajapalayam is famous for its cotton market. Gobichettipalayam is a significant white silk producer and is home to the nation's first automated silk reeling machine. Kanchipuram, Arani, Sathyamangalam, Salem, and Aruppukottai are well known worldwide for their silk sarees (Ibid).

Polyurethane (PU) is a type of plastics used to produce synthetic leather. 70% of India's leather tanning capacity and 38% of its leather footwear and components are produced in Tamil Nadu. Exports from Tamil Nadu make up 42% of all leather exports from India (Thiripurasundari and Ponsakthisurya 2018). Hundreds of leather and tannery companies are located around the cities of Vellore, Dindigul, and Erode, as well as the surrounding towns of Ranipet, Ambur, Perundurai, and Vaniyambadi (Ibid). Due to the tanning industry's extensive presence, Tamil Nadu has emerged as the nation's leading producer of leather and leather-based goods. 30% of leather exports and nearly 70% of leather produced in India originate from Tamil Nadu (Jagadeeswari, 2015).

The primary industries situated along the banks of the river Cauvery include dyeing units, sugar, distilleries, and paper mills in Pallipalayam, Namakkal. A study by Lata et al. (2015) shows that numerous of these industries are directly releasing untreated effluents into the river. Additionally, this basin is home to the Salem steel plant and numerous engineering industries located in Coimbatore and Tiruchirappalli. These effluents contain toxic chemicals and hazardous substances that contaminate the river water, such as copper, zinc, iron, lead, and manganese. The continuous discharge of these effluents into the river has significantly deteriorated the water quality and made it unsuitable for drinking.

2.3 Plastic waste management in Tamil Nadu

India generates 9.4 million TPA of plastic waste (DTE, 2022), of which 12.3% is recycled through mechanical recycling and 19.8% undergoes incineration (Singh and

Biswas, 2022). Around 60% of plastic waste (mostly PET bottles) is recycled as per the Union Ministry of Housing and Urban Affairs (MoHUA). 94% of recyclable plastic waste in India is mechanically recycled, whilst 0.83% is chemically recycled (Singh, 2021) (See text box below).

Common types of recycling methods in India explained:

Mechanical recycling methods

- Primary recycling: there are no major changes in the properties of the original plastics. It is suitable for Polyethylene terephthalate (PET), Polypropylene (PP), and Polystyrene (PS) without contaminants.
- Secondary recycling: It changes the properties of the original plastics and produces plastics of lower quality.

End of life recovery methods

- Tertiary or chemical recycling: It converts plastics into oil and gas which can then be used as fuel.
- Quaternary recycling: Use of plastic waste in road constructions, cement plants, and plastic-to-fuel. This process is largely incineration of plastics. It accounts for 5% of the total recycling (Hossain et al., 2023)

India recycles thermoplastics like HDPE (High-density polyethylene), PVC (polyvinyl chloride), and PET (Polyethylene terephthalate), while there is limited recycling capacity for polymers like LDPE (Low-density polyethylene), PP (polypropylene), PS (polystyrene) (CSE, 2019). Figure 2.4 shows the percentage distribution of plastics used in packaging in India with LDPE (Low-density Polyethylene) accounting for the largest share at 31% (Hossain et al., 2023).

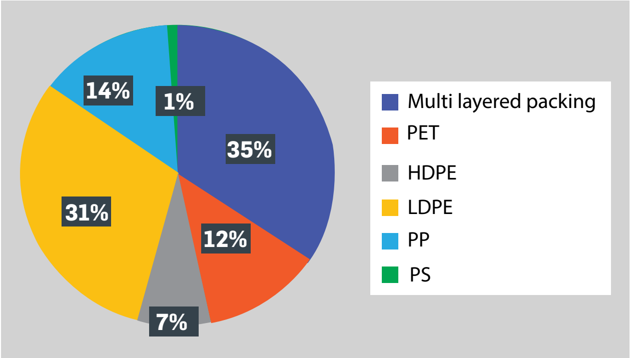


Figure 2.4: Percentage distribution of plastics consumption in packaging in India (Hossain et al., 2023)

Some of the methods adopted in India for PWM are listed below:

- **Bitumen Binder in asphalt road**: A secondary recycling type method was first introduced by professor R. Vasudevan, a chemistry professor at Thiagarajar College, Tamil Nadu in 2001. With the new technology, plastics like PS and PP can be used to mix with asphalt. Consequently, a government order of the Ministry of Road Transport mandated the use of plastics in road construction in 2015 (You et al., 2022).
- **Iron and steel manufacturing:** The Indian Government is looking into the opportunity to utilise plastic waste in the iron and steel industry. The steel industry can help address the significant environmental and social concern of generating carcinogenic gases like dioxin and furans. This issue is commonly encountered in processes such as incineration and energy generation, as high temperatures are maintained in steelmaking, which involves some pyrolysis processes. It is anticipated that for every 1 kilogram of plastics used, approximately 1.3 kilograms of coal can be replaced. Considering the current capacity, the iron and steel industry has the potential to utilise roughly 2-3 million tonnes of plastic waste annually. By 2030-31, this capacity could increase to over 8 million tonnes (PIB, 2022).
- **Synthetic fibres**: Sulochana Cotton Spinning Mills in Chitambalam, Tiruppur turns plastic waste bottles into fabric and garments (Preetha, 2023). Indian Oil Company has planned to convert 405 tonnes of plastics every year into yarn to make uniforms (PIB, 2022a)
- **Thermocatalytic pyrolysis**: This technology converts plastic wastes to fuel. Indian Oil Corporation Limited (IOCL) has developed the INDEcoP2F technology which claims to

convert more than 95% of plastic waste to fuel. It processes plastic waste in Delayed Coker Units (DCU) to convert it into fuel (IOCL, 2021). Needa Green Energy Limited (NGEL) set up a plant in Guntur, Andhra Pradesh to convert any type of plastics into kerosene, petrol, diesel, and activated carbon (TOI, 2020).

- **Plasma pyrolysis technology:** This technology disintegrates organic compounds into gases and non-leachable solids in the absence of oxygen. In a study conducted by Central Pollution Control Board (CPCB), the emissions of dioxins and furans are lower than the prescribed norms. The end products are CO, H_2, and CH_4, and a small quantity of higher hydrocarbon gases. Approximately 1KWH of energy is required for 1 kg of plastic waste (CPCB, 2016). It is estimated that power generation from 15 kg/hr system would be around 15 kWh (CPCB, 2016).
- **Power Generation**: In 2014, Dehradun-based Indian Institute of Petroleum (IIP) developed a technology to convert plastics into fuel. For 1 kg of plastics, 750 ml of automotive grade gasoline could be derived (MoST, 2017).

The following section outlines a selection of initiatives whose long-term effects and viability will require further evaluation. These are not suggested as best practices; but are just examples from work done by different research institutes across India. It may be noted that before scaling up pilot models, the deployment of such technologies needs to take the local environment into account and will also need further research inputs. It will be pertinent to mention that a lot of these examples are most suitable for waste that is neither recoverable nor recyclable.

- The Indian Institute of Hyderabad has developed a new technology where citrus peel extract is used with polystyrene waste to develop non-woven fabric. This fabric can absorb oil and is hydrophobic (DST, 2019).
- The Central Institute of Petrochemicals Engineering & Technology (CIPET) has developed four different grades of formulations utilising waste plastics collected from E-waste (DST, 2019).
- A pilot study project by the Institute of Chemical Technology (ICT), Mumbai, developed a process ICT-Poly Urja which converts plastic waste into Hydrocarbon oil using a patented process. It converts above 85% of feedstock into fuel. This technology has been tested using a vehicle-mounted mobile plant and can convert 100 kg/day of plastic waste into hydrocarbon oil (DST, 2023).
- IIT Bombay is developing an instrument called GoLDN to recycle dumped legacy waste by melt-mixing thermoplastic polymers and inorganic particulate fillers and manufactures polymer composites. The composites can further be utilized for developing tiles paver blocks, bricks, and other decorative items (DST, 2023).
- Kongu Engineering College in Erode, Tamil Nadu, developed a device for liquefaction of plastic waste with lignocellulosic biomass (like sawdust). It comprises a high-pressure screw reactor to perform Alkali catalysed Hydrothermal Co-liquefaction. The end products are biochar and bio-crude (DST, 2023). A technology is developed by the Indian Plywood Industries Research and Training Institute, Bangalore to recycle milk pouches and use it as a binding agent in the manufacturing of plywood and bamboo mat-based panels (DST, 2023).

Tamil Nadu has 21 municipal corporations, 138 municipalities, and 490 Town Panchayats entrusted with plastic waste management under the Plastic Waste Management rules from 2016 and amended in 2018. As per the latest TNPCB annual report (2021-2022), the estimated daily plastic waste generated in Tamil Nadu equals to 1,089 tonnes per day (TPD) (TNPCB, 2022). Out of this, 1028 TPD of plastic waste is collected, and 690 TPD is processed. This accounts to about 95% of plastic waste being collected and segregated by the respective ULBs, while 441 TPD of plastic waste is recycled, 14 TPD is utilised in road construction, and 148 TPD of plastic waste is co-processed in cement plants.

There are 216 registered plastic waste recyclers with a capacity of approximately 3,29,879 tonnes per year under the Plastic Waste Management Rules, 2016. Out of the total plastic waste collected, approximately 176,319 lakh tonnes (one lakh is equal to 0.1 million) have been diverted for recycling. 39 compostable plastic manufacturing facilities have registered with the Tamil Nadu Pollution Control Board in the State. However, the Board issued directives ordering the closure of 50 facilities producing prohibited plastic goods (TNPCB, 2022).

Waste management in Tamil Nadu begins with door-to-door collection, covering 11 million households and 1.17 million commercial establishments. The collected waste undergoes segregation practices, followed by transportation to resource recovery facilities. There, recyclable materials are sold to local vendors and registered recyclers, while non-recyclables are co-processed by cement manufacturers. There is a total of 216 plastic waste recycling units in the state and 8,025 tonnes of plastic waste has been recycled for road construction (TNPCB, 2022). About 4,375 tonnes tonnes of non-profitable and non-recyclable plastic wastes were used for laying 3,646 km of roads in the last 4 years. During the year 2019-20, 655 tonnes of non-saleable and non-recyclable wastes were used for laying 536 km of road in Tamil Nadu. The TNPCB has issued registration to 29 compostable plastic manufacturing units and 230 plastic waste recycling units.

All the municipalities in the state have material recovery facilities (MRFs) with installed shredder machines at the Municipal Compost yard, and the shredded plastics is mixed with aggregates and used in bituminous road laying. Using this method, from 2016-2020, 3,646 kms of road have been constructed in Tamil Nadu. About 116 ULBs have entered into an agreement with cement industries and sugar mills in the state to utilise plastic waste. Pyrolysis plants are proposed in various ULBs to produce Pyro oil from plastic wastes. From 2019 to 2020, around 450 tonnes of plastic waste is recycled in pyrolysis plants. 10 units of 100 TPD, 4 units of 10 TPD, 1 unit of 50 TPD, and 10 units of 5 TPD incineration plants are sanctioned to process non-recyclable combustible waste (TNPCB, 2020).

116 ULBs in Tamil Nadu have entered into an agreement with Ultratech Cements, India Cements, ACC Cements, Dalmia Cements, Alten Power Plant, and Ponni Sugar Mills for waste co-processing activities. Since May 2018, about 20,776 tonnes of non-recyclable waste have been disposed in cement factories in the state. Plastic wastes, including non-recyclable plastics, are transformed into paver blocks, interlocks, and tiles in pyrolysis plants. From April 2019 to March 2020, a total of 441.7 tonnes of plastic waste was sent to the pyrolysis unit of MAK India Pvt. Ltd. in Erode.

Additionally, incinerators and pyrolysis plants are planned for processing non-recyclable dry waste in clusters. Each district has a plastic shredding unit under the *Swachh Bharat Mission* (SBM) Scheme. All the ULBs enforce source segregation of wastes and the saleable fraction of plastic waste is sold to recyclers with remuneration being paid back to sanitary workers.

The state has also produced a directory of manufacturers and suppliers for eco-alternative materials for plastics for Tamil Nadu to identify potential producers in each district for commercial development of alternatives to plastics (TNPCB, 2022). Table 2.1 provides and overview of the current PWM and recovery infrastructure in Tamil Nadu state.

Table 2.1. PWM and recovery infrastructure in Tamil Nadu, 2022 (TNPCB, 2022)

Type of use	Details
Quantity of PW utilised in recycling	441 TPD
Quantity of PW utilised in road construction	14 TPD
Quantity of PW utilised in cement kilns	148.3 TPD
Number of recycling units	216
Quantity of PW utilised in Refuse derived fuel (RDF)	21.2 TPD
Quantity of waste used to produce waste to oil	6.8 TPD

2.4. Sources and management of waste in cities along the Cauvery River

In the subsequent subsections, we describe the sources and management of plastic waste in key cities and towns traversed by the Cauvery River. While recognising the integral role of districts for planning, coordination, and implementation of targeted interventions in plastic waste management, the following sections focus on the main urban centres and districts of Karnataka and Tamil Nadu, drawing on available secondary data. Although this baseline report primarily focuses on the state of Tamil Nadu, Karnataka state is also covered as the Cauvery originates in Karnataka and flows across state lines.

Karnataka State

The total stretch of the Cauvery River extends to about 100 kms in Karnataka, with the major tributaries Lokapavani and Kabini River joining Cauvery between Ranganathittu and Satheagala. The major towns along the river are Srirangapatana in Mandya District, Bannur and T. Narasipura in Mysore District, and Kollegala in Chamarajanagar District and Bengaluru. In its annual report, CPCB estimates that a 50 km stretch of the river is polluted, from Ranganathittu, upstream of Srirangapatana Town, to Sattheagala road bridge (CPCB, 2019).

Furthermore, it is estimated that 272,776 tonnes of plastics waste per annum was generated in Karnataka between 2018 and 2019 (ibid). Decentralised dry waste collection centres have been established at the ward level to collect, segregate, and recycle the dry waste from households and commercial establishments. According to CPCBs data from 2018/19, there were 239 registered and 128 unregistered plastic manufacturing and recycling units in the state, whilst 2025,500 tonnes of plastic waste was converted for co-processing in cement industries and 47,500 tonnes for recycling (CPCB, 2019a).

Bengaluru, Karnataka

The Bruhat Bengaluru Mahanagara Palike (BBMP), the city municipal body of Bengaluru, collected an estimated 144,000 tonnes of plastic waste in 2020 and 2021. BBMP has also established two facilities for processing and disposing of 10 tonnes of plastic waste per day. 141 Decentralized Dry Waste Collection Centre (DWCC) have been set up to manage waste at the ward level. DWCCs collect, segregate, and recycle dry waste collected from households and commercial establishments. A total of 66 plastic recycling units are registered in Bengaluru. It is estimated that 36,000 tonnes of low-value plastics are supplied to cement plants each year, while 108,000 tonnes channelled for recycling. Informal waste pickers play an essential role in this system as they engage in door-to-door dry waste collection and manage

Figure 2.5: Schematic diagram of flow of Cauvery River in the state of Tamil Nadu

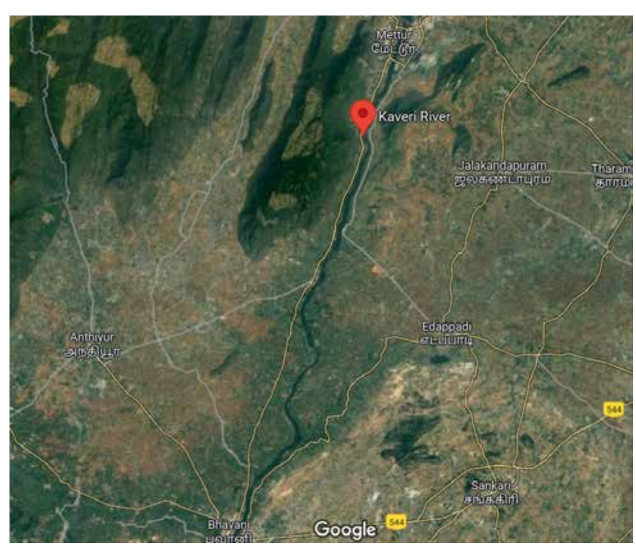


Figure 2.6: A stretch of Cauvery River from Mettur to Bhawani in Tamil Nadu

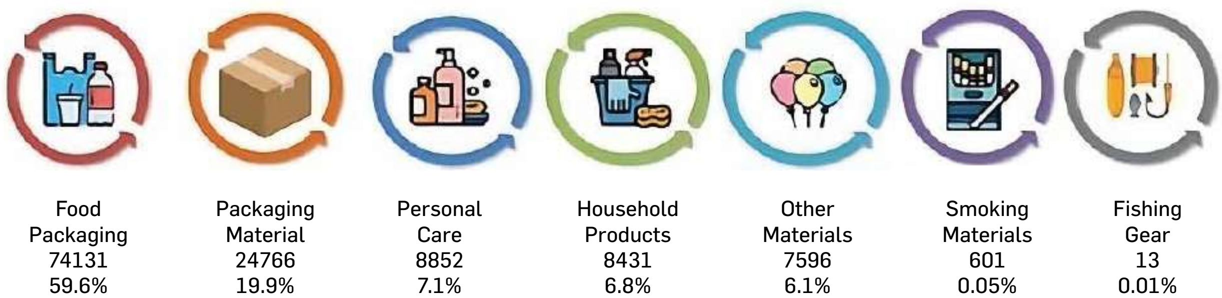


Figure 2.7: Plastic packaging materials identified in the brand audit of plastic waste generation from the household level (Source: Chandran et al., 2022)

the DWCCs. To enhance their efficiency, informal workers involved in dry waste collection has been provided with auto tippers for dry waste collection. According to recent brand audits, food packaging materials (60%), packaging material (20%), and personal care products (8%) are significant sources of plastics waste generation in the city (Figure 2.7), identifying large brands as significant sources of produced plastic waste, including large national and multinational brands like Dodla, Heritage, Milk Mist, Amazon, Unilever, Coca Cola, Reckitt Benckiser, ITC, and Britannia (Chandran et al., 2022). According to the audit, low-density polyethylene (LDPE) comprised the largest portion of generated waste at 33%, primarily originating from milk and curd packaging. Other food packaging, including biscuit packets, chocolate wrappers, shampoo packets, sachets, masks, and tetra packs, were followed by unknown, unidentified, or multi-layered plastics at 30.6% (Ibid).

Nagapattinam district, Tamil Nadu

The Mayiladuthurai municipality in the Nagapattinam district lies at the end of the Cauvery delta. Mayiladuthurai generates 14 TPD of dry waste, out of which 7 TDP is recyclable and 4 TDP is non-saleable and non-biodegradable (TNPCB, 2019). The recyclable waste is sold to registered vendors and the non-saleable and non-biodegradable waste is stored in the resource recovery centre at Ananthadhandavapuram Road and periodically disposed of to Ultra Tech Cement for co-processing (Ibid).

Rajagopalapuram Village in Kuthalam Town Panchayat generates 1.12 TPD of dry waste, of which 0.03 TPD is sold to identified vendors and 0.69 TPD non-recyclable waste is disposed of periodically (Ibid).

Mathirimangalam village panchayat in Nagapattinam district generates 0.17 TPD. 65% of the non-biodegradable waste is plastics (equalling to about 13 kg per day), of which a significant amount (35%) is used for roadmaking (Ibid).

Dindigul district, Tamil Nadu

The Panjampatty village in Dindigul district generates 250 kg of plastics per day, of which 60% is shredded each day in the local Plastic Waste Management Unit, while 86,000 kg of plastics have thus far been sold for roadmaking (*Swachh Bharat Gramin*, 2021).

Erode District

The industrial town of Erode is situated along the banks of the Cauvery River in the state of Tamil Nadu. It is a major hub of various industries, including textile manufacturing units specialised in power loom textile products, handloom products, and readymade textiles. Erode is also a leader in dairy products production, turmeric manufacturing, and hosts numerous textile facilities for bleaching, dyeing, and tanning.

The Erode City Municipal Corporation, comprising 60 wards, generates approximately 35–40 MLD of sewage, which is currently discharged untreated into the River Cauvery/Kalingarayan Canal. The ongoing installation of an underground drainage system within the 60 wards is in progress, and a Sewage Treatment Plant (STP) with a capacity of 50.55 MLD in Vendipalayam Village is prepared for commissioning. In Erode, the generation

Figure 2.8: Plastic waste dumped on Cauvery Riverbank in Erode (The Hindu, 2022a)

Figure 2.9: Plastic waste in the Cauvery River in Erode waste (EcoHubMap. N.d.)

of Municipal Solid Waste (MSW) amounts to around 250 tonnes/day, of which 110 tonnes/day undergoes processing (composting) at the Vendipalayam compost yard. The remaining Municipal solid wastes, approximately 140 tonnes/day, are deposited in the Vendipalayam dump yard and on the right bank of River Cauvery at Vairapalayam Village (NGT, 2021). There are plastic manufacturing units in the region (D. Govardan, 2022).

Salem District

Salem is an industrial town in Tamil Nadu and a major hub of steel factories and textile manufacturing units. Plastic waste is generated mainly from textile shops that use plastic covers for packing of clothes and garments. Salem Corporation has a decentralised approach to waste processing. Four Material Recovery Facilities (MRFs) were established in Micro Composting Centres (MCCs) to handle dry waste. According to estimates from 2019, about 17 TPD of plastic waste was sold directly to recyclers (while the sale revenues split amongst the sanitary workers) and other non-recyclable combusting waste

Figure 2.10: Plastic waste piled up outside textile shops on Bazaar Street in Salem (The Hindu, 2022b)

was disposed for co-processing in cement factories (NGT, 2019). Salem is the home to the 210-acre SIDCO Industrial Estate, which accommodates waste generating chemical industries, plastic industries, and engineering and fabrication industries.

Stanley reservoir (Mettur Dam) is one of largest fishing reservoirs in South India, situated in the Salem district of Tamil Nadu. Fed primarily by the Cauvery River, it faces pollution from various major industries in the Mettur area. These industries include the Mettur Thermal Power Station I & II, Chemplast Sanmar Limited Plant – I, II, III and IV – significant PVC manufacturer based in Chennai, the Madras Aluminum Company, and Malco Energy. The SIDCO industrial estate is a substantial source of pollution within the catchment.

The Mettur municipality oversees two Sewage Treatment Plants (STPs) with a capacity of 6.374 million Liters per day (MLD) each. While one STP treats a portion of the sewage, releasing the treated effluent into a surplus course, the remaining sewage is directly discharged into the Cauvery River. A report has highlighted concerns about Chemplast Sanmar, a plastic manufacturing unit in Mettur, allegedly discharging approximately 28 different chemicals into the Cauvery River with five of these chemicals identified as potentially carcinogenic (Sreedevi, 2007).

Namakkal District

In the Kumarapalayam and Pallipalayam areas of Kumarapayalam Taluk in Namakkal District, a total of

154 unauthorised textile dyeing and bleaching units have been identified. Among these, 98 are small-scale units releasing untreated trade effluent into the municipal drain and consequently polluting the Cauvery River (TNN, 2018). The Cauvery River also passes through the Namakkal district which is known for poultry farming and the production of poultry-related products, which may be associated with ancillary plastic packaging and processing industries (C. Paramasivan, 2011).

Karur District

In Karur District, the River Cauvery is joined by two tributaries, namely the River Noyyal and the River Amaravathi. The Noyyal River is polluted with dyeing effluent discharge from various dyeing and bleaching units in Tirupur District, making it a source of pollution in the Cauvery River (TNPCB, 2022).

Trichy/Tiruchirappalli District

The Cauvery River flows through Tiruchirappalli (also called Trichy), a district with a diverse industrial base. Trichy is known for its manufacturing activities, including the production of industrial components, leather industries and consumer goods (Selvakumar et al., 2017). Tiruchirappalli is also a major engineering manufacturing hub in Tamil Nadu and is intersected by the Cauvery River in its central region. It is an important industrial centre of Tamil Nadu, hosting major industries such as Bharat Heavy Electronics Limited (BHEL), Ordinance Factory Tiruchirappalli (OFT), and The Heavy Alloy Penetrator Project (HAPP). The district is home to cement factories, petrochemical industries, steel plants, sugar mills, and various traditional craft-based industrial clusters, including handloom production, korai mat manufacturing, synthetic gem production, and gold jewellery manufacturing units. The disposal of plastic waste in the city often leads to drain blockages, restricting free flow of wastewater through the drainage system. In Trichy District, the Cauvery River covers 20 local bodies, three Municipalities, and 16 Town Panchayats. MSW generates in Trichy District accounts to 222 TPD of wet waste and 168 TPD of dry waste, posing a potential threat to the water quality of the Cauvery River. The Trichy Corporation has opened resource recovery centres in 39 Micro Compost Centres (MCCs) to collect recyclable and reusable waste from residents and commercial establishments.

Figure 2.11: A polluted stretch of Cauvery River in Trichy located near an outlet of sewage. (Source: Authors)

Thanjavur District

Thanjavur district also passes through the Cauvery River and is primarily an agricultural region known for its rice cultivation (Thilagavathi et al., 2011). The total length of River Cauvery in Thanjavur District is 82.7 km. Several towns and villages are situated along the riverbank in this region, and a portion of the local sewage from these communities is discharged into the river via drainage systems and pipelines. Kumbakonam municipality, situated in the Thanjavur district of Tamil Nadu. Kumbakonam, often referred to as the temple city, is recognised for effectively managing legacy- and post-consumer plastic waste, the latter being primarily generated from its thriving food industry. This town accommodates a floating population of 25,000 individuals, resulting in the generation of 72 tonnes of waste per day, one-third of which constitutes non-recyclable wastes, primarily composed of plastics (22 tonnes) (Down To Earth, 2022). Out of this, non-recyclable plastic waste is mainly converted into refuse-derived fuel (RDF) for cement factories, recycled into oil bulbs, and shredded for road construction.

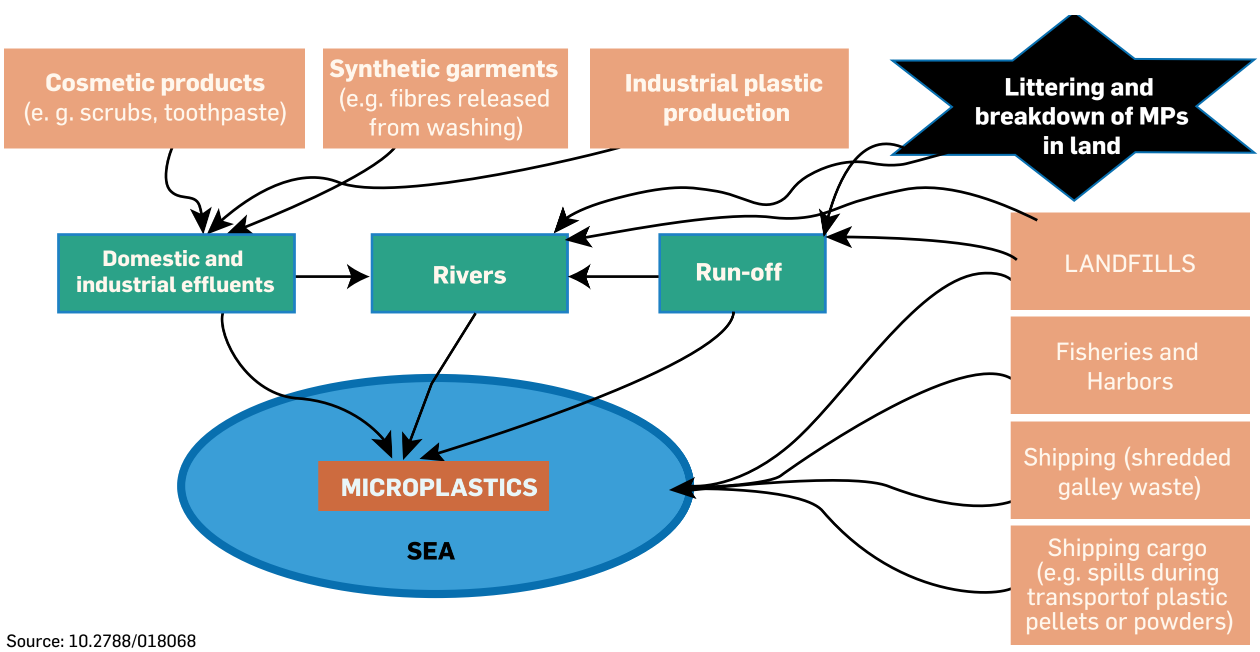
Tiruvarur District

Tiruvarur district is known for its agricultural activities, including the cultivation of paddy and other crops. Plastic materials such as mulching films and irrigation equipment used in agriculture may be a source of plastic pollution if not adequately handled.

2.5 Emerging contaminants of concern

The waters of River Cauvery are polluted by a range of emerging contaminants including pharmaceutically active compounds and other contaminants such as personal care products, plastics, flame retardants, heavy metals, and pesticides, among many others. Plastic pellets from industry, microfibers from clothing, microbeads from personal care products (PCPs) and paint, as well as microplastics from washing wastewater, wastewater treatment plants (WWTPs), rubber roads, artificial turf, and tire wear are the main sources of primary microplastic emission to the environment that have been identified (Wojnowska-Baryła et al., 2022). Larger plastic items that are not properly disposed of include secondary sources of microplastic pollution. These sources mostly consist of agricultural film, fishing waste, and municipal waste made up of plastic bottles, bags, tableware, and packing materials. Even though it takes years for large plastic debris to break down into microplastics under natural conditions, secondary sources recognised as a key source of microplastics into the environment. PCPs, like makeup cosmetics and cleaning products, frequently include microbeads. As per the PCP consumption and microplastics levels, the mass emission of global PCP-derived microplastics reach up to 1.2 × 104 tonnes/year (Sun et al., 2020).

Several studies have identified hotspot areas for microplastic accumulation in Tamil Nadu. A case study looking at microplastics abundance in the Noyyal River, a branch of the Cauvery River, found between 187 to 699 particles per kg in sediment from the mouth of the river (Ayyamperumal et al., 2022). Another study looked at the presence of microplastics in all water and sediment samples collected from the estuaries of Tamil Nadu. From the 19 estuary stations, a total of 39,644 particles were isolated as microplastics, of which 19,129 items (water: 8193; sediment: 10,936) were from the summer samples and 20,515 items (water: 8,982; sediment: 11,533) from the monsoon samples. The overall microplastic abundance (mean ± SD) ranged from 31.7 ± 3.78 to 154.7 ± 4.16 items/L



Source: 10.2788/018068

Figure 2.12: Sources of microplastics in the environment

in water and 51.7 ± 3.51 to 171.3 ± 9.02 items/kg in sediment (Jeyasanta et al., 2022).

Veeranam lake is situated in the district of Cuddalore, around the west of 25 km in the town of Chidambaram, Tamil Nadu. A recent study of microplastics in the Veeranam lake finds that the accumulation of maximum concentration of plastic particles falls under the category of extremely small fraction size (1 mm-0.3 mm), with the quantity ranging from 4 to 438 items/kg (and an average of 146 items/kg) (Bharath et al., 2021). The study also found a range of plastic particles in the sediment samples (92 to 604 items/kg, with a mean of 309 items/kg) and identified nylon as the most abundant microplastics fibre (Ibid).

A study of seasonal distribution of microplastics in the surface water and sediments of the Vellar estuary in Cuddalore, Tamil Nadu, found microplastics were found microplastic abundance in surface water and sediments to range from 1.15 ± 0.01 to 5.14 ± 0.04 items/m^3 and 24.8 ± 0.75 to 43.4 ± 0.98 particles/kg dry weight, respectively (Nithin et al., 2022). It found that microplastics were mostly retained in sediments due to transport by fluvial process.

Microplastic contamination has also been detected in surface water and sediment samples in the Kodaikanal Lake (Laju et al., 2022). The study found that abundance of microplastics in water ranged from 8.39 ± 1.25 to 53.33 ± 14.25 items/L, while in sediment, it varied from 15.0 ± 2.36 to 72.0 ± 22.79 items/kg. Furthermore, it identified municipal wastewater and surface runoff as key sources of microplastics in aquatic environments.

2.6 Cauvery River: A hotspot area for pollution

This chapter has identified the geographical characteristics of the case study sites along the Cauvery River, key sources of pollution, and prevalent waste management practices in the broader Tamil Nadu region with a specific focus on cities along the Cavuery river stretch. The chapter has identified that Tamil Nadu is home to a diverse and thriving plastic industry. The state has witnessed significant growth in plastic manufacturing, encompassing a wide array of products ranging from packaging materials to consumer goods and industrial components. The presence of industrial hubs like Chennai, Coimbatore, and Madurai has fuelled this expansion, making Tamil Nadu a significant contributor to India's plastic production. Key sectors within the plastic industry include packaging materials, consumer goods, industrial components, automotive parts, and textiles. The strategic geographical location and favourable business environment have attracted numerous plastic manufacturing units to establish their operations within the state. The proliferation of plastic industries in Tamil Nadu has resulted in a significant generation of plastic waste. This waste comprises various forms, including packaging materials, offcuts, defective products, and industrial packaging. Additionally, consumer-oriented plastic waste from households, commercial establishments, and the tourism industry has further compounded the issue.

The Cauvery River has been identified as a hotspot area for pollution. Industries situated along the riverbanks contribute to the pollution of this vital water source. In Salem, Erode and Trichy industrial activities, including chemicals and plastics industries, have been associated with pollution in the river. Untreated effluents containing toxic chemicals and heavy metals often find their way into the Cauvery, degrading water quality and posing risks to aquatic life and public health. At the same time, urbanisation and population growth have increased the pressure on sewage discharge systems. Inadequate sewage treatment facilities result in untreated wastewater being released into the river, impacting water quality and public health. Improper disposal practices, inadequate waste management infrastructure, and the release of untreated effluents have contributed to making the Cauvery River one of the most polluted rivers in India. As the river flows through various districts of Tamil Nadu, it is exposed to and causes significant pollution challenges, impacting both the environment and the communities residing along its banks.


R-CHN-02-MO-01

CHAPTER 3
REGULATORY PERSPECTIVES AND INITIATIVES FOR PLASTIC WASTE MANAGEMENT IN INDIA

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The sustainability challenges posed by plastic pollution from local to global scales necessitate solutions through both international and sub-national approaches (Hardesty et al., 2021). The recent emergence of plastic pollution as a focal point in international development has spurred a surge in regional and national policy initiatives and regulatory measures, often aimed at curbing the production and usage of problematic types of plastic waste, such as Single Use Plastic Products (SUPPs) (UNEP, 2018; EC, 2021; Diana et al., 2022). India committed to eliminate all SUPP in the environment by 2022 at the World Environment Day in 2018 and played a leading role in the adoption of a resolution "Addressing Single-use plastic producs pollution at UNEA-4 in 2019 (UNEP/EA.4/R.9) (MEA India, 2023). While the following chapter will delve more into detail on the ongoing international policy developments related to plastic pollution, this chapter focuses on national regulatory frameworks, policies, and initiatives aimed at tackling plastic pollution in India, with a particular focus on Tamil Nadu. It offers an overview of key regulatory measures and initiatives while identifying challenges toward achieving more efficient and sustainable plastic waste management practices.

3.1 National regulations for plastic waste management

Waste management policies in India are evolving in response to the emerging sustainability challenges associated with plastic pollution. Several regulatory and policy interventions have been implemented to address waste management in the India over the past three decades. On a national level, plastic waste imports have been banned since 2019. The Municipal Solid Waste Management rules were introduced in 2000, service level benchmarks were established in 2008, and the Plastic Waste Management (PWM) rules were implemented in 2011, which were replaced by new PWM rules in 2016. In 2018, 2021, and 2022, the rules were revised to introduce various specifications such as minimum thickness requirements for virgin plastic carry bags, definitions of SUPs, plastic waste processing[1], and non-woven plastic bags[2], as well as a centralised portal for operationalising extended producer responsibility

1 Plastic waste processing means any process by which plastic waste is handled for the purpose of reuse, recycle, co-processing or transformation into new products.

2 'Non-woven plastic bags' are bags that are made of plastic sheets, a web structured fabric of entangled plastic fibers or filaments bonded together by mechanical, thermal or chemical means. 'Non-woven fabric' describes a flat or tufted porous sheet that is made directly from plastic fibres, molten plastic or plastic films.

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(EPR)[3]. These rules outline specific responsibilities for various stakeholders, such as institutions that generate waste, Urban Local Bodies (ULBs), Gram Panchayats, producers, importers, and brand owners. Different states in India have enforced the PWM rules differently, with some banning plastic carry bags and others setting thickness criteria.

The Ministry of Housing and Urban Affairs (MoHUA) focuses on minimising plastic waste through the *Swachh Bharat* Mission-Urban 2.0 (SBM-U). The 5-year Mission launched in 2021 aims to achieve a Garbage Free Status for all cities through a 100 percent source segregation, door to door collection and scientific management of all fractions of waste including safe disposal in scientific landfills. This mission promotes PWM rules compliance, waste segregation, Material Recovery Facility (MRF) establishment, raising awareness about SUP reduction, and encouraging usage of alternative products.

Measures to control plastic packaging were introduced through the implementation of India's Plastic Waste Management (Amendment) Rules in 2022. Under this regulation, Producers, Importers, and Brand Owners (PIBOs) are legally obliged to establish collection systems for plastic packaging under Extended Producer Responsibility (EPR). These rules apply to various stakeholders including waste generators, local bodies, gram panchayats, manufacturers, importers, producers, brand owners, recyclers, the Central Pollution Control Board (CPCB), the State Pollution Control Boards (SPCB), and/or Pollution Control Committees (PCC). The latter enforce and monitor the effectiveness of these rules and mandate the registration of PIBOs and plastic waste processors. They also require specifying the minimum thickness for carry bags (must be at least seventy-five microns in thickness; w.e.f. 30th September 2021 and 120 microns with effect from 31st December 2022) and promote recycling and energy recovery. The roles of different stakeholders are outlined within the amended rules, with responsibilities for waste segregation, infrastructure development, and waste collection system establishment. Recycled carry bags must bear appropriate labels and meet set standards. An Advisory Committee at the state level will oversee the implementation of India's Plastic Waste Management (Amendment) Rules. Additionally, waste management guidelines are provided for urban local bodies, gram panchayats, PIBOs, SPCBs/PCCs, and local authorities. Some of the key national level policies and initiatives are outlined in Table 3.1, whilst the following text box outlines key features of the PWM Rules.

Swachh Bharat Mission (SBM) is the overall program that undertakes sanitation in urban and rural areas. In urban areas, SBM-U is implemented by the Ministry of Housing and Urban Affairs (MoHUA) and has been allocated a total fund of INR 2000 Crores (one crore is equal to 10 million) for 2022-2023. In rural areas, the SBM-Garmin (SBM-G) is implemented by the Ministry of Drinking Water and Sanitation and has been allocated a total fund of Rs. 7,192 Crore in the same year. The programme is funded by the Central Government and the states have planned for an expenditure of 22,264 Crore from all sources this year (PIB, 2023).

For villages, the Gram Panchayats (GP) should prepare a comprehensive Gram Panchayat Development Plan (GPDP) including PWM. Under SBM-G, depending on the population, GPs can get additional funds from the SBMG II, 15th Finance Commission Grants, Members of Parliament Local Area Development scheme (MPLAD), CSR, and through other convergent schemes of the State or Central Governments. Infrastructure funds are further allocated from SBMG, the 15th Finance Commission, Grants, and MGNREGA (SBM). With SBM 2.0, the goal is to segregate 100% of the waste at the source and set up a material recovery facility within urban areas to recover recyclables.

3 To streamline implementation processes of EPR, the PWM (Amendment) Rules of 2022 notified 'Guidelines on Extended Producer Responsibility for Plastic Packaging' according to which the Producers, Importers and Brand Owners (PIBOs) are mandated to register through the 'Centralized EPR Portal for Plastic Packaging' developed by the CPCB (https://eprplastic.cpcb.gov.in/#/plastic/home).

Table 3.1. A summary of national policies and initiatives to manage plastic waste in India

SN	National level policies and initiatives	Description
1	Plastic Recycling Guidelines, 1998	Guidelines for selection, segregation, and processing of plastic waste
2	Recycled Plastic Rules, 1999	Carry bags to be labelled as "recycled material" or "virgin plastic," and must have a minimum thickness of at least 20 microns
3	Recycled Plastic Rules (Amended), 2003	Restriction on manufacture, sale & use of virgin/recycled plastics, Registration of virgin/plastic manufacturers with SPCBs/PCC
4	Service Level Benchmarks (2008)	Extent of segregation of plastic wastes
5	Plastic Waste (management & handling) Rules, 2011	Ban on plastic sachets for gutkha/tobacco/pan masala, no use of recycled or compostable plastics for food packaging; recycled carry bags must meet specific BIS standards with a minimum thickness of 40 microns and prescribed colours
6	Plastic Waste Management Rules, 2016	Increase the minimum thickness of the carry bags made of plastics to 50 microns, Responsibility of Waste Generators, Extended Producer's Liability and Collect back system, Pre-Registration Fee collection from importers/ producers
7	Plastic Waste Management Rules, (Amended) 2018	Phasing out of Multilayered Plastic (MLP) that is non-recyclable with no alternate use, central registration system for the registration of the producer/ importer/brand owner
8	Plastic Waste Management Rules, (Amended) 2021	Reduce and subsequently eliminate the use of SUPs, Thickness of carry bags increased from 50 microns to 75 microns by 30th September 2021, and to 120 microns by 31st December 2021
9	Plastic Waste Management Rules, (Amended) 2022	Redefining EPR Guidelines, responsibility list of PIBO (Producers/Importers/ Brand Owners), Online portal for registration/filling annual reports of PIBO, imposition of fines on PIBO
10	Swachh Bharat Mission-Urban 2.0 (SBM-U), 2021	Reduce plastic waste, enforce PWM Rules, implement waste segregation, establish Material Recovery Facilities (MRFs), raise SUP reduction awareness, and promote alternative products

Urban plastic waste management falls into the administrative domain of Urban Local Bodies (ULBs). The ULBs have dedicated funds under SBM2.0 for solid waste management. They can also use funds from MPLAD, MLALAD, CSR, Industrial units, and grants from Ministry of Housing and Urban Affairs.

3.2 State level regulatory efforts to reduce plastic waste

It is the responsibility of all states to manage their plastic waste and abide by the regulations prescribed by the state government regarding

Salient features of Plastic Waste Management Rules (PWM Rules), 2022

The Plastic Waste Management (Amendment) Rules from 2022 provide measures against the consumption of plastic packaging in India. The Producers, Importers, and Brand Owners (PIBOs) that produce/use plastic packaging are legally bound to follow the system of collection back of the plastic packaging introduced by them through their products under the Extended Producer Responsibility (EPR).

- These rules shall apply to every waste generator, local body, gram panchayat, manufacturer, importer, producers, brand owners, recyclers/waste processors, CPCB and SPCB/PCC.
- It provides mandates for PIBOs, with the responsibility to develop a collect back system for the equivalent quantity of plastic packaging waste introduced by their products into the Indian market.
- It mandates registration of PIBOs and plastic waste processors (plastic recyclers, waste to energy, waste to oil, and industrial composting) through the centralized online portal developed and maintained by CPCB.
- The PIBOs and plastic waste processors cannot carry out any business without registration under PWM Rules.
- The rule encourages recycling, alternate use, and energy recovery of plastic waste vis-a-vis waste to energy, waste to oil and cement kilns, gasification and for road construction.
- Important conditions for the manufacture, import, stocking, distribution, sale and use of carry bags, plastic sheets or like, or cover made of plastic sheet and multilayered packaging are as follows:
  - Carry bags made of virgin or recycled plastics, shall not be less than seventy-five microns in thickness; w.e.f. 30th September 2021 and 120 microns w.e.f. 31st December 2022.
  - Plastic sheet or like, which is not an integral part of multilayered packaging and cover made of plastic sheet used for packaging, wrapping the commodity shall not be less than fifty microns in thickness except where the thickness of such plastic sheets impairs the functionality of the product.
  - The manufacturer cannot sell, provide, or arrange plastics for use as raw material to a producer, who does not have a valid registration from the concerned SPCBs or PCCs.
  - Sachets containing plastic material cannot be used for storing, packing, or selling gutkha, tobacco and pan masala.
  - Non-woven plastic carry bag shall not be less than 60 Gram Per Square Meter (GSM) with effect from the 30th of September, 2021.
  - Manufacture and use of multi-layered plastic packaging which are non-recyclable or non-energy recoverable or without alternate use, if any, should be phased out.
  - The provision of thickness is not applicable to carry bags made up of compostable bags and commodities and shall conform to the IS 17088:2008 titled as specifications for compostable plastics and shall obtain certificate from CPCB.
- The carry bags or products made of recycled plastics can be used for storing, carrying, dispensing, or packaging ready to eat or drink food stuff, subject to standards and regulations under the Food Safety and Standards Act.
- The Plastic Waste Management by the urban local bodies in their respective jurisdiction shall be as under plastic waste, which can be recycled, channelized to authorised plastic waste recycler and recycling of plastics shall conform to the Indian Standard: IS 14534:1998 titled as Guidelines for Recycling of Plastic, as amended from time to time.

- Thermoset plastic waste should be processed and disposed of as per the guidelines issued from time to time by the Central Pollution Control Board; and the inert material from recycling or processing facilities of plastic waste shall be disposed of in compliance with the Solid Waste Management Rules, 2016 or as amended from time to time.
- A State Level Advisory Committee headed by Secretary, Urban Development Department shall be constituted by The Government of NCT, Delhi for effective monitoring of implementation of these Rules.
- Each recycled carry bag shall bear a label, or a mark recycled and should conform to the Indian Standard: IS 14534:1998.
- Each carry bag made from compostable plastics shall bear a label and should conform to Indian Standard ISO 17088:2008.

The roles and responsibilities of different stakeholders are described below:

- Institutional waste generators, event organizers are required to segregate waste and handover to the authorized agency and shall pay user fee as prescribed by ULB and spot fine in case of any violation.
- The urban local bodies are encouraged to use plastic waste for road construction or energy recovery or waste to oil or co-processing in cement kilns etc. They are also held 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 by their own or engage an agency to set up, operationalize and coordinate for waste management in the rural area under their control. They are also responsible for segregation, collection, storage, transportation, plastic waste and channelize recyclable plastic waste fraction to recyclers having valid registration.
- Producer, Importers and Brand Owners are entitled 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 Boards (SPCB) or Pollution Control Committees (PCC) are required to enforce the provisions of PWM Rules, 2016/2018, related to registration, manufacturing of plastic products and multi-layered packaging, processing, and disposal of plastic wastes.
- The Secretary-in-charge of Urban Development in urban areas and Gram Panchayat in rural area of the State or Union Territory are the responsible authorities to enforce the provisions of PWM Rules, related to waste management by waste generator, use of plastic carry bags, plastic sheets or covers and multilayered packaging.
- District Magistrate or Deputy Commissioner shall provide the assistance to SPCBs/PCCs, Secretary-in- Charge, Urban Development Department and Gram Panchayat for the enforcement of provisions of PWM Rules, 2016 as and when required.

plastic waste management. States and Union Territories (UTs) have additionally enacted partial bans and legal constraints on specific plastic packaging, such as those in proximity to religious, historical, or natural sites. Nevertheless, the consistency and extent of bans and restrictions on SUPPs often exhibit considerable diversity throughout the nation. Figure 3.1 shows a map illustrating how the ban on SUPs has been implemented across different states.

India, comprising 28 states and eight union territories, has seen several state and territorial governments imposing bans on plastic bags and other single-use items through their respective notifications. 24 States/UTs (Andaman & Nicobar, Bihar, Chandigarh,

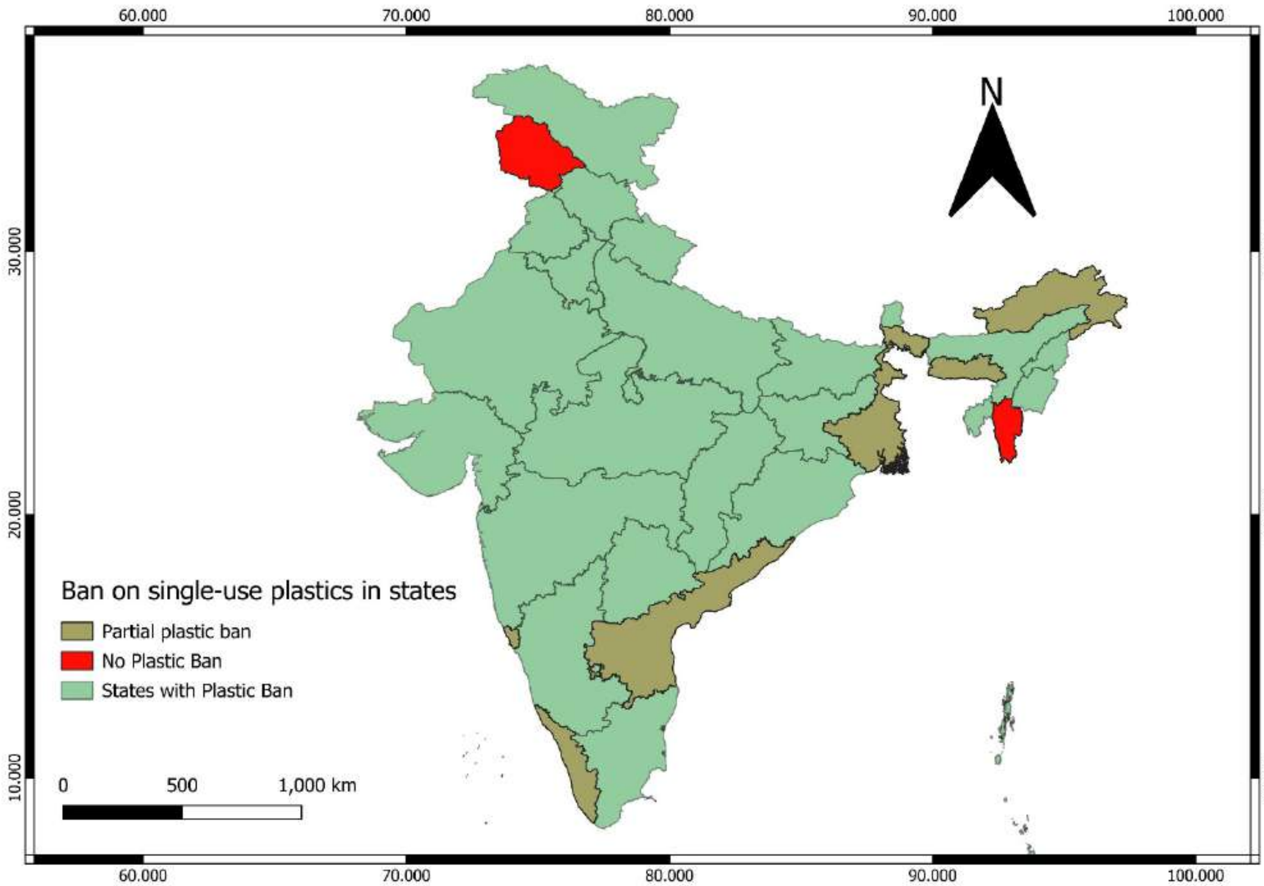

Figure 3.1 Map showing the ban on single-use plastics in different states in India

Chhattisgarh, Daman Diu and Dadar Nagar Haveli, Goa, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Odisha, Punjab, Puducherry, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh) have issued orders imposing a complete ban on plastic carry bags, while five States/UTs (Arunachal Pradesh, Jammu & Kashmir, Meghalaya, Mizoram, Nagaland) have imposed a ban on plastic carry bags with thickness less than 50 microns (CPCB, 2021).

3.3 Regulatory efforts and initiatives to reduce plastic waste and pollution in Tamil Nadu

Tamil Nadu is one of the pioneering states in India to take decisive actions to address plastic pollution and is committed to eliminate SUPPs. In 2019, the Government of Tamil Nadu issued a ban on fourteen types of plastic items that can be used and thrown away, regardless of thickness. However, actions to curb plastic pollution in the state dates back to the early 2000s'. In 2002, the State Government of Tamil Nadu (GoTN) launched the "Tamil Nadu Plastic Articles (Prohibition of Sale, Storage, Transport and Use)". Consequently, an "Expert Committee" was established to assess health and environmental risks associated with plastic use. The committee recommended the adoption of a "throwaway plastic (avoidance) policy", a legislation for manufacturing carry bags with a thickness of at least 50 microns and a minimum size of 8 x 12 inches, and a ban on throwaway plastics at mass gatherings (Philip et al., 2018). These recommendations served as the basis for the ban on "Use and Throwaway Plastics", announced by the Department of Environment & Forests on June 5 in 2018, including items such as all plastic carry bags, plastic sheets, plates, coated teacups and tumblers, plastic straws, plastic flags, and plastic water pouches.

As part of the implementation and monitoring of the ban on single-use and throwaway plastics, the State Pollution Control Board has taken various actions in coordination with line departments. The following Government Orders have been issued since 2018 to support the implementation of the bans.

Government Orders issued to support the implementation of the single-use plastic bans:

- The Government Order (Ms) No. 82, dated June 15, 2018, appointed Regional Coordinators to oversee the implementation of the ban.
- The Government Order No. 92, dated July 5, 2018, formed a Steering Committee chaired by the Chief Secretary to review the progress of the ban.
- The Government Order (2D) No. 30, dated July 5, 2018, provided financial support for regional workshops to raise awareness.
- The Government Order No. 265, dated September 20, 2018, facilitated the ban's implementation within government departments.
- The Government Order (D) No. 319, dated November 10, 2018, nominated TN-PCB officials to assist Regional Coordinators in executing the plastic ban.

To support implementation of the bans, a special team was appointed to conduct unannounced checks across Tamil Nadu, whilst the Plastic Waste Management Cell and District Level Monitoring Committees were established. In addition to this, the GoTN has launched several large-scale campaigns to increase public awareness and support the shift towards reducing single-use plastics, as outlined in the examples below.

Campaigns to raise public awareness and support implementation of the single-use plastic bans:

- **"Operation Blue Mountain" in Nilgiris:** In 2001, the Operation Blue campaign in Nilgiris has been highlighted as a successful example of generating awareness to support regulatory efforts to reduce plastic pollution in the district, using imagery of impacts of plastics' detrimental impacts on animals and linking how unmanaged plastics clog drains and leak into water bodies (MoHUA 2019, p. 11)
- **"Meendum Manjappai" awareness campaign against single-use plastic bags:** The Meendum Manjappai was launched by the Government of Tamil Nadu in December 2021 to increase public awareness about the harmful effects of single-use plastics and encourage changing to alternatives, in this instance, traditional cloth bags (Manjappai). The awareness campaign was implemented in all districts and included videos, vehicle campaigns, distribution of pamphlets, and display of posters in public gathering places such as hospitals, hotels, industrial estates, malls, bus stops, railway stations, and theatres.
- **Engaging manufacturers to raise awareness and showcase alternatives to single-use plastics:** A conference showcasing sustainable alternatives to single-use plastics was organised by MoEF&CC in Chennai from 26th-27th September 2022 to create awareness on the adverse impacts of single-use plastics and support the regulatory bans (TNPCB, 2023). The Conference titled 'National Expo on Eco-Alternatives to SUPs' provided and opportunity for manufacturers of alternatives to single-use plastics to showcase their products and increase awareness amongst the public about the various alternatives to single-use plastics that are available on the market.

3.4 Regulatory challenges related to plastic waste management

Although plastic waste management policies in India have advanced significantly, especially with the recent amendments to the Plastic Waste Management rules in 2021 and 2022, several regulatory challenges persist.

Limited strategic planning, inadequate waste collection/segregation coverage, and a lack of government finance regulatory framework are major obstacles to effective PWM policy implementation. Besides, state and union territory policies and regulations differ, creating issues in compliance and enforcement. Monitoring implementation and enforcing regulations can also be challenging without effective mechanisms. Furthermore, the informal sector plays a significant role in collecting and recycling municipal waste across India but operates outside the formal regulatory framework. This workforce consisting of skilled individuals and established network structures must be recognised to effectively design and implement PWM policies. MSW is managed by municipal authorities in India, however, their budgets are not adequate to cover the costs associated with the development of proper waste collection, storage, treatment, and disposal systems.

Plastic waste management programs also remain under-advertised and under-participated in by the public. Limited awareness of the harmful societal and environmental impacts plastic pollution remains a challenge to shift consumption patterns towards reduce and reuse. Limited knowledge about sustainable waste management practices may also be a challenge across the board, indicating a need for training to build capacity amongst households, businesses, and municipalities to manage waste in a safe and sustainable manner.

Alternative solutions to SUPs should encompass their entire lifespan, from production to collection and disposal, and consumers need to be encouraged to embrace these alternatives. Biodegradable and other options may necessitate separate waste streams, particularly as these alternatives become more accessible. However, in regions with insufficient household waste segregation, collection infrastructure, and awareness, this can put an additional strain on waste management systems. Currently, there is a lack of established collection or recycling processes for biodegradable alternatives due to factors such as low awareness, unclear labelling systems, and limitations in source separation.


Tamil Nadu Pollution Control Board
DISCARDED FISHNET COLLECTION CE
Let not only the Beach but also the Ocean be Clean

Chapter 4
INTERNATIONAL GOVERNANCE TO END PLASTIC POLLUTION

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National and state-level policies are important to develop locally tailored strategies to eliminate plastic pollution. At the same time, plastic pollution must be recognised as a global challenge spanning socio-economic, cultural, geographical, and jurisdictional boundaries (Raubenheimer and McIlgorm, 2018). Plastic pollution emerged on the international policy agenda in the 1970s (Karasik et al., 2020). Yet to date, the global governance of plastic pollution has been uneven, fragmented, and inadequate for addressing the scale of the problem at hand (Dauvergne 2018; Raubenheimer and McIlgorm 2018; Simon et al., 2021). In response to the fragmented global policy landscape and the growing scale of the plastic pollution issue, the international community agreed to develop a legally binding instrument to end plastic pollution (henceforth, the plastics treaty), as UNEA Resolution 5/14 was adopted during the resumed fifth session of the United Nations Environment Assembly (UNEA 5.2) in Nairobi, 2022 (UNEP, 2022). This chapter summarises key developments relevant to addressing the plastic pollution issue through multilateral environmental agreements (MEAs), particularly focusing on key debates in the ongoing plastic treaty negotiations and their relevance for national and local policy contexts.

4.1 The emergence of plastic pollution on the international agenda

Since the 1970s, multilateral environmental agreements (MEA[4]s) addressing plastic pollution[5] have largely focused on marine litter from sea-based sources, despite most of the plastics pollution originates from land (Simon and Schulte, 2017; Simon et al., 2021; Raubenheimer and McIlgorm, 2017), as seen below.

MEAs considered applicable to address marine plastic pollution, 1970-1995:

- The International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted in 1973, and the Protocol signed in 1978. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) was signed in 1972 and the Protocol signed in 1996. It was subsequently amended in 2006 as the first international MEA addressing maritime sources of plastic pollution.

4 MEAs provide obligations for States to undertake individual or joint action to implement international legal instruments (CIEL and WCEL, 2023)

5 Note that MEAs included in this overview not exclusive and several other MEAs have offered arenas for states to discuss cross-cutting areas of pollution control.

[1]Norwegian Institute for Water Research (NIVA)

- The conservation of land and freshwater ecosystems threatened by marine plastic pollution is addressed under the Convention on the Conservation of Migratory Species of Wild Animals (SMS), signed in 1979.
- The United Nations Law of the Sea (UNCLOS) signed in 1982, prohibits ships from dumping plastics into the sea with the objective of protecting and preserving the marine environment. The Law of the Sea Convention is to date the only instrument that provides a mandate for the prevention of marine debris on a global scale, but implementation has been fragmented with varying regional approaches and adoption of legally binding protocols (Raubenheimer and McIlgorm, 2017).
- The Convention on Biological Diversity signed in 1992, provides targets aiming to reduce pollution and its impacts on marine and coastal biodiversity.
- The Food and Agriculture Organisation (FAO) Code of Conduct for Responsible Fisheries agreed in 1995, sets out principles and international standards for sustainable and responsible fishing practices and the conservation of marine resources. Hence, minimising pollution and marine litter and assessing the impacts of plastic pollution on marine ecosystems.

Source: Karasik et al., 2020.

Plastic pollution has grown from a marine pollution and waste management concern, towards being treated as a systemic issue with climate and health impacts across the entire plastic life cycle (Simon and Schulte, 2017; Dauvergne, 2018; Haward, 2018; Simon et al., 2021; Barrowlcough and Birkbeck, 2022). 28 international policies have been agreed upon since the beginning of 2000, of which "none include a global, binding, specific, and measurable target to reduce land-based sources of plastic pollution" (Karasik et al., 2020). This also applies to microplastics, as there are currently no legally binding measures on the global level addressing microplastic pollution (Rognerud et al., 2022). While no MEA to date has tackled the multitude of sources and impacts of plastic pollution, the Basel and Stockholm conventions provide frameworks relevant for tackling plastic pollution on land (See textbox below). The Stockholm and Basel Conventions can arguably contribute to reducing the impacts of plastics globally, both in terms of hazard potential and quantity of mismanaged waste, but gaps remain in the management across all lifecycle phases for most plastics which is not classified as hazardous (Raubenheimer and McIlgorm, 2018). It is relevant to look at challenges and successes of these and other related instruments when negotiating a new plastics treaty.

Tackling land-based plastic pollution through existing MEAs

The Basel Convention on the Control of Transboundary Movements of Hazardous Waste (Basel Convention) was adopted in 1989 and entered into force in 1992.

- By addressing international trade and management of hazardous waste, it includes certain types of plastic waste classified as hazardous, as per the Plastic Waste Amendments (2019).
- A range of steps have been taken under the Conference of the Parties to explicitly address plastic waste, including the establishment of the Plastic Waste Partnership. The partnership provides a global multi-stakeholder platform to promote the environmentally sound management of plastic waste to prevent and minimise its generation.
- However, the Basel Convention contains loopholes and does not address who should pay for the transition needed to phase out plastics from the global economy (Stoett 2022).

The Stockholm Convention on Persistent Organic Pollutants (POPs) was signed in 2001 and became effective in 2004.

- The convention restricts the production, use, and disposal of hazardous chemicals, some of which are added to plastics to confer specific properties, such as flame retardancy.

- The sound management of plastic waste containing POPs is important to reduce potential human and environmental exposure to these chemicals, which may occur from the uncontrolled burning of plastic waste and leaching of microplastics.
- The Stockholm Convention includes a non-comprehensive list of prohibited chemicals that may no longer be used as additives, yet most chemical additives remain to be addressed (Aurisano et al., in Simon et al., 2021).

Several of the Sustainable Development Goals are relevant for reducing plastics pollution, particularly 14.1 'prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution'. While these universally agreed common goals are intended to foster global collaboration to address key socio-economic and environmental challenges, integrating them into national plans and policies is voluntarily, relying on the commitment and cooperation of member states to achieve the shared global objectives.

Plastic pollution is also continuously addressed through the United Nations Environment Assembly (UNEA)[6]. UNEA originated in 1995 when the United Nations Environment Programme (UNEP) adopted the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities. The adoption of the GPA led to the launch of the Global Partnership on Plastic Pollution and Marine Litter (GPML)[7] at the UN Conference on Sustainable Development (Rio+20) in June 2012. Key outcomes from UNEA meetings significant for addressing plastic pollution are listed in the textbox below.

6 UNEA resolutions are not legally binding but represents the joint aspirations of the international community, frame consensus around actions to be taken, and help coordinate development aid and technical assistance.

7 GPML is a multi-stakeholder partnership and platform where actors working to prevent marine litter and plastic pollution can share knowledge, experiences, and collaborate to create and advance solutions to plastic pollution.

Key outcomes from UNEA meetings related to addressing plastic pollution

- **UNEA 1** (2014) adopted resolution recognising the emerging global problem and requested UNEP to provide a report on marine plastics and microplastics.
- **UNEA 2** (2016) requested UNEP to produce an assessment of the effectiveness of global and regional governance strategies for marine plastics and support for developing countries in combatting marine litter.
- **UNEA 3** (2017) revealed that there is no existing global framework effectively dealing with marine litter and microplastics and established an ad hoc open-ended expert group on the same.
- **UNEA 4** (2019) adopted resolutions related to, inter alia, sustainable consumption and production, resource efficiency, and chemicals and waste. This included the strengthening of global governance on marine litter and microplastics, sound management of chemicals and waste, and addressing single-use plastics pollution.
- **UNEA 5** (2021/2022) concluded with several declarations, resolutions and decisions related to curbing pollution and protecting and restoring nature worldwide. It included the establishment of an Intergovernmental Negotiating Committee (INC) with the mandate to forge an international legally binding instrument (ILBI) to end plastic pollution by the end of 2024.

Sources: (IISD 2022; GEN, n.d.)

UNEA resolutions represent the joint aspirations of the international community, frame consensus around actions to be taken, and help to coordinate development aid and technical assistance. However, these resolutions are not legally binding. Following years of growing concern about the challenges associated with plastics and the need for global action, UNEA requested its executive director to convene an intergovernmental negotiations committee (INC) to develop an international legally binding instrument on plastic pollution, including in the marine environment. This landmark resolution offers a "once in a lifetime opportunity" (Inger Anderson, Executive Director, UNEP, INC-2, 2023) to comprehensively address the systemic and transboundary challenge of plastic pollution through a holistic approach across the plastic lifecycle. The following sub-chapter will outline some of the key elements and ongoing debates towards developing this treaty.

4.2 The process towards a global plastic treaty

The timeline for developing a global plastic treaty is highly ambitious, with five INC meetings scheduled between November 2022 and the end of 2024, with the aim to adopt the treaty at the first Conference of the Parties in mid-2025. In addition, a preparatory open-ended working group meeting was held in Dakar, Senegal in May-June 2022, to set out the negotiation schedule and rules of procedures to guide of the forthcoming INCs. The first INC meeting (INC-1) was held in Punta del Este, Uruguay from 28th November to 2nd December 2022. It included discussions on the scope, objectives, structure of the instrument, potential elements standard provisions and further work to be undertaken. In addition, procedural and organizational issues related to election of the bureau and voting rights (ISSD 2022). The second INC meeting (INC-2) was held in Paris, France, from 28th May to 2nd June, with the ambition of determining the treaty's scope and potential elements, including measures across the plastic lifecycle. A significant outcome of INC-2 was for the Chair of the INC to develop a Zero-Draft text of the plastic treaty based on the objective, core obligations, and means and mechanisms of implementation discussed during the INCs and in submissions by member states. The Zero Draft text was released on 4th September and provided the basis for the third INC meeting (INC-3), which took place in Nairobi, Kenya from the 11th to the 19th of November 2023. The fourth INC meeting (INC-4) took place in Ottawa, Canada from the 22nd to the 30th of April 2024, and included in-text negotiations to streamline and move closer towards a final treaty text. The fifth and final INC meeting (INC-5) is scheduled to take place in South Korea in the end of November 2024.

Considering the ongoing and rapidly evolving plastic treaty negotiations, the following sections examine some of the overarching themes that are being deliberated. This is based on negotiations during the first two INC meetings and related discussions in the intersessional period leading up to INC-3, including the first version of the Zero Draft of the treaty text. The overarching themes outlined below are not exclusive but aim to provide insights into key policy discussions and debates surrounding the transition towards ending plastic pollution.

4.2.1 Protecting human health and the environment

There is broad consensus that there is a need for an internationally legally binding agreement that tackles plastic pollution across the plastic lifecycle, with the objective of ending plastic pollution whilst protecting human health and the environment. It is yet to be determined whether the objective should include a timebound and measurable target for ending plastic pollution, such as in the Paris Agreement[8], which calls for reduced emissions by 2030 and net zero by 2050. Those in favour for a measurable and timebound target generally argue that it would allow for assessment and monitoring of the progress, underlining the urgency of addressing the issue at hand. Those against, commonly argue that it would be impossible to come up with a representative target, highlighting the inaccuracy and methodological issues of the 1.5-degree target in the Paris Agreement, while arguing that a specific timeframe would limit the lifetime of the instrument.

4.2.2 Global vs nationally driven commitments

International, regional, national, and local approaches are relevant to holistically address

8 The Paris Agreement refers to the United Nations Framework Convention for Climate Change (UNFCC) adopted in 2015, entering into force in 2016.

the transboundary challenge of plastic pollution (Haward, 2018; Hardesty et al., 2022). A key area of debate is whether the plastic treaty should target plastic pollution through strong, legally binding targets or if countries should form national commitments based on overarching objectives to reduce plastic pollution. Many argue that the plastic treaty offers a unique opportunity to set legally binding targets and criteria for reducing plastic pollution across the plastic life cycle. At the same time, the treaty may also allow for some flexibility for countries to determine their own plans for meeting their obligations of the treaty, based on nationally determined targets that recognises the principle of common but differentiated responsibilities (CBDR) and respective capacities.

National plans are generally considered a measure to aid implementation[9] under the plastic treaty. National plans may be considered a useful tool for capturing local variabilities for the sources of microplastics across contexts (Rognerud et al. 2022) and for identifying context-applicable measures to ensure a just transition for informal waste and recovery workers (UN-Habitat and NIVA, 2022). However, ambitious, collective, and legally binding targets and commitments are needed to achieve the ambitious objectives of the plastic treaty, which may be translated into robust national plans that consider individual circumstances (CIEL and WCEL, 2023). Concerns persists related to weather a treaty largely based around nationally determined goals and targets may be inadequate for reaching the long-term goals of reducing plastic pollution across the plastic lifecycle in line with the UNEA 5/14 mandate.

9 "Implementation refers to the process by which countries establish national policies that reflect their obligations" (Escobar-Pemberthy and Ivanova 2020, in CIEL and WCEL, 2023). Means of implementation and implementation measures discussed as part of the plastics treaty includes national reporting, periodic assessments and monitoring, financial mechanisms, capacity building, technical assistance, and technology transfer, international cooperation, information exchange, awareness raising, education and research, and stakeholder engagement.

4.2.3 Addressing plastic pollution across the plastics lifecycle

Policy approaches and practices to reduce plastic pollution have commonly focused on downstream solutions at the end of the plastic life cycle, including strengthening waste management and recycling capacities. However, it is increasingly recognised that downstream measures must be complemented by upstream measures addressing plastic pollution at its source in a broad lifecycle approach, including measures such as reducing plastic production and designing an increasingly circular plastic economy (Barrowclough and Birkbeck, 2022).

While some countries continue to primarily identify plastic pollution as a waste management and littering issue, others call for an increasingly holistic approach addressing leakages across the plastic lifecycle, from the extraction of fossil and bio-based feedstocks for primary plastic polymers, through to the environmental remediation and compensation of communities affected by pollution. During INC-2, several member states reiterated that "we cannot recycle ourselves out of the plastic pollution crisis", contemplating that downstream waste management and clean-up measures are not enough. These efforts must be complemented with clear targets for reducing plastic pollution, including production, consumption, primary plastic polymers and chemicals of concern, problematic and avoidable plastic products, single-use plastic products, and intentionally added microplastics, whilst focusing on enabling systems for reuse and redesign. Greater transparency and harmonised information about the chemical properties and additives in plastic products, while reducing their hazard potential across the plastic lifecycle, is also essential (Raubenheimer and McIlgorm, 2018).

While upstream and midstream solutions are important to reduce plastic pollution at the extraction, production, design, and consumption stages, downstream solutions such as waste management remain a key tool to increase resource efficiency and limit leakages at the end-of-life of plastic products. Measures to ensure that plastic waste is managed in a safe and environmentally sound manner throughout the different stages of waste management and in accordance with the zero-waste hierarchy is key in this regard. This links to possible options for member states to establish and operate extended producer responsibility systems, addressing legacy plastic pollution, and promoting a just transition for affected populations in the implementation of the plastic treaty.

4.3 From global to local scales

Ongoing policy debates about reducing plastic pollution at global, regional, national, and local levels are significant, as common multilateral goals and objectives rely on policy alignment and implementation across all levels. In the context of India's rapidly developing plastics policy environment, there are possibilities that negotiated legally binding targets and commitments may differ from national priorities and regulations, such as bans on single-use plastic products, extended producer responsibility rules, and regulations, for example those permitting the use of recycled packaging for food. Actively engaging in ongoing national and multilateral policy processes to ensure local anchoring and the participation of a broad range of stakeholders is key to ensuring policy compliance and effective implementation while avoiding potential unintended social, economic, and environmental consequences. It is also significant to develop policies that can be strengthened or adapted, considering multilateral policy priorities as well as new scientific evidence.


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CHAPTER 5
STATUS OF ENVIRONMENTAL MONITORING IN INDIA AND INTERNATIONALLY

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5.1 Existing monitoring methods and standards for macroplastics: sampling and analysis

Concerns about plastic pollution continue to increase, highlighting the importance of developing effective monitoring methods to assess and mitigate the presence of macroplastics in our environment. To address these issues, various monitoring techniques and methodologies have been established across the globe. Here, we will explore some of the existing monitoring methods for macroplastics and discuss their strengths and limitations. Macroplastics are defined as plastic items larger than 25 mm in size, that vary in shape, size, morphology, and chemical composition (GESAMP, 2019).

5.1.1 Sampling and analysis of macroplastics in terrestrial environments, beaches, and shorelines

To assess the extent of macroplastics in the terrestrial environment, beaches and shorelines, various sampling techniques and methods for assessing the state of coastal environments can be used. This includes activities such as visual surveys and manual shoreline clean-ups, as well as more systematic techniques such as quadrat sampling and transect surveys. Several protocols for such systematic approaches have been developed, each offering distinct recommendations for data collection in terms of area, time, specific methods, etc. Examples of recommendations are described in Table 7.1. Many of these protocols employ visual identification of macroplastics, which typically involves categorisations according to type, size, weighing (if feasible), counting, and in some cases, identifying their sources.

A key strength of hand-collection and visual analysis of macroplastics lies in the ease of harmonization across different matrices and countries, allowing for the establishment of international monitoring databases. This method requires no sample preparation, ensures quick and accessible data retrieval, and it is cost-effective primarily in terms of personnel. However, the introduction of human collectors may introduce biases in what is collected and identified as macroplastics. Clean-up campaigns between sampling sessions can also impact monitoring data and trend assessments. Additionally, it's important to note that collecting macroplastics can be potentially harmful to local fauna, as some plastic litter becomes integrated into the ecosystem over time (Falk-Andersson et al., 2020, 2023). Conversely, hand-collection and visual analysis offer an opportunity for citizen science integration, involving schools, non-profit organizations and more. This not only reduces

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Table 5.1. Examples of different guidelines or recommendations for sampling of macroplastics along beaches

Guideline/ organisation	Recommendation	Reference(s)
OSPAR	Counting all visible litter items larger than 5 mm within a 100 m sampling transect on beach surfaces	(OSPAR, 2020)
MSFD-TGM	Sampling at least two sections of 100 meters in length on lightly to moderately littered beaches	(Piha et al., 2011)
HELCOM	Collection of items (>0.5 cm) along a 100 meter transect	HELCOM (2022)
CSIRO	Use of transects	(Schuyler et al., 2020)
NOWPAP, UNEP/ IOC, & NOAA	Hand-collection of litter in designated areas with visual identification and recording of item weights for each category collected	NOWPAP (2017), UNEP/ IOC (2009), NOAA (2013)
WIOMSA	Hand-collection of samples in a well-defined beach area, preferably along a 500 m transect, followed by visual identification and categorisation	(Barnardo & Ribbink, 2020)
GESAMP	Visual observation of shorelines, with visual identification and assignment to agreed categories	GESAMP (2019)

personnel costs, but also has the potential to increase the sampling frequency and extent.

5.1.2 Sampling and analysis of macroplastics in water environments

In environments such as rivers, manual collection of macroplastics can be challenging, making visual analysis the most commonly employed method. When examining macroplastics in riverine settings, the prevailing methods fall into two categories: observation-based and interception-based techniques (Hurley et al., 2023). The observation-based approach comprises recording of visible floating macroplastics within a river during a predefined observation period. This method requires a suitable vantage point, such as a bridge, to provide the analyst with a clear view of the river surface. A recommended observation interval is no more than 15 minutes to maintain the observer's focus (Hurley et al., 2023). For extensive riverine systems, multiple observation points may be required, or the river width may be subdivided into sections for observations. The strengths of visual observations for macroplastics in rivers lie in its cost-effectiveness and minimal physical demands on the observers. However, there are notable weaknesses associated with this method. Challenges include difficulties in accurately identifying plastic items during rapid flow velocities, high turbidity, strong winds and various weather conditions affecting visibility (Wendt-Potthoff et al., 2020). Additional complexities arise from potential entanglement of plastics in riverside vegetation, the impact of vantage point heights on the ability to detect smaller-sized plastic fractions, and the influence of plastic chemical composition and exposure duration on buoyancy, with certain plastics possibly sinking to the riverbed (van Emmerik et al., 2022). Other factors to consider include accessibility to river areas, and seasonal variations, such as the impact of cyclone seasons on repeatability of sampling (Roebroek et al., 2022).

In both river and ocean environments, nets, mesh screens, and bags are also often employed to assess macroplastics. These tools are designed to capture items floating on the surface, submerged in the subsurface, or resting on the river or ocean bed. Nets designed for collecting surface and subsurface macroplastics can be deployed from various platforms, such as bridges or buoys, and remain in operation either for predetermined time intervals or until they become clogged (Hurley et al., 2023). Multiple net types are available for macroplastic sampling, including manta nets, bongo nets, neuston nets, WP2 nets, trawl nets, passive, and active nets. Examination of macroplastics from the seafloor and sediments is often integrated into fish stock trawl surveys. However, this approach can pose challenges due to potential disruption of benthic fauna (van Emmerik et al., 2022). Upon completing the sampling process, the collected nets are retrieved, and visual analysis of the gathered items can take place on site or in a laboratory at a later stage. The analysis can involve isolation into categories, counting, and weighing. To ensure consistency and reproducibility in sampling efforts, both the choice of net and associated sample metadata is important to report. This includes specifying factors such as mesh size, flow velocity, and suspended load, as these variables have the potential to impact the overall results.

Although currently less popular in monitoring activities, several other innovative sampling technologies have been developed to sample macroplastics in oceans or rivers. These include pumps (Schmaltz et al., 2020), traps (Caviedes et al., 2022), vessels with conveyor belts (Schmaltz et al., 2020) or skimming mechanisms (Johannes et al., 2021), robotic systems, and boats (Schmaltz et al., 2020) Despite the diversity of available technologies, a lack of knowledge and testing – including in rural and remote areas –remains. Many of these technologies rely on manual operation, have primarily been tested in calm waters, or require access to a power source (Winterstetter et al., 2021), presenting challenges in remote areas. Furthermore, additional testing is needed to mitigate potential adverse ecological impacts (Falk-Andersson et al., 2020). Alternative non-human observation methods, such as aerial surveys (e.g., planes, drones), remote sensing, and unmanned aerial vehicles (UAVs) are particularly valuable in areas with limited accessibility (Sakti et al., 2021; Veettil et al., 2022). These imaging tools can be proficient in assessing water surfaces for macroplastics and, depending on the specific device, can survey to a certain depth beneath the surface. Similar to when using a human analyst, these methods may be influenced by factors like turbidity and observation distance, potentially affecting the detection of floating plastics. The advantages of deploying these techniques are multifaceted, encompassing increased sampling intervals and the ability to identify a higher plastic load that might pose challenges for human analysts (van Lieshout et al., 2020; Veettil et al., 2022). Nonetheless, it's important to note that these methods may have limitations concerning data capacity and scope of their field of view.

5.2 Existing monitoring methods and standards for microplastics: sampling and analysis

Microplastics (<5mm) have become a major environmental concern due to their widespread presence in various ecosystem. This underscores the importance of establishing robust methods for monitoring and analysis, which are essential for assessing potential impacts.

5.2.1 Sampling and sample preparation of microplastics in terrestrial environments, beaches, and shorelines

Numerous methods are currently being employed for the purpose of sampling microplastics within terrestrial environments, specifically along beaches, shorelines, and riverbanks. The most frequently used techniques include the employment of a metal scoop, shovel, or spatula to sample the uppermost layer of sediment, typically to a depth of 1-5 cm (Stock et al., 2019). Various expert groups, including GESAMP (2019) and NOAA (2013), have described and endorsed these methods. Additionally, experts often recommend collecting samples from a 1 m^2 quadrat (AMAP, 2021; (Barnardo & Ribbink, 2020), often along transect lines from shoreline to vegetation, with a high number of replicates (Besley et al., 2017) to ensure representativeness (Schuyler et al., 2020). Additionally, recording sample weight and volume is important to get the best representation of the distribution of microplastics in the environments. Here, for instance, Frias et al. (2018) recommends the collection of triplicates with the dimensions of 30 x 30 cm x 5 cm (length x width x height) using metal shovels in intertidal areas, and to collect more than 6 samples per site using a box corer in subtidal areas (Vianello et al., 2013). Visual identification and manual sorting extraction methods, such as with tweezers, are not recommended procedures as the likelihood of overlooking and consequently underestimating microplastic particles is high (Stock et al., 2019).

For sampling bottom sediments in water, Ekman or Van Veen grab samplers are most commonly used (Löder & Gerdts, 2015; Mai et al., 2018). This entails sampling the upper 2-5 cm of sediment and is usually replicated through 2-3 hauls, following guidelines set by HELCOM (2022) and GESAMP (2019). According to NOAA (2015), certain protocols suggest collecting 400 grams of wet sediment using core or grab samples. The advantage of using shovels, corers, and grab samplers for sampling microplastics in the sediment, shorelines and bottom sediments in water is their ability to gather comprehensive samples and offer a view of microplastic deposition in the terrestrial environments over a period of time. Furthermore, these methods can be tailored to target specific local sources of contamination. However, it's important to note that larger sample quantities may be required to accurately detect microplastics, as concentrations are generally lower in sediments, particularly for larger particle sizes. Additional weaknesses include high variability among samples, which can be further influenced by factors such as sediment grain size composition and deposition patterns, especially in coastal areas such as beaches and shorelines (Mai et al., 2018). In addition, the current lack of effective control measures during sampling processes, both in terms of quality and quantity, raises concerns regarding the potential for sample contamination. Conversely, the opportunity of these methods is the potential to analyse time trends by investigating different sediment depth layers.

The extraction of microplastics from sediment typically involves a series of sample preparation stages, with density separation being the most commonly used method to isolate plastics from sediment grains. Saturated sodium chloride (NaCl) solution with a density exceeding 1.2g/cm^3 is frequently used, although other higher density salt solutions are needed to effectively isolate microplastics made of higher density polymer types (Rodrigues et al., 2018). Density separation offers the advantage of selectively removing natural inorganic materials like sand and silt and can be easily adjusted to accommodate different sample sizes (Prata et al., 2019). Yet, density separation does have some drawbacks. For example, if the chosen solution density is not-well suited for the research objectives, there is a risk of excluding certain plastic particles from the analyses, potentially leading to an underestimation of the abundance of microplastics in the sample and limiting the ability to investigate a broad range of polymer types. In some methods, a digestion step is incorporated to get rid of natural organic matter. Oxidative digestion, using agents like H_2O_2 and Fenton's reagent, is the most commonly adopted approach for handling sediment samples from beaches, shorelines, sediment from seafloor and terrestrial environments. When applied under optimized conditions of temperature, reagent concentration, and time, these chemical agents are generally non-destructive to most polymers and effectively reduce other organic components, such as biological material. However, variations in digestion efficiency can lead to fluctuations in method quality and data outputs (Munno et al., 2018). Approaches must also be selected and optimised appropriately to ensure preservation of target microplastics (Stock et al., 2019). In some cases, for instance with regards to challenging sample types, it is recommended to implement multiple digestion steps and consider the possibility of combining these with enzymatic digestion for enhanced results and to avoid destroying microplastics with single-step and harsher protocols.

5.2.2 Sampling and sample preparation of microplastics in water environments

The distribution of microplastics within the water column and surface depends on a variety of properties, including density, shape, size, absorption of chemicals, and biofouling. Their dispersion is further influenced by environmental conditions, such as water density, wind patterns, currents, and wave dynamics. Consequently, the quantity and quality of microplastics recovered during sampling are dependent on sampling locations and depths. While many sampling and sample processing procedures are designed for use in both freshwater and saltwater environments, it is important to note that variations in microplastic distribution patterns can be observed in each system. These variations are influenced by environmental factors, such as hydrodynamic profiles and water density.

Sampling for microplastics is typically conducted using a variety of established sampling strategies (GESAMP, 2019). Nets and pumps are the most commonly used, where each approach offers its own sets of advantages and considerations. Nets are recommended to have a mesh size of 300 μm and can include neuston, plankton, bongo nets and manta trawls (Lippiatt et al., 2013; Masura et al., 2015; Michida et al., 2019). The choice of net depends on the specific research objectives. Both bongo and plankton nets are deployed through the water column, typically at low velocities, where bongo nets consist of paired nets, enabling the simultaneous collection of samples at various depths in the water column (Prata et al., 2019). The towing of manta and neuston nets is a widely employed for surface water sampling, suitable for use in both river and ocean environments. When deployed in the ocean, it is typically towed behind a boat, while in rivers, it is often anchored to a bridge. Submerged pumps are designed to efficiently collect water samples from beneath the surface layers. These pumps are often deployed by lowering them into water, either facilitated from onboard a ship or as part of a larger ship-sampling system. This allows for coverage of extensive areas and collection of a large number of samples. A distinction between using manta/neuston trawls and pumps lies in the depth at which samples are collected, where manta/neuston trawls sample the full surface microlayers, and therefore will more efficiently collect microplastics floating on the surface. This can result in a potentially higher concentration of lighter microplastics, which tend to accumulate in the top surface layers. However, the efficiency of manta trawl sampling is dependent on factors such as current, wind and wave conditions during sampling, which in turn can affect the accuracy of the sampling. When sampling with pumps, a lower water volume is collected compared to sampling with manta trawls, but the repeatability of volume measurements is enhanced when using pumps (Karlsson et al., 2020). Another advantage of using pump sampling is the enclosed sample filtration system, which reduces the risk of sample contamination. All these factors should be evaluated when selecting the appropriate technique for monitoring, based on the specific monitoring objectives.

The extent of sample preparation required typically depends on the amount of organic matter present in the samples. In cases where organic material levels are low, common methods involve the use of filtration or sieving to separate microplastics from the water. It's important to note that the choice of filter pore sizes or sieve mesh can vary significantly, and this selection directly influences the lower size limit of microplastics that can be detected. Where digestion of organic content is needed, it is crucial to prioritize approaches that efficiently remove the specific organic material present without adversely affecting the physical properties of the plastics, such as shape, size, or complete dissolution (Lusher et al., 2020). Several digestion methods are often used. Alkaline digestion, typically using potassium hydroxide (KOH) is known for its non-destructive nature with most polymers, provided it is applied under optimised conditions of temperatures, solvent strength, and duration. This method is rapid and effective on removed organic material. Nevertheless, it is worth noting that certain polymers may not be stable under these conditions, requiring a careful balance between efficiency and risk of plastic degradation. In contrast, acid digestion is less commonly used and is in fact recommended against by GESAMP (2019). For samples with higher organic material, oxidative digestion may be considered. However, like alkaline digestion, there is a potential risk of polymer degradation if the digestion parameters are not well-optimized. Therefore, careful consideration of specific characteristics of samples and the choice of digestion method is essential to ensure an accurate microplastics analysis.

5.2.3 Microplastics Analysis

To ensure comprehensive reporting of microplastics concentrations in samples and to accurately assess their in-situ presence in the environment, detailed characterisation is required. Guidelines for identifying microplastics typically include visual parameters such as colour, shape, size (length and width), surface properties, texture, and features of fibres. Most studies categorise microplastics into six primary shape groups, including fragments, beads, pellets, films, foams, and fibres. Visual identification requires no analytical instruments, making them suitable for fieldwork as well as laboratory settings. However, this approach also has its limitations, notably in its inability to identify smaller microplastics and chemicals, potentially resulting in an underestimation of microplastics presence and conclusion that may not accurately reflect the extent of pollution (Munno et al., 2023; Prata et al., 2021). Optical microscopy, while cost-effective, can provide visual identification and quantifications of microplastics but not polymer identification in samples (Lusher et al., 2020). This could result in false positives or negatives, which, in turn, can lead to an over- or underestimation of the abundance of microplastics. However, combining optical microscopy with polymer identification techniques, such as staining or fluorescent dyes, allows for higher accuracy of detection. Spectroscopic methods, particularly Fourier-transform infrared spectroscopy (FTIR), allows for precise polymer identification for plastics down to 0.3 mm. Micro – FTIR (μ-FTIR) imaging provides polymer information for particles as small as 10 μm based on their measured spectra, leading to more comprehensive and detailed knowledge base covering a wide range of particle sizes. Raman spectroscopy allows for high spatial resolution when analysing sample surface and is also well-suited for small sample sizes (Araujo et al., 2018). However, the technique has the potential to damage the sample due to the high energy of the laser used, and the analysis is very time consuming for high particle loads. Micro-Raman (μ-Raman) has a low detection limit and provides comprehensive polymer information, including detection of additives. Fluorometric approaches, such as Nile red staining, is a low to moderately priced alternative. These approaches allow for particle identification and quantification through imaging analysis, enabling the indication of polymer types. Additionally, many dyes do not specifically stain polymers, and a strong reduction of organic matter is important for reliable results, as co-staining of organic matter may lead to false positives, potentially resulting in an overestimation of microplastics abundance (Chen et al., 2021). Pyrolysis with gas chromatography/ mass spectrometry (Py-GC/MS) involves subjecting microplastics to high temperatures in a controlled environment, which breaks them down into individual components allowing for information on the composition of polymers (Funck et al., 2020; Hermabessiere et al., 2018). These approaches are gaining traction in the research field to rapidly provide polymer concentration, but they miss particle information such as size or shape which may be needed depending on the monitoring objectives.

5.2.4 Quality Control

Microplastics are present in every environment, including both indoor air and outdoors. Therefore, during field sampling, the implementation of air blanks is important to account for potential contamination originating from atmospheric deposition, clothing materials and equipment usage. These air blanks not only facilitate an evaluation of the sampling air, but also serve to assess and mitigate contamination risks. Nevertheless, establishing a direct correlation between the exposed blank and its genuine influence on the sample can be a complex task, primarily due to the potential disparity in blank placement for capturing airborne particles, which might not fully reflect the conditions.

When working in the lab, best practice includes working in enclosed filtered air environments (e.g., fume hood and laminar flow cabinets), as well as adopting clothing policies to minimize contamination from synthetic fibres. Procedural blanks are also frequently employed to detect potential sources of contamination, which may include contamination from equipment, chemicals, air, and clothing. The use of positive controls is recommended when processing samples, as they are essential for assessing method accuracy and recovery (Lusher et al., 2020; Munno et al., 2023; Prata et al., 2021). Implementing these measures helps to enhance data quality.

5.3 Overview of environmental monitoring of micro- and macroplastics in India

Thus far, there is no national level monitoring plan for macro- or microplastic pollution in India. There is not yet a national Action Plan for marine litter or plastics; although, a National Marine Litter Policy is currently being formulated. India has established a number of policies that aim to reduce environmental or marine pollution – such as the Plastic Waste Management Rules – although none of these specifically mandate monitoring of plastics in the environment (Sivadas et al., 2022). Instead, monitoring of plastic pollution has largely been undertaken by universities or institutes, resulting in a growing body of evidence related to plastic pollution in the Indian environment. To date, over 150 scientific journal articles have been published reporting plastic monitoring data. This has included several monitoring campaigns linked to government initiatives, such as monitoring of coastal and offshore microplastic pollution and beach litter undertaken by the National Centre for Coastal Research, linked to the Ministry of Earth Sciences (Ministry of Earth Sciences, 2022).

Figure 5.1 presents a map of monitoring or sampling locations studied in published scientific

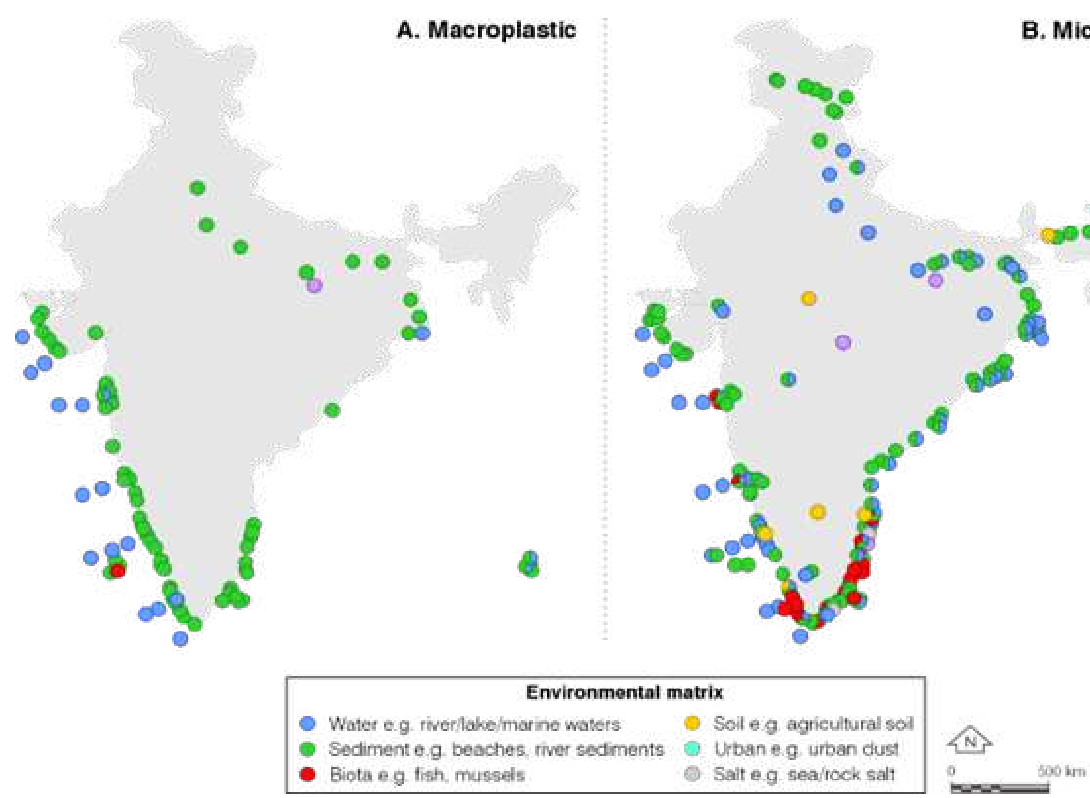

Figure 5.1. Locations of environmental monitoring for macro- and microplastic pollution in India

articles. Initially, scientific papers reported on pollution from plastic pellets or marine litter, and predominantly focused on beach environments. Since the mid-2010s, however, there has been a shift towards microplastic monitoring, and a wider diversity of environmental compartments have been investigated as part of an exponential increase in papers published each year. While coastal research continues to dominate the geography of plastic monitoring in India, an increasing number of studies are now shifting their focus inland, reporting on riverine and terrestrial pollution.

5.3.1. Macroplastic monitoring

The majority of macroplastic monitoring undertaken in India has been in the form of beach litter surveys (5.1 A). These are largely clustered along the western and southern coastline in the states of Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra, and Gujarat – where Tamil Nadu, Kerala, and Karnataka have the highest density of coastal monitoring locations. Additional clusters are present around Goa, Mumbai, and the Lakshadweep Islands. Beach litter monitoring in these locations has revealed several important sources: tourism, littering, fishing activities, and industry, and has identified key pathways of release: riverine export, dumping, and drainage outlets (Sivadas et al., 2022).

Beyond beach studies, monitoring of marine waters has also been performed along the western coast of India by Naidu et al. (2021). These authors reported the highest abundances of marine litter in the Central and Southeastern Arabian Seas. Only a single study thus far has specifically monitored the interaction between macroplastics and biota, in an investigation of sea bird entanglement on the Kerala coastline and the Lakshadweep islands (Nisanth and Kumar, 2019). The only inland assessments of macroplastic pollution in the published scientific literature comprise riverbank monitoring of abandoned, lost, or otherwise discarded fishing gear (ALDFG) in the River Ganga (Nelms et al., 2021) and quantification in litter aggregation pathways, such as along walkways or in open gutters, in the city of Varanasi along the Ganga River (Youngblood et al., 2022). The limited number of scientific articles published thus far on freshwater or terrestrial macroplastic pollution reveals a strong focus towards the marine environment in Indian macroplastic monitoring. This is in line with a global trend. Particularly in the early stages of research, marine litter studies were more prevalent. Now, many countries have amassed more data on macroplastic pollution in inland environments and the focus is gradually shifting from monitoring the marine environment to understanding the sources of plastic litter, which are predominantly land-based (Al-Zawaidah et al., 2021). A similar shift may be observed in India in the coming years, following this global trend.

5.3.2. Microplastic monitoring

In contrast to macroplastic monitoring, the geographic distribution of microplastic sampling sites and the diversity of environmental matrices sampled is wider (Figure 5.1 B). A majority of these monitoring efforts have taken place in the years after 2015 and there is currently an exponential increase in the number of studies reporting microplastic pollution data in the Indian environment each year. As with the macroplastic monitoring, the coastlines of Tamil Nadu and Kerala have been subject to the most intensive monitoring activities. However, when considering India as a whole, the diversity of matrices investigated for microplastic pollution exhibits greater diversity. This includes monitoring of microplastics occurrence in biota (e.g., Anandhan et al., 2022; Joshy et al., 2022; Karthik et al., 2018), urban dust (e.g., Narmadha et al., 2020; Pandey et al., 2022; Patchaiyappan et al., 2021), soils (e.g., Reethu et al., 2023; Singh et al., 2023; Tun et al., 2022), and sea salt (Ravikumar et al., 2023; Selvam et al., 2020).

The geographic spread of monitoring sites also covers more of the coastline and more inland areas than is observed for macroplastic monitoring (Figure 5.1). The Ganga River, for example, has been subject to several monitoring campaigns (e.g., Napper et al., 2021; Neelavannan et al., 2023; Sarkar et al., 2019). Microplastic data for other rivers, such as the Brahmaputra and Indus rivers of the Indian Himalayas (Tsering et al., 2021), are also emerging. In the last two years, a small number of studies have been published reporting microplastic monitoring data for Indian soils, focusing mostly on urban mangroves or dumpsites (e.g., Kannankai et al., 2022; Reethu et al., 2023; Sarkar et al., 2022; Singh et al., 2023; Tun et al., 2022). Additional studies have also reported data for agricultural soils but these typically do not provide sufficient location data to be included in the map to preserve the anonymity of farmers of the sampled fields (e.g., Kumar and Merline, 2021; Mahesh et al., 2022; Maji and Mistri, 2021).

5.3.3. Future of Indian plastic monitoring

It can be expected that monitoring of plastic pollution in India will continue to follow global trends, with an increasing focus on land-based sources that contribute to marine pollution and a shift towards new areas such as soil or air, where there are some early papers already emerging on the Indian research landscape. The focus on microplastic is likely to persist given a strong global focus on this topic at present. However, growing pressure to reduce plastic pollution (in terms of masses released) in line with ongoing negotiations towards a Global Plastics Treaty may transfer some of this attention towards better understanding macroplastic pollution and stemming dominant sources. This may already begin as negotiations develop but is likely to increase once an agreement is enacted, after 2027. Moreover, upcoming national legislation which recognize and commits to reducing plastic pollution may introduce new mandates for pollution monitoring activities, including more monitoring through government initiatives or government agencies.

To maximise the benefits of this future monitoring activity in India and internationally, there is an urgent need to address harmonisation of sampling methodologies, data collection, and data reporting. Some components – such as beach litter monitoring – generally follow international guidelines for sampling and reporting, but many other studies addressing different aspects of plastic pollution use a wide variety of different methods for sampling and analysis of macro- and microplastic pollution (Veerasingam et al., 2020). The upshot of these differences is that studies are poorly comparable. Studies that use different methods may be measuring different things (different size classes or different parts of the environment) and there is a wide variety of reporting units that hinder direct data comparisons (Sivadas et al., 2022), where methods are sometimes not sufficiently well described to facilitate interpretation of what the monitoring data represent. This challenge transcends Indian national boundaries: it is a global issue. There is therefore a need to coordinate monitoring activities, collaborate nationally and internationally, and converge methods towards a more harmonised approach (Hurley et al., 2023; Shaikh and Shaikh, 2021). Future plastic pollution monitoring in India can play an important role in addressing this global challenge.

5.4 Status of international environmental monitoring for micro- and macroplastics

Plastic pollution is receiving increased attention from researchers, citizens, and policymakers. Consequently, the monitoring of plastic pollution has become a top priority for governing bodies, both at local levels within various countries and on an international scale. Additionally, global concerns have resulted in the development of a legally binding global initiative to combat plastic pollution, established during the Fifth Session of the United Nations Environment Assembly (UNEA 5.2) (Sun et al., 2021)

Monitoring programs for macro- and microplastics provide insights into environmental

Figure 5.2. Overview of the organisation of guidelines and monitoring programs at a global and regional level.

pollution levels and establish baseline values before and after mitigation or remediation measures have been implemented. Typically, monitoring requirements are set in motion by the needs of specific entities, with environmental agencies often taking the lead at the national level, responding to national and international regulations (Lusher & Primpke, 2023; Provencher et al., 2022; Figure 5.2).

At the global level, established monitoring programs and guidelines have been put forward by organisations like the United Nations Environment Programme (UNEP) (Cheshire et al., 2009; Wendt-Potthoff et al., 2020) and the Joint Group of Experts on the Scientific Aspects of the Marine Environmental Protection (GESAMP). UNEP brings together extensive expertise in marine litter assessments and recommends survey methods, monitoring techniques and reporting protocols. Harmonisation through the development of standardised surveys and set guidelines to assess floating litter on beaches, in benthic environments and in aquatic environments is one of their primary goals. In parallel, GESAMP provides recommendations, practical advice, and guidance to establish monitoring programmes that cover various environments: shorelines, water columns, water surfaces, sediments and biota, and plastic categories, including macro-, meso-, and microplastics (GESAMP, 2019). Within the Regional Seas initiatives, numerous reports have been published, often with regulatory overlaps (Table 5.2).

Regarding monitoring activities within the European Union (EU) and European Regional Seas, many initiatives fall under the Marine Strategy Framework Directive (MSFD), The Convention for the Protection of the Marine Environment of the North-East Atlantic, Oslo-Paris Convention (OSPAR), International Council for the Exploration of the Sea (ICES), The Baltic Marine Environment Protection Commission (HELCOM), and UNEP-MAP. The MSFD monitoring guidelines represent a comprehensive framework that consolidates insights from UNEP and NOAA. They involve diverse sampling methods on beach litter, both macro and micro, inter-and subtidal sediments for microplastic sampling, macro and microplastics in the water column, seafloor litter and biota (Holzhauer et al., 2016; Piha et al., 2011). The guidelines provided by OSPAR countries (Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom) open the potential to contribute to a harmonised monitoring program for marine litter. These guidelines are based on experiences gained during the OSPAR piloting phase from 2000 to 2006 and incorporate information from UNEP's efforts to establish a global guideline. The guidelines are designed to offer a practical and cost-effective approach to assess marine litter on beaches while aligning with the goals of the Marine Strategy Framework Directive (OSPAR, 2020). Additionally, HELCOM provides its own set of guidelines for sampling of beach litter and for assessing microplastics in seabed sediments and the water column in the Baltic Sea. The Mediterranean Action Plan of the United Nations Environment Programme (UNEP-MAP) offers assessments in the Mediterranean, addressing litter on the beaches, in surface waters, seabed and biota.

Table 5.2. Examples of Regional Seas initiatives of guidelines and monitoring programs for marine litter

Regional Seas Initiatives	Provide strategies/guidelines for	Reference(s)
The Arctic Monitoring and Assessment Programme (AMAP)	Sampling microplastics in atmospheric samples, ice, surface water, water columns, aquatic sediments, shoreline sediments, terrestrial soil, seabed, and biota. Sampling macroplastics on shorelines	(AMAP, 2021; Primpke et al., 2022)
The Commonwealth Scientific and Industrial Research Organization (CSIRO) for marine environments in Australia and surrounding regions	Addressing microplastics along the coastlines, as well as within upstream and riverine systems	(Schuyler et al., 2020)
The Ministry of the Environment Japan (MOEJ)	Cabinet-level ministry of the Government of Japan responsible for global environmental conservation and pollution control, established guidelines, and monitoring programs for surface waters for microplastics	(Michida et al., 2019).
National Oceanic and Atmospheric Administration (NOAA) Marines Debris Program is the U.S. Federal government	Marine debris with focus on marine litter, both macro and micro at shorelines	(Lippiatt et al., 2013; Masura et al., 2015; NOAA, 2013)
The Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region (NOWPAP), collaborative effort involving the People's Republic of China, Japan, The Republic of Korea, and the Russian Federation	Preventing marine litter, monitor its quantity and distribution, and remove existing litter. Their monitoring program enables the identification of key sources of marine litter and facilitates an assessment of temporal trends in litter found on beaches and shorelines.	(NOWPAP, 2017)
The Western Indian Ocean Marine Science Association (WIOMSA) consisting of Somalia, Kenya, Tanzania, Mozambique, South Africa, Comoros, Madagascar, Seychelles, Mauritius and Rèunion (France)	Examines marine litter on beaches, in sediments and in both ocean and terrestrial surface waters. Additionally, it involves the establishment of baselines at six different regions, with the goal of preventing and reducing marine pollution by 2025, in alignment with SDG 14.1.1	(Barnardo & Ribbink, 2020).

5.5 Technological advancement in the assessment of nano and microplastics

One component of the ever-expanding knowledge base on plastic pollution in the environment has been a shift towards focusing on smaller microplastics and nanoplastics (MNPs). This is likely driven by the desire to identify particles that cause adverse effects if taken up by humans or other organisms, where smaller particles have been reported to pose more of a risk. Much of the literature available on the topic derives from research projects that attempt to develop new or optimised analytical detection methods. However, in many instances the developed methods have limited uptake by the wider research community and there has been a divergence in approaches. Furthermore, where methods vary in analytical aspects, the level at which the results are comparable or transferable has been called into question (e.g., Koelmans et al., 2022). Policymakers and scientists are motivated to endorse monitoring plans based upon ready-to-deploy methods for different analytical scenarios (Aliani et al., 2023a). Tools and protocols have been developed to quantify plastic pollution, but these methods often provide incomparable results, even if applied to the same environmental matrix and target the same size plastics.

For larger microplastics (>300 μm), methods may have a minimum level of best practice, meaning that there is generalised consensus on how to handle the samples, however variations in methods still exist. Thus, most research activities are focused on validating approaches to address goals and comparing methods. Where methods have a minimum best practice recommendation that is accessible across the international research community, the focus has been to initiate and establish monitoring programmes that enact them across time and space. Yet, target plastic typologies (e.g., polymer type, size, shape), sampling strategies, available infrastructure, analytical capacity, and harmonization of generated data remain as limitations (Lusher and Primpke, 2023). Methods for detecting micro- and nanoplastics, despite significant technological advancements, are far from being harmonised. Research activities have typically concentrated on applying refined and focused methods, however, the reproducibility of the data is still limited due to expensive and specific instrumentation and variations across individual laboratories and their in-house methods. In terms of comparability, it may be necessary for laboratories to use the same analytical setup to compare results. Although it is desirable that all teams use the same protocols all over the world, this is not realistic. From a monitoring perspective, it is possible that different research groups with different analytical setups can obtain results that are comparable. This is the aim of harmonisation activities.

5.5.1 Reproducible analytical pipelines in plastics research

Reproducible Analytical Pipelines, or RAPs, refer to the elements which make up an analytical process (Aliani et al., 2023a). RAPs are especially helpful for multilevel workflows (like many plastic analysis methods). In terms of plastic pollution research and monitoring, these include the fundamental steps needed for analysis from sample collection to data reporting such as survey design, sample collection, sample preparation, analytical detection, quantification, and data reporting (Figure 5.3).

Generation data on environmental plastic pollution can be time-consuming and outputs need to be both accurate and timely given that assessing and quantifying the impacts of plastics on the environment has emerged as an urgent political and public interest. Optimising the processes involved in plastic monitoring and analysis is of high priority. RAPs can be used to help decide if a single step in the RAP (such as the use of analytical instruments to confirm the polymeric identity of particles) is mature enough to be implemented in all monitoring guidelines. If the method is not yet mature, then further research and development can be recommended. To support this decision-making, it is important to use a robust and synthetic approach to assess the maturity of each step of a plastic RAP (that is, how much a technology is ready to fulfil the expected tasks). The RAP approach represents a potential solution for advancing plastic pollution assessment in the environment.

MNPs in water matrices

Proportionally, research on plastics in water bodies is dominated by larger microplastics and macroplastics, with very few studies focusing on smaller microplastics or nanoplastics. Studies that target nanoplastics tend to focus on method development, and do not consider the generation

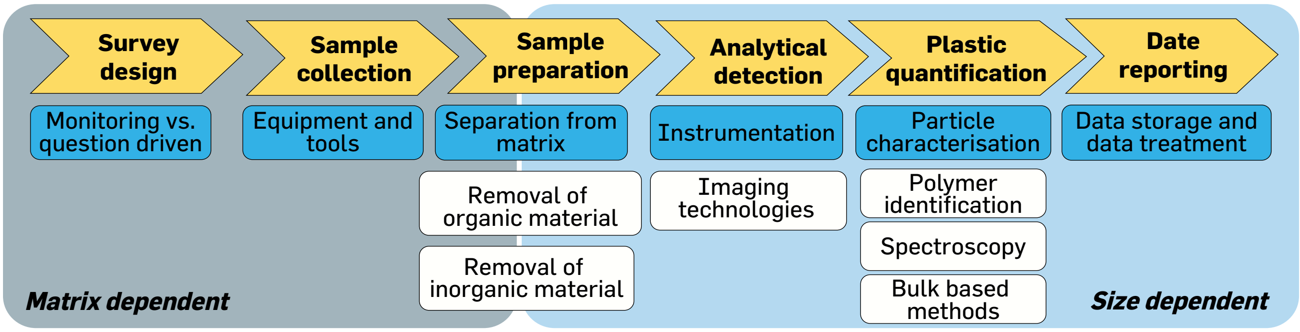

Figure 5.3: Steps of a Reproducible Analytical Pipeline (RAP) for environmental plastics studies. Orange boxes represent the fundamental steps in plastic analysis. Blue boxes provide an example of elements which form part of the fundamental steps. White boxes represent examples of method variations. Figure from Aliani et al. (2023b).

of comparable data across institutes. RAPs for water matrices are therefore compiled based on the available literature on microplastics. ***Survey design*** and ***sample collection*** tends to be focused using nets and pumps, with pumps providing the most suitable approach to avoid contamination during field sampling and achieve a lower detection limit (<100 μm, Primpke et al., 2023). The volume of samples needs to allow reporting of particles in values that exceed the limit of detection (LOD). ***Sample preparation*** steps for the extraction of MNPs from water samples vary depending on the composition of the water samples. The cleaner the sample, the fewer the steps and thus the fewer potential steps to reduce procedural contamination. Sample preparation for MNPs focuses on cleaning the matrix to support analysis and include pre-oxidation or digestion (oxidative, acid, or alkaline), sieving and density separation (all performed with a variety of different reagents).

5.5.2 Technological readiness levels in plastics research

Once a Reproducible Analytical Pipelines (RAP) has been established, an assessment of its application for comparative research should be performed. Namely, the Technological Readiness Level (TRL) can be assessed. TRLs have recently been highlighted as a digestible approach to distinguish the suitability of methods or choice of methods for monitoring or research (Aliani et al., 2023a). By establishing a TRL scale for plastic pollution research, all method steps (such as those included in a RAP) can be ranked according to basic research (TRLs 1–3), applied research (TRLs 4–5), in development (TRLs 6–8) and implementation (TRL 9) (Figure 5.4).

Measuring a technology's maturity can indicate the limits and benefits of a specific approach. When assessing the TRL for micro and nanoplastics in different environmental compartments, methods are still in the applied research and development phases. Looking at the available scientific literature, there is a growing body of literature on methodological and technological aspects, but in many instances the description of methods provided is insufficient to fully understand and replicate the protocol. Most have a low TRL and are not at an acceptable scientific level for comparative research.

In summary, with the growing understanding of plastic pollution as an international environmental problem, the focus on what size of plastics to target will be closely linked to either (1) scientific curiosity and pushing the boundaries of analytical sciences, or (2) the reproducible and comparable methods that can provide data and knowledge required by policy makers and/or regulators.

5.6 Harmonising international monitoring methods for plastic pollution

Insights from international strategies and approaches to plastic pollution monitoring can provide useful guidance in establishing effective monitoring in India, including addressing needs

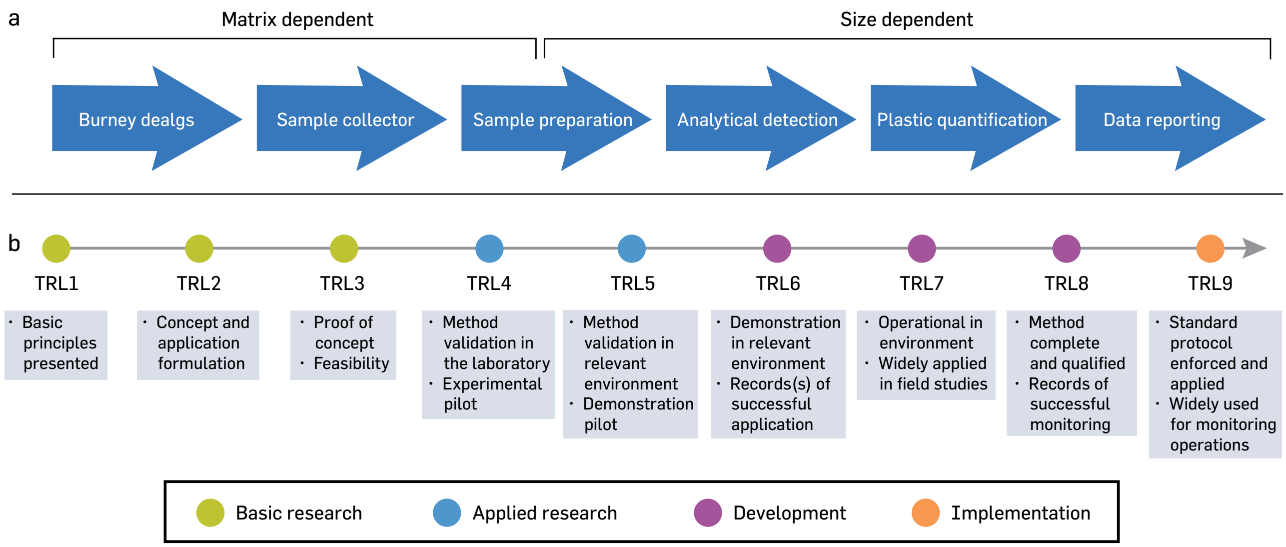

Figure 5.4: RAPs and TRLs in plastics monitoring (Aliani et al., 2023a)

for harmonisation and data comparability that can set Indian monitoring data in a global context. This chapter provides an overview of current initiatives for detecting both macro and microplastics across India, alongside existing programs and guidelines for marine litter at global and regional levels. It also highlights established techniques for sampling and detecting both macro-and microplastics, as well as methods for analysing microplastic particles across various matrices, all within established guidelines. Utilising RAPs and TRLs in plastic monitoring programs enables the selection of methods that not only meet minimum best practice standards but also facilitate comparative and harmonised data collection.

CHAPTER 6
AGRI-PLASTICS USE AND MANAGEMENT

[1]Rachel Hurley

Plastics are increasingly being used in agricultural applications globally. These products – often termed agriplastics – exploit the low cost, light weight, durability, and versatility of plastics as a material to enable several benefits that increase agricultural productivity and quality and enhance farm economies. Agriplastics can be used extensively throughout food production systems in production, harvesting, storage, and distribution. Their use in protected cultivation systems can enable production of crops beyond traditional seasonal limitations and in spite of adverse environmental conditions, increasing both yields and quality and meeting increasing global demands related to food and nutrition security (EIP-AGRI Focus Group, 2021). Agriplastics can also significantly reduce water and agrochemical consumption, reducing pressures or stressors at the farm level (Espí et al., 2006). However, emerging evidence also points towards negative consequences of agriplastics use and waste handling, related to the generation and release of plastic residues which cause soil pollution (Hurley and Nizzetto, 2018; Steinmetz et al., 2016). It is estimated that Asia represents the largest user of agriplastics, accounting for up to half of the annual total of plastics used in agriplastic applications worldwide (FAO, 2021). Yet, there is a paucity of data on the usage, waste generation, baseline soil pollution, or potential risks of agriplastics use in the Indian context.

6.1 Plastics and the agricultural sector in India

Agriculture plays a critical role in the Indian economy. 58% of the Indian workforce are engaged in the agricultural sector; a sector which has grown at an annual average rate of 4.6% since 2017 (Government of India, 2023). The use of plastics in agricultural production has been heralded as a potentially important component of a 'second green revolution' in India, enabling enhanced food security and reinforcing farm economies and the global competitiveness of Indian agriculture (Akhter et al., 2021). Yet, agriplastics saw a relatively slow uptake in India relative to the rest of the world, where the utilisation of polymer by agriculture was only 2% in 2015, compared to a global average of 8% (TATA Strategic Management Group, 2017).

India's slow uptake of agriplastics is expected to change. Whilst China represents the main player with regard to agriplastics use globally, the Indian market is the fastest growing and contributes substantially to projections of large increases in the use of conventional and biodegradable plastic thin films for protected cultivation systems in Asia by 2030 (FAO, 2021; Market Research Future, 2023). Various economic forecasts for several different agriplastics point towards India as an emerging key player, including micro-irrigation systems, polymer-coated controlled release fertilisers, and plastic agri-textiles

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(Mordor Intelligence, 2023, 2016; Sharma et al., 2022). India is also expected to become one of the biggest global consumers of bale wraps (Briassoulis, 2023). In addition, several initiatives have been funded by the Government of India to encourage greater use of agriplastics. Subsidies of up to 50% are available for farmers cultivating several major crops in several districts within all Indian states to purchase protected cultivation systems such as mulching films, greenhouses, polyhouses, shade nets, and low tunnel systems[10] and of up to 100% for irrigation systems with water saving technologies[11]. Precision Farming Development Centres (PFDCs) have been established across India to promote research and development into precision farming, with a specific focus on agriplastics applications. India now represents an important domain for agriplastics research, internationally.

6.2 Use and management of agriplastics in India

As with countries globally, there is a lack of inventories or data on the use of plastics in agriculture in India. In lieu of this, a scoping exercise was undertaken to generate a list of products and relevant polymer types used for agricultural applications and sold on the Indian market. Whilst this may not be exhaustive, it is clear that a wide array of plastic products is already available in India for several different agricultural applications, utilising many different polymer types (Table 6.1). Different formulations of polyethylene represent the dominant polymer type used in the compiled list of products; although, polypropylene, polyethylene terephthalate, and polyvinyl chloride are also often described. Table 6.1 demonstrates that a wide variety of plastic products are available for purchase, but data are still missing on the actual usage of these products in India.

10 Operated under the Mission for Integrated Development of Horticulture (MIDH) through the National Horticulture Mission (NHM) and the Horticulture Mission for North East & Himalayan States (HMNEH) in all Indian states to cover all major crop types

11 Operated under the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) programme.

Mismanagement of plastic waste represents a global issue and agriplastics have several additional inherent challenges that complicate effective end-of-life handling of these products. Used agriplastics is typically spatially disperse across rural landscapes and with poor connectivity to facilities for handling waste. Many agriplastics applications, such as thin films used in protected cultivation systems, generate large volumes of waste that can be challenging to transport and may additionally be contaminated by soil, plant, or agrochemical residues rendering it poorly recyclable from a practical or technical standpoint (Briassoulis, 2023). In the absence of effective waste collection schemes, alternative approaches adopted by farmers globally include dumping, burial, landfilling, and open burning (Briassoulis et al., 2013; FAO, 2021). However, these practices can cause air, soil, and aesthetic pollution, impact on wild animals and livestock, block water flows and increase flood risk, and contribute towards degrading soil quality (Briassoulis et al., 2010; FAO, 2021).

Data on agriplastic waste generation and handling is missing in many countries and regions (FAO, 2021). This is also the case for India, where there is no official data available on volumes of agriplastic use, waste generation, or on the practices for disposing of this waste. Toxics Link surveyed farmers in Karnataka and Maharashtra regarding waste handling of plastic mulching films (Mahesh et al., 2022) and found that dumping of films on land was mostly commonly, reported by 65% of respondents. 20% of farmers burn mulching films after use, whilst another 10% disposed of them in water bodies. The report also mentioned the possibility of a return scheme, whereby the distributor would receive used mulching films and submit to recycling; although, uptake of this opportunity was described as being low. These findings mirror several issues related to agriplastics use globally, where very few countries have implemented strategies for effectively handling agriplastic waste. One possibility for addressing this challenge in India is to use data collected as part of ongoing subsidy schemes to track usage and expected waste generation of agriplastics at the local or regional

Table 6.1. Uses of plastics in Indian agricultural production. The list is compiled from online retailers selling agricultural plastic products in India or to the Indian market and may not be exhaustive. Non-plastic alternatives are also available for several of these products/applications, but only plastics versions are listed here.

Product	Applications	Common polymer type(s)
Thin films		
Mulching films	Films applied below or above soil to modulate soil temperature and moisture conditions and limit pests	LLDPE, LDPE, HDPE, EVA, PP, Biodegradable plastics
Greenhouse/polyhouse covering films	Films to cover greenhouses or polyhouse used in medium- to long-term crop protection systems	LDPE, LLDPE, HDPE, EVA
Low tunnel films	Films used in temporary crop protection systems, similar to a small greenhouse/ polyhouse	LLDPE, LDPE, HDPE, EVA
Silage films	Protection and storage of silage (i.e., hay bales)	LDPE
Nets		
Shade nets	Protecting crops from sunlight; often green or black in colour and used in greenhouse or low tunnel systems	PP, HDPE
Anti-bird nets	Protecting crops from pests	PP, HDPE
Anti-hail nets	Preventing hail damage or damage from other adverse weather conditions (e.g., wind)	PP, HDPE
Anti-insect nets/seed cages	Protecting crops from pests; seed cages are also used when pollinating is undesirable such as in seed breeding	PP, HDPE, PA
Tea withering nets	Used to support tea withering process (reducing moisture content/drying)	HDPE
Floriculture nets	E.g., rosebud nets for protecting flower buds or carnation/floriculture nets for supporting upright growth of flowers	(HD)PE
Sericulture nets	Supporting the formation and harvesting of silkworm cocoons and maintain hygienic conditions	(HD)PE, PA, PET
Nurseries and crop cultivation support		
Seedling trays	Growing crops in the early stage of growth (seed germination, seedlings)	PS, (HD)PE, EPS
Plant pots	Growing plants	HDPE, PP
Grow bags	Alternative to plant pots; sometimes often improved breathability	(HD)PE, PET, biodegradable plastics
Crop supporting clips	Holding plants to support structures e.g., for tomato or cucumber cultivation	PP
Crop supporting wire/twine	Tying plants to support structures	PET

Product	Applications	Common polymer type(s)
Tree protectors/wraps/guards	Protecting young trees from pests or mechanical abrasion	PE, PP, PVC
Hoop houses/low tunnel pipes	Scaffolding for films or nets in low tunnel systems or polyhouses	PVC
Packaging of agricultural products or harvests		
Fertiliser bags	Sacks to contain agrochemicals such as fertiliser	Woven PP, LLDPE
Agrochemical bottles	Bottles for container liquid agrochemicals	HDPE, PET
Crates/trays	Packing, storing, and transporting harvest crops	HDPE, PP
Packaging nets/leno bags	Packing, storing, and transporting harvested crops such as fruit and vegetables	Woven HDPE, Woven PP
Rice/grain bags	Bags for packing, storing, and transporting rice and grain that offer oxygen/moisture protection	LDPE
Irrigation		
Irrigation pipes	Supplying water to an irrigation system	PVC, HDPE, LDPE
Driplines/rain hose pipes	Delivering water to crops as drips or sprays	HDPE, PVC
Drippers/drip emitters	Mounted to pipes to deliver irrigation to crops	(LD)PE
Sprinklers	Mounted to pipes to deliver irrigation to crops	(HD)PE, PVC, ABS
Stakes/risers	Scaffolding for pipelines or for securing them in place	PP, PE
Grommets/joiners/couplings	Joining or sealing components of irrigation systems	LDPE, Thermoplastic rubber e.g., EPDM
Tape	Sealing leaks or securing components	PTFE
Microencapsulation and coatings		
Controlled release fertilisers	Fertiliser encapsulated in a polymeric shell to enable slow release of the fertiliser over a period of months	Not reported: *"elastic polymer", "polymer coating", polymer-sulphur coating"*
Seed coatings	Polymeric seed coatings to protect seeds during handling, improve germination, and reduce the need for herbicides	Not reported
(Geo)textiles		
Pond/underground water storage liners	Sealing edges of ponds, canal, or other water storage structures	Woven HDPE, PVC
Tarpaulins	Drying of spices, nuts, and other crops, fumigation of tobacco leaves, grapes, or other crops; covering tendu leaves, tamarind, etc.	Woven HDPE, PVC

Product	Applications	Common polymer type(s)
Weed mats	Suppress weeds as competition for young trees and crops	Woven PE, Woven PP
Poultry curtains	Protect livestock in open farming systems	Multi-layer PE
Other		
Plastic flooring	E.g., for cattle or goat farming	EVA
Plastic cups	Used for collection of rubber latex (typically replaces coconut shells)	HDPE
Rain guards/tapping shades	Prevent rain disruption to harvesting of rubber latex	PVC, LDPE
Banana bunch cover bag	Protecting banana harvests from adverse weather conditions or pests	LDPE

level and develop schemes to collect and process this waste (Ananth et al., 2022).

6.3 Agriplastics and soil pollution

Many agriplastic products have the potential to contaminate soils with residues produced during or after their use. This includes the degradation and fragmentation of thin films (such as mulching films) due to exposure to UV solar radiation or other forms of adverse weather, residues of seed coatings or controlled-release fertiliser that use polymeric encapsulation, or the breakdown of agriplastic waste when improperly disposed of. Several studies from across the globe have confirmed the pollution of soils by residues of agriplastics or agriplastic waste (Zhang et al., 2022).

Thus far, only a small number of studies have reported on plastic pollution in Indian agricultural soils. Kumar and Merline (2021) measured plastic residues in four agricultural fields in Tamil Nadu subject to 2-10 years of mulching film application for vegetable cultivation (tomato or bean). Up to 4.96 $\pm$ 0.08 g kg^{-1} of plastics was observed in the fields, where the highest concentrations were founded in the upper 0-10 cm of the fields and in the fields that had received more applications of mulching film over time. Toxics Link conducted a study of microplastic contamination in mulched and un-mulched sites, and at dumpsites where mulching film had been discarded on land, in Karnataka and Maharashtra. On average, microplastic concentrations at mulched sites were double the levels observed for sites where there had been no use of plastic mulching. However, the concentrations at the dumpsites for used plastic mulching films were more than double the concentrations of the mulched soils, indicating that waste mismanagement is a bigger contributor to soil pollution than the use of mulching films in the field (Mahesh et al., 2022). An additional study examined other sources of microplastic contamination to agricultural fields in West Bengal: the application of compost and sewage sludge to land. Higher microplastic concentrations were observed in treated fields than at control sites, where control sites were also identified as having more desirable soil physicochemical properties (Maji and Mistri, 2021). This highlights the need to include agriplastics use within the context of other sources of plastic pollution to agricultural land. There is a need for further research to monitor agricultural soils in India and establish a baseline for contamination arising from agricultural plastic use and to better understand the potential risks associated with different levels of plastic pollution.

A growing body of research has also identified the potential for this soil plastic pollution to impart changes in soil physicochemical properties, interact with soil organisms, and affect plant production and quality (e.g., de Souza Machado et al., 2018; Wang et al., 2022; Wei et al., 2022; Zantis et al., 2023;

Zhang et al., 2022). At present, it remains difficult to conclude on the quantifiable risks posed by agriplastic residues in soils due to variable reported responses for different endpoints, a wide variety of different agriplastic residue typologies (with a corresponding lack of appropriate test materials), and the high level of complexity inherent in soil systems (de Souza Machado et al., 2019; Wang et al., 2022). More research is needed to identify potential risks specific to the Indian context, including for example studies of agriplastic residues relevant to Indian agriculture or soil types representative of different Indian environments. This knowledge is essential to evaluate the balance between the benefits and potential costs of agriplastic use in India.

6.4 Concluding remarks

There is a need to balance the benefits of agriplastic use with the potential costs in a specific Indian context to better understand how to secure long-term sustainability in agricultural production, food and nutrition security, and farm economies. To achieve this, data on the usage, applications, and waste generation and handling of agriplastics at the farm, local, and regional level are needed, as well as research into baseline contamination of farm soils, the potential consequence of soil plastic pollution for Indian environments, and best practices for the use and handling of different agriplastics to minimise negative effects.

CHAPTER 7
HEALTH, EXPOSURE, AND RISK – AN OVERVIEW

[1]Avanti Roy-Basu, [1]Mary Abraham, [1]Nathaniel B. Dkhar

Plastics have become an integral part of our daily lives, yet their extensive use may lead to the proliferation of plastic-borne chemicals in the environment, both intentionally added and unintentionally generated during the degradation of plastic materials. Plastics represent a complex mixture of polymers, plasticizers, colorants, flame retardants, and various other additives. The pervasive presence of chemicals in our environment, particularly those associated with plastics in various forms and sizes, has raised concerns about potential human exposure and the associated health risks (Campanale et al., 2020). This has created a media, public, and political focus on plastic pollution that needs to be further addressed by research. Understanding routes of exposure is crucial for assessing and mitigating health risks associated with plastic pollution and chemical contaminants in the environment. To shed light on various pathways through which humans can come into contact with potentially harmful substances, this chapter focuses on potential routes of exposure to nano-, micro-, macro-, and plastic-borne chemicals.

7.1 Routes of exposure to nano, micro, macro, and plastic-borne chemicals

Recent studies have detected microplastics in various sample types including tap water, food products, and air, highlighting the variety of potential exposure routes (Ghosh et al., 2023; Pironti et al., 2021; Ziani et al., 2023)ubiquitous in nature and therefore affect both wildlife and humans. They have been detected in many marine species, but also in drinking water and in numerous foods, such as salt, honey and marine organisms. Exposure to microplastics can also occur through inhaled air. Data from animal studies have shown that once absorbed, plastic micro- and nanoparticles can distribute to the liver, spleen, heart, lungs, thymus, reproductive organs, kidneys, and even the brain (crosses the blood–brain barrier. One of the primary routes of exposure to plastic-borne chemicals is ingestion. This can occur when individuals consume food and beverages contaminated with microplastics (Jin et al., 2021; Ziani et al., 2023). A summary of recent studies examining the presence of plastics in different food products is provided in Table 7.1. These microplastics can originate from various sources, including the breakdown of larger plastic items, such as bottles and bags, or the shedding of microplastic particles from clothing made of synthetic materials. While evidence exists indicating that humans ingest microplastics from different sources, more research is needed on the potential health implications of this ingestion.

Another route of exposure is inhalation, especially concerning nano- and microplastics. Particles

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Table 7.1. A summary of selected recent studies on microplastics in food products from across the world (adopted from Ziani et al. (2023)).

Type of food	Abundance average particles	Range size particles	Type of polymer	References
Sea salts from Bangladesh	2,676 MP/kg	0.1–5 mm	Polystyrene (PS), Ethylene-vinyl acetate (EVA), High-density polyethylene (HDPE), Nylon (polyamide 6), Polyethylene terephthalate (PET)	(Parvin et al., 2022)
Salt from India	46–115 particles/200 g	100–1000 μm	PE, PVC (Polyvinyl chloride), PS	(Vidyasakar et al., 2021)
Sugar from Germany	249 ± 130 particles/kg		PET, PE, PP	(Liebezeit and Liebezeit, 2013)
Glass bottled water from Germany	35,436 MP/L	90% < 5 μm	PET, PE, PP	(Oßmann et al., 2018)
Raw water from Germany	0–7 MP/m^3	50–150 μm	PE, PA(Polyamide), PS, PVC	(Mintenig et al., 2019)
Drinking water from Saudi Arabia	1.9 ± 4.7 particles/L	25–500 μm	PE, PS, PET	(Almaiman et al., 2021)
Plastic food containers from China	1–41 MP per container	≤500 μm; 501–100 μm; ≥1001 μm;	PS, PP, PE, PET	(Du et al., 2020)
Plastic food tray with sealing film from France	4.0–18.7 MP/kg	<1 mm	XPS (Extruded polystyrene)	(Kedzierski et al., 2020)
Tea bags from Canada	11.6 billion MP per cup of tea beverage	10 nm–150 μm including nanoparticles	PET, Nylon	(Hernandez et al., 2019)
Infant feeding bottles from China	16.2 million MP/L	1–20 μm	PP	(Li et al., 2020)
Crustaceans from South Korea	0.97 ± 0.74 particles per individual	65% < 300 μm	PE, PP, PS, PES	(Cho et al., 2019)
Fish (*Siganus rivulatus, Diplodus sargus, Sardinella aurita, Sphyraena viridensis, Atherina boyer*) from Egypt	28–7527 particles/fish	25–2000 μm	PVA (Polyvinyl alcohol), LDPE, HDPE, PET, PP, Nylon	(Shabaka et al., 2020)

Type of food	Abundance average particles	Range size particles	Type of polymer	References
23 milk samples (22 for adult and 1 for child) from Mexico	6.5 ± 2.3 particles/L	0.1–5 mm	PES, PSU (Polysulfone)	(Kutralam-Muniasamy et al., 2020)
Honey from Switzerland	32–108 Fibers/kg	30 and 1 µm	PET	(Mühlschlegel et al., 2017)
Canned sardines from Australia and Malaysia	1–3 fragments per individual	149 and 8 µm	PP, PET	(Karami et al., 2018)
Fruits (pear, apple) Vegetables (lettuce, broccoli, carrot) Food and beverage packaging from Italy	52,600–307,750 MP/kg 72,175–130,500 MP/kg	1.81–2.29 µm 1.51–2.52 µm	Not specified	(Oliveri Conti et al., 2020)

released into the air through the degradation of microplastic items can be inhaled, potentially leading to respiratory and cardiovascular issues (Prata, 2018; Ageel et al., 2022; Liao et al., 2021). Exposure to airborne nano- and microplastics is an emerging concern as conclusive research is still yet to emerge on their potential health risks. These small particles may carry plastic-borne chemicals, which can potentially enter the respiratory system and, if they enter the bloodstream, circulate throughout the body, raising concerns about systemic health effects (Prata, 2018).

Dermal exposure may also occur when individuals come into direct contact with products containing plastic-borne chemicals. Some chemicals present in plastics are known to be skin irritants, allergens, or sensitizers, leading to various skin issues (Anderson and Meade, 2014; Panico et al., 2019). Dermal exposure is often overlooked but can be a significant route of contact with plastic-borne chemicals in our daily lives. However, it is important to investigate whether these chemicals are available for uptake through dermal contact, and the specific conditions under which this might occur.

Understanding the routes of exposure to nano-, micro-, macro-, and plastic-borne chemicals is essential for assessing and mitigating the health risks associated with plastic pollution. These routes include ingestion, inhalation, and dermal contact, with each presenting its unique challenges and concerns. Further research is needed to comprehensively evaluate the health impacts of exposure to plastic-borne chemicals and to develop effective strategies for reducing human exposure to these contaminants. Addressing the issue of plastic pollution requires a multifaceted approach that includes better waste management, reduced plastic use, and the development of safer plastic alternatives.

7.2 Human, societal, and environmental risks associated with plastic pollution

Plastic pollution has emerged as a global crisis, with far-reaching consequences for human health, society, and the environment. The proliferation of plastics in our daily lives, coupled with inefficient waste management practices, has led to widespread contamination of terrestrial and aquatic ecosystems. Plastic pollution is not solely an environmental problem; it is a public health concern as well. This subsection delves into the multifaceted risks posed by plastic pollution, focusing on human health, societal challenges, and the environmental impacts of this escalating problem.

Potential human health risks typically relate to the release of plastic additive chemicals in the body. Exposure to high concentrations of these chemicals has been linked to endocrine disruption, which can cause a range of different health implications (La Merrill et al., 2020). However, it is important to undertake further research on the mechanisms of actual release of chemicals in the body and the associated health risks under relevant levels of exposure. This includes the extent to which particles are taken up, versus passing through the digestive system. Other potential risks are associated with inhalation, where small particles (including non-plastics) are known to cause respiratory issues (Khan and Jia, 2023; Prata, 2018). The specific risk of micro- and nanoplastics and the exposure of humans needs to be further researched to better understand the potential risks.

There are also emerging concerns related to the role of microplastics in transferring antibiotic resistant genes or bacteria (Tuvo et al., 2023), but the extent of the risk needs to be further investigated. Plastics in aquatic environments can harbour bacterial biofilms, creating a breeding ground for antibiotic-resistant bacteria. When humans are exposed to such bacteria, it can reduce the effectiveness of antibiotics in treating infections.

The interaction between plastic pollution and other pollutants in the environment may also lead to cumulative health effects (Wang et al., 2020). Plastics can transport and concentrate chemical pollutants, exacerbating their toxic impact on humans. For instance, plastics in the environment can adsorb harmful substances such as heavy metals and persistent organic pollutants (POPs). However, the role of plastics versus other organic debris in the environment in conveying these chemicals, including exposure pathways for human and environmental health, requires further investigation.

The potential health risks associated with plastic pollution underscore the need for comprehensive efforts to reduce plastic waste, improve recycling and waste management practices, and regulate the production and disposal of plastics and their additives. Public awareness, responsible consumption, and collective action are essential in mitigating the health hazards posed by plastic pollution and preserving both our environment and well-being.

The societal risks associated with plastic pollution extend to economic burdens (Lee, 2015). Local governments and municipalities often bear the financial responsibility for managing plastic waste. This includes collection, disposal, and the development of recycling infrastructure. The high costs of waste management divert resources that could be allocated to other essential public services, such as education and healthcare. Additionally, the economic impacts of plastic pollution manifest in reduced tourism revenue in areas marred by littered beaches and waterways. The aesthetic deterioration of natural landscapes due to plastic pollution has profound societal consequences. Littered beaches, rivers choked with plastic debris, and urban areas marred by unsightly plastic waste detract from the quality of life. The loss of aesthetic value diminishes the appeal of tourist destinations and affects the overall sense of well-being within communities. This can lead to a decline in property values and negatively impact the local economy.

Plastic pollution poses a grave threat to ecosystems, particularly aquatic environments. Marine life, from fish to seabirds, can ingest or become entangled in plastic debris. This not only leads to injuries and deaths but also disrupts the balance of marine ecosystems. Plastic pollution has far-reaching

Sources of Plastic and POP pollution and exposure routes to humans

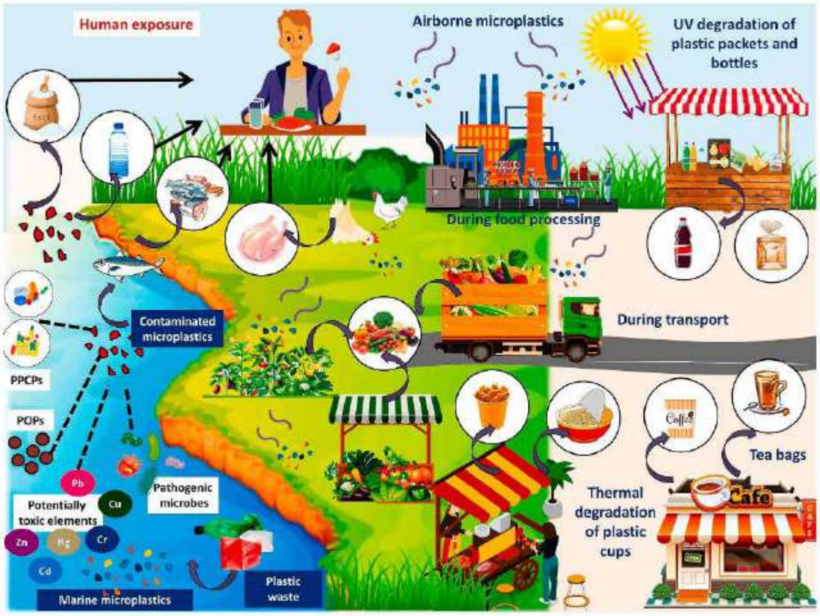


Figure 7.1. Illustration of fate and important sources of plastic- and POP pollution in the environment, their important exposure routes to humans (Sewwandi et al., 2023).

implications for biodiversity, potentially driving species to the brink of extinction (Lee, 2015). Moreover, plastics persist in the environment for centuries, further exacerbating their impact on ecosystems.

Plastic pollution contaminates natural resources such as water bodies, soil, and the atmosphere. Plastic waste can leach harmful chemicals into groundwater, leading to soil and water pollution. Contaminated water supplies can pose health risks for communities that rely on these sources for drinking water (Ziani et al., 2023).

The human, societal, and environmental risks associated with plastic pollution are intertwined and complex. The battle against plastic pollution is not only a matter of environmental conservation but also a pressing public health and societal concern. As plastics continue to pervade our daily lives and the environment, it is imperative to recognize the multifaceted nature of these risks and work collectively to address them. Protecting human health, preserving societal well-being, and safeguarding the environment require coordinated efforts at the individual, community, and global levels. Reducing plastic use, improving waste management practices, and developing sustainable alternatives are critical steps toward mitigating the harmful consequences of plastic pollution.

7.3 Interlinkages between plastic pollution and Persistent Organic Pollutants

The interplay between plastic pollution and Persistent Organic Pollutants (POPs) is a complex and pressing issue for human health and the environment. This subsection explores the interlinkages between plastics and POPs, shedding light on the various ways in which plastics may act as carriers and/or sources of these harmful chemicals. Understanding this connection is essential for addressing the challenges posed by both plastic pollution and POP contamination.

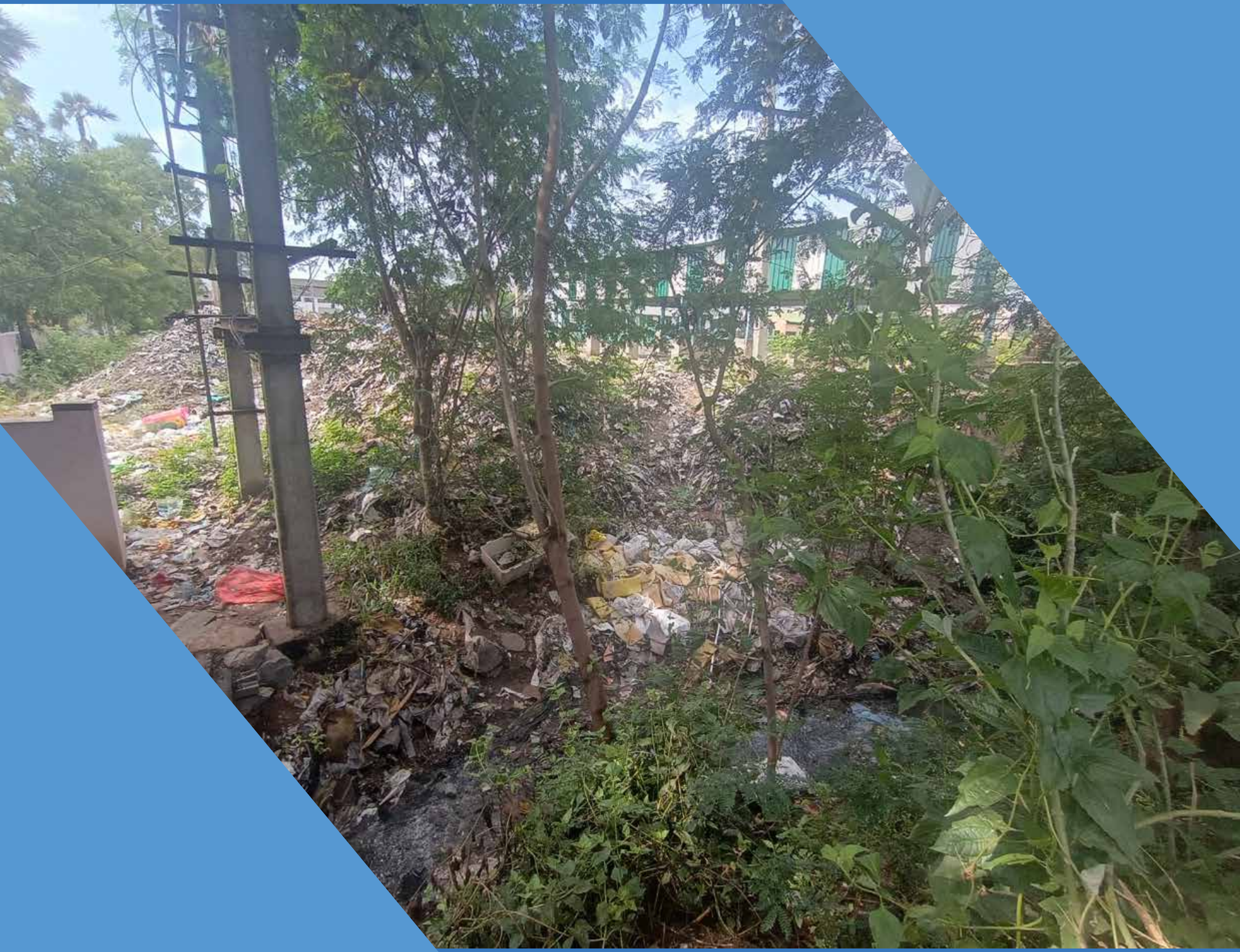
POPs are toxic synthetic substances that degrade poorly in the environment and may bioaccumulate in organisms. POPs are mainly associated with industrial processes and applications, such as pesticides, flame retardants, and polychlorinated biphenyls (PCBs) (Wang et al., 2020). Plastics can act as vectors for POPs through several mechanisms. Plastics have a high surface area, and their hydrophobic nature makes them prone to adsorbing hydrophobic POPs. These chemicals can attach themselves to plastic surfaces, leading to the concentration of POPs on plastic particles (Wang et al., 2020).

Over time, POPs may leach from plastic products, releasing them into the surrounding environment. This process is exacerbated when plastics are exposed to sunlight, heat, or mechanical stress. These leached POPs can contaminate soil and water (Li et al., 2024). Plastic debris in the environment can be ingested by organisms, depending on their size and feeding behaviours (Li et al., 2024). Following ingestion, POPs may leach from the plastics and be transferred to the organism. The specific conditions under which this may occur is likely to vary based on the polymer type, particle characteristics (size, shape, extent of degradation), the chemicals adsorbed or contained in the plastics, and the conditions inside the organism.

The interlinkages between plastics and POPs may have significant consequences for the environment and human health. The persistence of both plastics and POPs in the environment could exacerbate the contamination of ecosystems. Plastics may act as a vector for POPs, which could then be transferred to organisms and bioaccumulate, and may also be passed through the food web. This could represent a potential exposure pathway of POPs to humans, although the relative extent compared to other pathways should be considered and assessed. Accumulation of POPs to high levels in the human body is associated with a range of adverse health effects, including developmental and neurological issues, hormonal disruption, and carcinogenicity (Li et al., 2006).

7.4 Addressing the nexus between plastic pollution, POPs, and health

The interlinkages between plastics and POPs underscore the urgent need for a comprehensive approach to address environmental pollution and its consequences for human health. Recognising plastics as potential carriers and sources of POPs highlights the complexity of the issue and the necessity for global cooperation to find effective solutions, both under the Stockholm Convention and the upcoming United Nations' Plastics Treaty. Reducing plastic pollution and limiting POP contamination necessitates a combination of regulatory measures, improved waste management, and sustainable alternatives to plastics. By addressing these interlinkages, we can take significant steps towards a healthier, more sustainable future for both the environment and human well-being.



CHAPTER 8
ENABLING A JUST TRANSITION FOR PEOPLE AND COMMUNITIES INEQUITABLY IMPACTED BY PLASTIC POLLUTION

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The transboundary impacts of plastic pollution adversely affect and pose threats to environments, human health, and sustainable development across the plastic life cycle (Lau et al. 2020; Lavers et al., 2022; UNEP, 2021a). At the same time, it causes injustices and hampers the world's ability to achieve the 2030 UN Sustainable Development Goals (Bennett et al., 2023).

The ecological and socio-economic impacts of plastic pollution are inequitably distributed, particularly impacting people and groups in low-income and vulnerable situations (Orellana, 2021; Owens and Conlon, 2021; Karasik et al., 2023), including women, children, migrants, informal workers, indigenous peoples, and people with disabilities (UNEP, 2021b). Environmental injustices across the plastic lifecycle may occur when communities are displaced by deforestation for oil extraction, or by being situated in near proximity of petrochemical plants contaminating air and waterbodies (Terrell and St Julien, 2022). Mismanaged plastic waste and pollution is also seen to affect coastal communities dependent on marine resources (English et al., 2019; Fuller et al., 2022; Bennett et al., 2023), as well as waste pickers and other waste workers and communities living in or in near proximity of waste dumps (Human Rights Watch, 2022).

The systemic changes required to address the causes of plastic pollution are also likely to impact certain communities, industries, and livelihoods more than others (Nagarajan, 2022; Nøklebye, 2023). Addressing environmental and socio-economic injustices whilst protecting the rights and wellbeing of workers and communities who continue to be disproportionately impacted by plastic pollution and corresponding control measures, is key to ensure a just transition (See textbox below) (Bennett et al., 2023, Wang and Lo, 2021; Stoett, 2022; ILO, 2024).

Just transition in plastic governance

A "just transition" implies the effort to balance gains and losses related to the 'green transition' when societies shift from fossil sources of energy to mitigate detrimental impacts of climate change, and most recently, plastic pollution (Morena et al., 2019; Stevis and Felli, 2020). Having evolved from the labour unions of the 1960s, the concept of "just transitions" is drawing on the universally recognised human right to a clean, healthy, and sustainable environment (UNGA, 2022) and International Labour Organization (ILO) standards. This includes the ILO declaration on social justice for a fair globalisation (ILO, 2022a), fundamental principles of rights and work (ILO, 2022b), the strategy towards the social and solidarity economy

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(Gutberlet et al., 2020; ILO, 2022c), and the four pillars of the Decent Work Agenda (employment creation, social protection, rights at work, and social dialogue) (ILO, 2019). The latter are integral elements of SDG 8: Decent Work and Economic Growth (UNGA, 2015). A just transition in relation to ending plastic pollution through plastic governance implies leaving no-one behind by reducing inequality, ensuring decent work opportunities for affected communities and workers across the plastic value chain, and tackling the inequitably distributed impacts of plastics on marginalised communities and workers (UN-Habitat and NIVA 2022; ILO, 2023).

To ensure a just transition in relation to plastic pollution, it will be critical to avoid that efforts to reduce plastic pollution does not exacerbate social inequalities or violate human rights. Strong regulatory controls that enhance transparency and accountability for the environmental injustices caused by plastic pollution is essential, supported by necessary technical and financial assistance (Dauvergne, 2023).

A global plastics treaty may include the objective of ensuring that the transition towards ending plastic pollution is safe, inclusive, and equitable for all stakeholders involved (UN-Habitat and NIVA, 2022; UNEP, 2023). However, a just transition will require that contextual challenges on the ground level are addressed. This necessitates engagement with a range of stakeholders, including local governments, civil society actors, businesses, and the scientific community, to ensure the rights- and knowledge holders are part of driving the transition towards ending plastic pollution.

8.1 A just transition for workers in plastic waste management

Improving waste and resource management is often considered an essential downstream measure to reduce plastic pollution at its end-of-life stage (Kaza et al., 2018). This is also part of solving the broader systemic changes needed to address the multitude of sources and impacts of plastic pollution (UNEP, 2022).

Waste management in countries characterised by high levels of economic and industrial development (the "Global North") have often relied on technological fixes to manage waste, while shipping waste labelled as recyclables to countries with lower levels of economic and industrial development (the "Global South"). This "waste colonialism" place further strains on fragile waste management infrastructure and contributes to cause environmental injustices in the Global South (Liboiron, 2021; Fuller et al., 2022).

In the Global South, around 2.7 billion people lack access to waste collection, whilst around 40 percent of collected municipal solid waste is estimated to be inadequately managed, including open dumping and burning (Wilson, 2023). This causes significant environmental and health risks to workers and nearby communities (Powrie et al., 2021; Pathak, 2023). Workers operating without adequate health and safety standards across the plastics value chain are adversely affected, particularly informal and otherwise marginalised waste workers and communities. They often work and live under hazardous and exploitative conditions without recognition and access to social protection, oftentimes in near proximity of waste dumps and open burning sites (UNEP, 2021; Human Rights Watch, 2022) (See textbox below).

Interlinkages between plastic waste, persistent organic pollution, and workers' health

Mismanaged waste and pollution often have a profound impact on workers, especially due to the presence of harmful chemicals in plastics. Endocrine Disrupting Chemicals (EDCs), such as phthalates, bisphenol A (BPA), lead, perfluorinated substances (PFAS), and polybrominated diphenyl ethers (PBDEs) have been linked to serious health issues like cancer, birth defects, and disruptions to the immune, endocrine, and reproductive systems (Flaws et al., 2020).

Workers in various industries encounter plastics throughout their daily activities, spanning the entire life cycle of plastics, from production to disposal. Some workers are disproportionally at risk, due to the duration of exposure and level of concentration of contaminants associated with plastics and plastic waste, as well as limited occupational safety and health regulations, low remuneration, and minimal social protection measures offered in many work environments. Sudden changes in the global political economy, such as those caused by the COVID-19 pandemic, can alter the flow of plastics into the environment and cause disruptions to waste management, economies, and livelihoods. Studies have shown that COVID-19 significantly impacted recovery activities and reduced the availability of high-quality waste for informal waste pickers and recyclers, adding to existing livelihood insecurities (INOPOL, 2020). Gendered differences in the workplace may disproportionately expose women to hazardous chemicals. EDCs pose a particular health risk among women at all levels of the plastic industry, from processing plastics, manufacturing plastic products, working with rubber or synthetic textile fibers, and engaging in waste collection, cleaning, and sorting (DeMatteo et al., 2013; Arora, 2023).

8.1.1 Waste pickers contributing to global plastic pollution reduction without recognition

Waste pickers[12] are central to achieving social and environmental sustainability outcomes within a circular plastics economy (Gutberlet and Carenzo, 2020; Barford and Ahmad, 2021; Velis, 2022; Schroeder and Barrie, 2022) and the broader objective of reducing the pollution burden on people and communities in vulnerable and marginalised situations (Schroeder, 2020). Waste pickers' work contributes to cleaner communities, improved public health, effective circular waste management systems (Velis, 2017; Van Niekerk and Weghmann, 2018; Barford and Ahmad, 2021), higher municipal savings (Kaza et al., 20218; Harrisberg, 2019) and reduced climate emissions (WIEGO, 2021). Yet, waste pickers bear the socio-economic burden of mismanaged plastic waste. Waste pickers frequently endure hazardous and exploitative working conditions, in the absence of labour standards and without access to health care and social protection (WIEGO, 2018; Ferronato and Torretta, 2019; Harriss-White, 2020).

Women and children in informal waste work are particularly at risk to the inequitably distributed impacts of plastic pollution, as women are often overrepresented in more labour intensive and low-income work. Women exposed to chemicals in plastics may suffer from other health impacts than men due to physiological and biological factors, social roles, cultural norms and types of professions. Evidence indicates adverse impacts on foetus and/or children if women come in contact with toxic substances while pregnant and/or breast-feeding (Arora, 2023). Estrogenic EDCs associated with plastics, such as Bisphenol A, have also been linked to ovarian disfunction, fibroids in the uterus, and reduced fertility of women (Gore et al, 2014). Women also tend to deal with competing demands from domestic and childcare responsibilities resulting in children often participating in waste collection activities with their mothers. Children involved in informal waste work may be deprived of their childhood and education, hampering their physical and mental development and their social mobility.

In addition to the above-mentioned concerns, waste pickers continue to receive limited recognition in policies and strategies aimed at reducing plastic pollution (Talbott, 2022). This historical and ongoing marginalisation and exclusion contributes to exacerbate preexisting socio-economic vulnerabilities and hampers opportunities to utilise existing waste collection and recovery infrastructure to enhance plastic waste management. Enabling a just transition is therefore particularly urgent for the estimated 20 million waste pickers around the world (GRID-Arendal, 2022), who contribute to the recovery of around 58 percent of post-consumer plastic waste (Lau et al., 2020).

12 Waste pickers, in accordance with the International Alliance of Waste Pickers' definition, includes individuals involved in the collection, segregation, sorting, transporting, and sale of recyclables in an informal or semi-formal capacity as own account workers, within the informal or semi-formal sorting/recovery/recycling sector, and any of the above who have been integrated in municipal waste management or occupy new roles in recycling organisations.

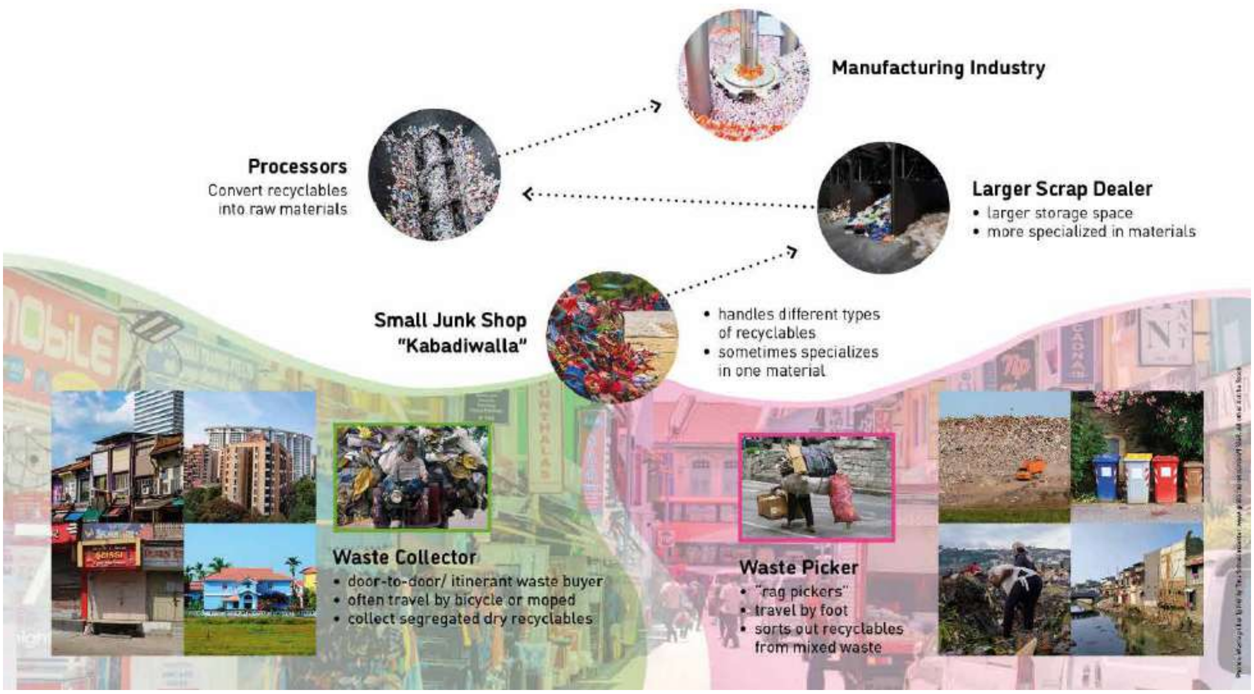

Figure 8.1 Simplified overview of actors in the informal waste and recovery sector

Source: Developed based on Gill 2010, Hande 2019, and authors' fieldwork

8.1.2 Waste pickers recovering plastic waste in India

Waste pickers in India are often characterised as entrepreneurial individuals, highly skilled within their occupations and often managing micro-businesses (Gill, 2010; Harriss-White, 2020). Contemporary research indicates that most waste pickers in India belong to the informal work force, and conservative - yet uncertain - estimates suggest that 2-4 million waste pickers collect up to 60% of recovered post-consumer plastic waste (Chikarmane, 2014; Raveendran, G. and Vanek, J., 2020). Recovery rates for polyethylene terephthalate (PET) plastics are considered even higher, with up to 70% being collected and recovered through informal means (Shanker et al., 2022).

Waste pickers are linked to a network of actors in the formal and informal waste and recovery sector, involved in the collection, segregation, cleaning, processing, and trading of plastics and other recoverable materials of value (See Figure 8.1) (Hande, 2019). The informal sector does not operate in isolation from the formal sector, as the processes involving trade of materials, roles, and relationships often transgress economic, political, and spatial domains (Gill, 2010; Harriss White, 2020). Considering this, ensuring a just transition for all workers across the informal waste and recovery sector is key, with specific recognition and mitigation measures identified and implemented for those most vulnerable to inequitably distributed impacts of plastic pollution, as well as proposed control measures.

8.1.3 Snapshot of waste pickers in Tamil Nadu

The following section provides a snapshot of some of the challenges faced by waste pickers in Tamil Nadu, drawing on empirical research conducted in Vellore city (Sivasankar, 2019), Puliangudi municipality (Selvanayaki and Kailasasundaram, 2019) and Rajapalyam municipality (Ashifa and Devi, 2017)[13].

13 As for any empirical case study, it does not represent the situation of all waste pickers in Tamil Nadu. The situation may have changed for waste pickers since the time of data collection, considering the potential implications of external factors such as COVID-19, climate change, and a rapidly evolving policy environment.

The studies show that most waste pickers in Tamil Nadu are situated at the lower end in the hierarchy of urban informal workers and low-income groups. Few waste pickers interviewed had formal education, and many remain in their occupation for decades. A significant amount of waste pickers started working with waste as teenagers and some were recruited by parents working in the same sector. The work was reported to be physically demanding, and few waste pickers would recommend this line of work to others.

Working hours and incomes vary amongst waste pickers and across genders, with many waste pickers indicating an average working week of 10-12 hours per day, five days a week. Men often earn more than women due to being able to sell collected materials at a higher price. Common materials collected by waste pickers include bottles, glass, plastics, and iron. The amount, quality, and price of collected materials varies across contexts and determine waste pickers' income. Estimates concerning the amount of collected waste ranging from 8 to 43 kg per day. Certain categories of plastic waste appear to be most lucrative, followed by paper. Studies from Tamil Nadu indicate that waste pickers earn between 50-100 rupees per day (Selvanayaki and Kailasasundaram, 2019). Other estimates suggest that waste pickers' average income is between 300-400 rupees per day (Sivasankar, 2019).

The studies reveal a lack of adequate protective safety equipment such as masks, gloves, and proper shoes. They also indicate that most waste pickers in Tamil Nadu, many of them women and children, suffer from health problems. Whilst incidents of fever are being reported as most common, respiratory illnesses and back pain were also mentioned. Between half to three quarters of waste pickers surveyed in one of the studies in Vellore city report to visit medical facilities regularly. Lack of financial resources and limited trust in governmental health institutions were highlighted by others as barriers for not seeking medical support.

The studies highlight similar challenges observed elsewhere, highlighting the need for promoting laws and policies that improve livelihood security and working conditions for waste pickers, integrating waste pickers into municipal solid waste management, and providing accessible training and health services. This may contribute to increasingly participatory policies and practices where workers are part of the shift towards safe and just zero waste systems and not made redundant as a consequence of implementing new technological waste management solutions.

8.2 Ongoing policy developments and justice considerations

Despite the substantial societal and environmental contribution of waste pickers, existing regulatory frameworks aimed at reducing plastic waste in India largely fail to recognise waste pickers in the development and implementation of strategies to reduce plastic pollution (Nagarajan, 2022). Informal waste pickers have received limited recognition under the Solid Waste Management Rules (2016), the Plastic Waste Management Rules (2016), and their subsequent amendments, as well as under the new Extended Producer Responsibility guidelines[14]. Limited recognition of waste pickers and other informal waste workers in the development and implementation of such policies might lead to unintentional adverse social outcomes and ineffective implementation (Nøklebye et al., 2023).

As new EPR guidelines were rolled out across India in 2022, it is becoming increasingly important to understand how such a system affects livelihoods across sectors and geographies. EPR initiatives in India are currently voluntary and generally run by individual corporations, oftentimes supported under Corporate Social Responsibility schemes[15]. The EPR

14 Extended Producer Responsibility (EPR) is a policy approach holding producers responsible for the financial and operational burden of treating and disposing post-consumer plastic waste.

15 Corporate Social Responsibility (CSR) is a business model by which companies make a concerted effort to operate in ways that enhance rather than degrade society and the environment. In India, companies are required to spend a minimum of 2 percent of their net profit over the preceding three years as CSR.

guidelines state that producers, importers, and brand owners (PIBOs) should set up their own collection systems and, in places where waste pickers or urban local bodies collect, they must hand over the collection to the PIBOs. As a result, PIBOs and new actors entering the plastic recovery market are now competing with waste pickers for recoverable materials (Talbott et al., 2022). The waste pickers are thus at risk to lose their source of income. Consequently, it is argued that EPR is developed and implemented in collaboration with all relevant stakeholders, including the informal sector (Talbott et al., 2022).

As EPR occurs with simultaneous policy changes to plastic governance in India, such as bans on single use plastic (SUP) products, concerns related to the unequal financial and operational capacity of informal workers and Micro, Small & Medium Enterprises (MSMEs) to comply with strengthened plastic waste regulations. Larger corporations with high level of public visibility and financial stability are more likely to proactively engage in voluntary and forthcoming plastic control measures, giving them a competitive advantage compared to informal workers and MSMEs, who may find it more challenging to adapt to legislative changes (Pathak and Nicther, 2021).

Justice concerns persist as long as waste pickers and other informal waste workers are not included in the development and implementation of policies that affect them (Talbott et al., 2022). EPR has the potential to boost material recoverability while simultaneously enhancing the working conditions and income stability of informal waste workers, if implemented through participatory policy processes including elements of how to ensure a just transition for affected workers (UN-Habitat and NIVA, 2022). This may include protection of human and labour rights, access to social services and healthcare programs, fair remuneration, inclusive EPR systems, and the provision of financial and technical support to establish or strengthen safe and sustainable reuse, repair, and recycling facilities (O'Hare and Nøklebye, 2023).

8.3 Partnerships between municipal, private, and informal workers

The emerging initiatives to integrate informal workers are commonly pursued through different levels of partnerships between municipal, private, and informal actors. Initiatives integrating informal waste pickers into municipal waste management systems are often considered mutually beneficial, contributing to income stability for the integrated workers whilst increasing source segregation at reduced costs for the municipality. The following sections include some examples to illustrate approaches to integrate informal waste pickers into public and privately run waste management systems. These examples are based on secondary information, are not exhaustive, and do not necessarily reflect best practices. Assessing the sustainability of these initiatives requires engagement with integrated workers and other involved actors over time, to better understand the long-term implications and learn from commonly pursued integration approaches.

- In Warangal, the municipality has integrated waste pickers as private waste collection drivers, by providing loans that enable integrated workers to purchase waste collection vehicles directly from the municipality (Henam and Bandela, 2020). It is worth noting, however, that the beneficiaries of this model appear to be primarily men, and may as such, further subjugate women to informal and low-income labour opportunities.
- In Bhopal, approximately 2,000 waste pickers received identity cards and were granted the right to collect waste from specific areas by the municipality (Ibid.). The model highlights the need for a close collaboration with the municipal authorities to develop, implement, and monitor the system.
- In Bangalore, the local government (Bruhat Bengaluru Mahanagara Palike) has worked towards integrating waste pickers in municipal

solid waste management by establishing ward-level Dry Waste Collection Centres (DWCCs). A MoU were directly signed with waste pickers to operate the centers, with NGOs like Hasiru Dala serving as a supporting resource organisation.

Informal waste pickers, collectors, traders, and recyclers may organise themselves in cooperatives or associations, with the aim to advocate for their rights, recognition, inclusion, and integration in formal MSWM systems, including improved working conditions, gender equity and higher income. Waste picker organisations in India have both national and local reach. The Alliance of Indian Waste Pickers was created to coordinate efforts to include waste pickers in various national-level programmes. Other examples for local and state-level organisations are the SWaCH waste picker cooperative in Pune and Hasiru Dala in Bangalore:

- **The Alliance of Indian Waste Pickers** is a decade-old national coalition of organisations working with waste-pickers and other informal waste collectors to have coordinated efforts to ensure the inclusion of waste pickers in various national-level programmes.
- **SWaCH** in Pune is India's first wholly owned waste picker cooperative, with a current membership of 3,800 waste pickers. Since 2008, SWaCH has a Memorandum of Understanding (MoU) with the Pune Municipal Corporation to provide door to door collection of waste in the city, on user fee recovery basis. The SWaCH cooperative in Pune provides an example of how EPR systems can reduce plastic pollution and improve working conditions for informal sector workers when implemented with active stakeholder participation and in close collaboration with waste picker organizations. The SWaCH approach to managing multilayered plastics (MLP) builds upon the existing informal waste collection systems within the city, where waste pickers are financially compensated for the multi-layered plastics (MLP) they collect through financial support from brand owners working in direct cooperation with SWaCH. This model is commonly considered successful as it is developed through an inclusive and participatory approach, has elevated the earnings of informal waste collectors, and enhanced the recovery rates for multilayered plastics in the city.
- **Hasiru Dala** is a social impact organisation in Bangalore, dedicated to empowering and ensuring a just transition for waste pickers and other waste workers. Hasiru Dala has been instrumental in ensuring waste picker inclusion in the establishment of Dry Waste Collection Centres and in Bengaluru's SWM by-laws.

Waste picker organisations (including associations and cooperatives) can play a key role in the development and implementation of just and sustainable systems and practices to reduce plastic pollution. Collaborative and participatory systems that involves local governments, households and consumers, organised and unorganised waste pickers, and private actors.

Private companies are increasingly taking up space in the waste management landscape, being granted contracts for collecting and processing waste in specific areas. While privatisation may lift the burden of cost from local governments, there are concerns that private actors are taking over collection and handling operations which provide the main source of livelihood for many waste pickers and other informal waste workers. Privatisation of waste management thus comes with concerns related to justice and unequal power-dynamics but may also offer opportunities to integrate informal workers into increasingly formal arrangements for collection and recovery. While not extensive nor providing examples of best practices, the below examples outline some ways in which waste pickers have been included in private sector driven waste management initiatives:

- **Facilitating waste pickers' access to applicable government insurance schemes**:

Project Adhikaar is an initiative by the Dalmia Foundation under the waste management company

Dalmia Polypro aiming to support waste workers within their supply chain. The project's core objective is to bridge the gap between marginalised individuals engaged in waste management and various government welfare programs. According to Project Adhikaar's final report, the initiative has reached out to 675 citizens, raising awareness about social security schemes and providing vital support in the process of registering for and accessing the benefits offered by these programs, centering on areas including COVID-19 vaccinations, the establishment of bank accounts through the Pradhan Mantri Jan-Dhan Yojana, participation in life and accident insurance programs, and facilitating registrations under the e-Shram initiative (Dalmia Foundation, 2022).

- **Using technology and informal sector partnerships to streamline waste management**:

Lucro Plastecycle uses tracking software developed in collaboration with ICICI Bank to record all materials received at their collection centers to capture data material type, source, and quantity. They have also made it easy to track each bale of material with a QR code. In collaboration with ICICI bank, this transparent system makes it simple for waste workers to open bank accounts and receive payments digitally for collected waste.

- **Building homes from low-value recycled plastics for informal waste workers and their families:** Plastics for Change India and Kimberly-Clark launched the 'Project Ghar' in 2021 with the aim of offering sustainable housing to waste workers in India (CRS Times, 2021). The project diverted 22,500 kilograms of multilayered plastics and low-density polyethylene (LDPE) from the environment. Apart from enhancing sanitation and creating secure living conditions, the project engaged 30 informal waste workers daily in the collection of plastic waste.

Research into the short- mid- and long-term social, economic, and environmental impacts of these initiatives may contribute to identify barriers and enabling mechanisms for fostering and scaling up increasingly just and sustainable private-informal partnerships.

8.4 Fostering inclusive and participatory integration practices

Evidence from India indicates that local-level initiatives to integrate informal workers in municipal waste handling systems have mainly focused on formalising waste pickers rather than strengthening existing network structures of the sector (see for example, Chikarmane, 2014; and Henam and Bandela, 2020). Formalisation of the waste economy has the potential to improve the conditions and income of waste pickers (Pereira, 2010; Serrona et al., 2014). At the same time, formalisation may contribute to reduced income and heightened precarity for formalised waste workers (O'Hare, 2020), especially when waste pickers are not actively involved in the development and execution of policies that impact them (Samson, 2020; Parra and Vanek, 2023).

Formalisation is often used interchangeably with the integration of informal waste workers. Whilst formalisation refers to changes in the legal policy landscape that recognise and integrate informal waste workers in law or practice (ILO, 2019), emphasising labour and social protection as a means of attaining a just transition within the informal sector[16], integration refers to the different means of integrating informal waste workers as active stakeholders in municipal waste management systems. Integration approaches vary across different socio-political, temporal, and geographic contexts, and it carries distinct socio-economic implications for stakeholders within the informal sector. These processes can be inclusive and participatory, but also influenced by unequal and external power dynamics, which may prioritise environmental and economic considerations over

16 See for example, the ILO Centenary Declaration for the Future of Work and SDG 8, underlining that formalisation can stimulate economic growth and foster decent employment.

safeguarding the livelihoods and interests of the stakeholders (Nøklebye et al. 2023).

Irrespective of approach taken to integrate waste pickers and other informal waste workers into municipal and/or privately run waste management systems, it is imperative to include the interests and voices of informal workers in the development, implementation, and monitoring of such integration initiatives. In practice, a just transition for waste pickers and other informal waste workers should include participation in decision-making processes, the protection of human and labour rights, access to social services and healthcare programs, fair remuneration, and provision of financial and technical support to establish or strengthen sorting, reuse, repair, and recycling facilitates. It should build on experiences made by local and international waste picker organisations, where both affiliated and unaffiliated waste pickers obtain better working conditions, such as SWaCH (India), Ground Score Association (USA), Amelior (France), FACCyR (Argentina), and the MNCR Brazil (COOPESOL Leste and ACARI).

Guidelines for developing and implementing inclusive, equitable, and fair partnerships with the informal sector can contribute to enable a just transition (UN Habitat and NIVA 2022). Such guidelines should be co-developed with key stakeholders and based on universally recognised principles of the human right to a clean, healthy, and sustainable environment and relevant ILO Conventions and standards. This includes the ILO declaration on social justice for fair globalization, fundamental principles of rights and work, the social and solidarity economy, and the four pillars of the Decent Work Agenda (employment creation, social protection, rights at work, and social dialogue). Baselines, clear targets, and monitoring mechanisms may contribute to track and monitor progress towards a just transition for Informal Waste and Recovery Sector (IWRS) workers while working towards ending plastic pollution.

A key step towards enabling inclusive and participatory integration practices is recognition of waste pickers in relevant policies, from the global Plastics Treaty to the Indian PWM Rules and related EPR Rules. Beyond official recognition, there is a need for research into the immediate and long-term implications of commonly pursued integration initiatives. Evaluating local-level experiences across stakeholders and contexts may contribute to a better understanding of barriers and enabling factors for fostering increasingly just and sustainable waste management practices.

CHAPTER 9
INITIATIVES TO REDUCE PLASTIC POLLUTION IN INDIA

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Unsustainable plastics consumption and mismanaged plastic waste represents significant threats to sustainability due to its persistence in the environment, and has harmful effects on human health and ecosystems. To ensure short term solutions do not hinder long-term progress towards ending plastic pollution, there is a need to align circular economy and waste hierarchy goals, including waste prevention, production reduction, design for longevity, and reuse systems (Syberg et al. 2024). Building on the commonly promoted 3Rs principle (Reduce, Reuse, and Recycle), the waste hierarchy provides an extended framework for prioritising waste management strategies and solutions. Within this context, this chapter introduces the waste hierarchy and structures initiatives to reduce plastic pollution in Tamil Nadu and other states in India accordingly.

9.1 Waste hierarchy

The waste hierarchy constitutes a framework that outlines a series of priorities to guide efficient resource use and diverse waste management strategies, ranking actions based on their (environmental) sustainability from the most to the least favourable. It positions the most environmentally beneficial waste management options at the top, aligning with their positive environmental impact. Preventing the generation of waste, for example by improving product design and consumption, is the most preferred option, with landfill and incineration as the least desired option. The waste hierarchy framework promotes a transition from a linear to a circular waste management approach and exists in different versions. Many of these prioritises reduction, reusing, and repurposing in favour of recycling, downcycling, and recovery, before treatment and disposal are considered (See for example, Figure 9.1). Several also include the need for redesign the top of the pyramid as a means of reducing waste (Zero Waste International Alliance 2024).

Actions of the waste hierarchy explained:

- **Reduction**: It includes all actions taken to reduce the amount of plastic waste generated from households, as well as commercial, industrial, and all other establishments. Preventing or reducing the waste generated at the source is the most favourable environmental strategy. It can contribute to minimise the emission of greenhouse gases, control pollution and toxicity of waste as well as to conserve more energy.
- **Reuse/repurposing:** It involves reusing the materials several times for which they are designed. By reusing materials without further processing, energy costs can be reduced and virgin materials can be conserved.

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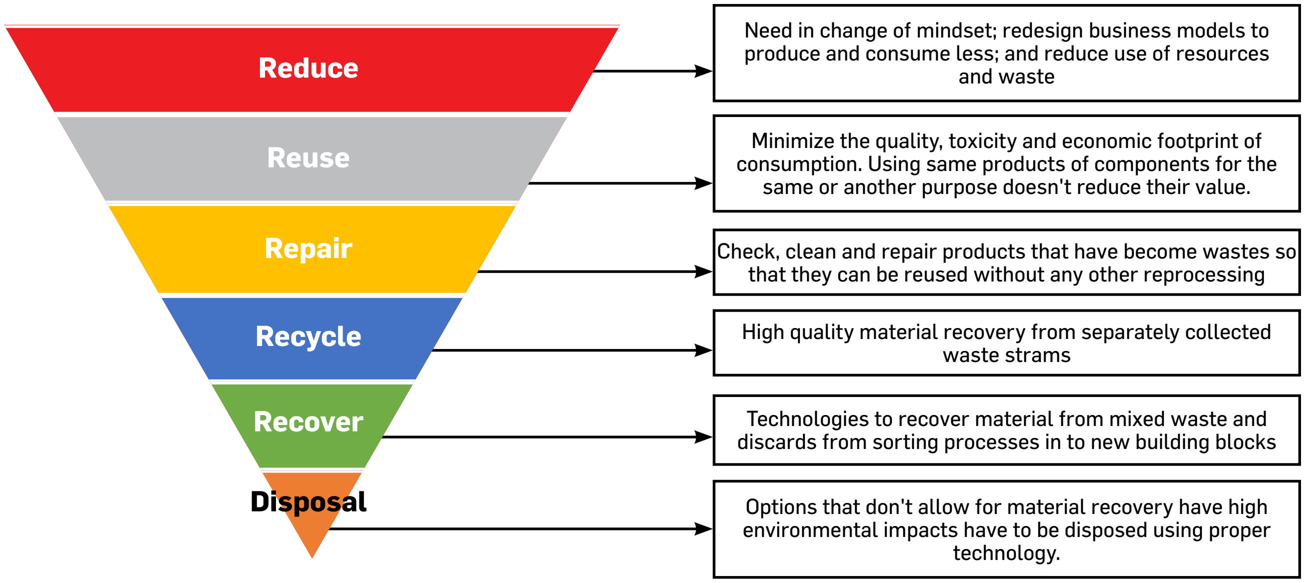

Figure 9.1: Illustration of Waste Hierarchy (Source: Kibria et al. 2023)

- **Recycling and downcycling**: Typically, plastic products are recycled, upcycled, or downcycled into reusable goods. It involves the processing of waste materials to make the same or different products and contributes to decreasing the need for new or virgin materials. Recycling includes the collection of used, unused, or reused items, sorting, and processing of recyclable products into raw materials, and remanufacturing of recycled materials into new products. It also facilitates the efficient use of recovered resources. Recycling can offer multiple benefits such as a reduction in the demand for virgin polymer, reduction of carbon dioxide emissions, and environmental pollution, and can provide several economic benefits. However, recycling processes may also have negative impacts on the environment and human health. While upcycling involves the conversion of materials into products of greater value without breaking it down, downcycling is a process in which used products are repurposed into new items of slightly lesser quality, such as fleece or polyester in clothing and carpeting.
- **Energy or other forms of recovery**: Energy recovery can be employed where further recycling of waste materials is non-feasible. It involves the conversion of non-recyclable waste materials using heat, electricity, or fuel through a variety of processes, such as combustion, gasification, pyrolisation, anaerobic digestion, and landfill gas recovery. Conversion of non-recyclable waste materials into electricity and heat can potentially reduce carbon emissions by offsetting the need for energy derived from fossil fuels. However, it needs to be proven safe for human health and the environment.
- **Treatment or Disposal:** This method is typically employed for waste materials that are hazardous and inappropriate for reuse, recycling, or energy recovery. Treatment of such waste materials before disposal can contribute to reducing their volume and toxicity, whilst stabilising and minimising their impacts on environments and human health. Treatment can be physical (shredding), chemical (incineration), and biological (anaerobic digestion). However, risks also exist in terms of potential leakages of pollution that may be hazardous for human health and surrounding ecosystems in the treatment process. The same goes for disposal in landfills which according to the waste hierarchy should be the last resort for waste that cannot be reused, repurposed, recycled, downcycled, recovered or treated via other means.

9.2 Ongoing initiatives to reduce plastic waste

This sub-chapter provides examples from India focusing on plastic waste reduction. Reducing plastic waste is among the most favourable strategies, following the framework of the waste hierarchy. The initiatives below have been initiated by local governments, non-governmental organisations, and private sector actors, from the local to the national levels.

People's Campaign for Throwaway Plastics in Tamil Nadu

The Government of Tamil Nadu launched the 'Meendum Manjappai' campaign to prevent single-use plastic (SUP) pollution and revive the use of traditional cloth bags as viable alternatives. The campaign showcased eco-friendly alternatives at the exhibition stalls along with the machinery used to produce these alternatives. A short film to raise awareness on the negative effects of SUPs was presented, promoting the use of traditional cloth bags, Manjappai (Yellow bag). Figure 9.2 shows the Manjappai awareness campaign that was conducted on the 76th Independence Day ceremony across Tamil Nadu.

Subsequently, an awareness campaign was carried out in all the districts through vehicle campaigns, distributing pamphlets to the public and displaying posters in public gathering areas, such as hospitals, hotels, industrial estates, malls, bus stands, railway

Figure 9.2 Manjappai Awareness Campaign (TNPCB, N.d.)

Figure 9.3 Automated Vending Machine dispensing yellow cloth bag (TNPCB, N.d.)

stations, and theatres. An automated vending machine that dispenses a yellow cloth bag for a 10-rupee coin or note was also installed (Figure 9.3).

"Operation Blue Mountain" in Nilgiris: In 2001, the Operation Blue campaign in Nilgiris has been highlighted as a successful example of generating awareness to support regulatory efforts for reduction of plastic pollution in the district, using imagery of detrimental impacts of plastics on animals and linking how unmanaged plastics clog drains and leak into water bodies (MoHUA 2019, p. 11)

"Meendum Manjappai" awareness campaign against single-use plastic bags: The Meendum Manjappai was launched by the Government of Tamil Nadu in December 2021 to increase public awareness about the harmful effects of single-use plastics and encourage changing to alternatives, in this instance, traditional cloth bags (Manjappai).

Engaging manufacturers to raise awareness and showcase alternatives to single-use plastics: A conference showcasing sustainable alternatives to SUPs was organised by MoEF&CC in Chennai from 26th-27th September 2022 to create awareness on the adverse impacts of SUPs and support the regulatory bans (TNPCB, 2022). The Conference titled 'National Expo on Eco-Alternatives to SUPs provided an opportunity for the manufacturers to showcase their products and increase public awareness about the range of SUP alternatives available on the market.

Protecting nature from plastic waste in Nilgiris, Tamil Nadu

Nilgiris is a biodiversity hotspot in the Western Ghats and one of the oldest mountain ranges located at the tri-junction of the states of Tamil Nadu, Kerala, and Karnataka. The District Administration has taken various steps to retain and protect the unique natural environment through regular cleanup drives in all parts of the district and awareness campaigns to curb the usage of plastics (The Nilgiris District. N.d.). In 2018, the district administration implemented a ban on plastic bags, plastic cups, plastic plates, paper plates with plastic or foil lining, plastic spoons, forks, and straws. The ban also included styrofoam/ thermocol plates and cups, polypropylene (PP) (non-woven) carry bags and packing bags, chefs hats, plastic caps and bed sheets, plastic gloves, water packets, silver foil covers, plastic buntings, plastic and foil gift wrap, laminated brown paper, laminated bakery boxes and cling wrap, besides paper cup and tumbler. This initiative aimed to minimise the overall generation of plastic waste. To facilitate the implementation of the ban by fostering public acceptance, several activities were carried out in cooperation with citizens. This included regular checks by the Green Brigade, a group of volunteers who monitored littering of plastic waste on the streets. The government further imposed a penalty in case of any violations of the plastics ban. They also launched a scheme wherein women self-help groups (SHGs) and elderly people were trained to sew affordable jute shopping bags. Shopkeepers in the district earned goodwill by giving these bags out for free. During the early lockdown days of the COVID-19 pandemic, free food grains were distributed in cloth instead of plastic bags. In 2019, a complete ban on plastic bottles was imposed on the sale of water and soft drinks. About 70 water ATMs and four plastic crushing machines were installed across the district (**Figure 9.4**). SHG kiosks were installed in the Kallar and Kunjapanai check posts to sell alternatives to SUPs, such as steel containers, copper bottles, and other permissible containers to the tourists and wider public at the entry points of the district.

Figure 9.4: Water ATM (The Hindu, 2019)

Awareness campaign on single-use plastic ban and alternatives in Tamil Nadu

The Namma Ooru Super (My village is best) Campaign was organised from May 25-June 3, 2023 to promote awareness on the ban of SUPs and the use of alternatives to protect the environment in Tamil Nadu. About 227,184 people from all panchayats across the state participated in the rallies and awareness activities at colleges, shops, and other commercial establishments. The promotion of cloth bags through the Meendum Manjappai was also conducted during the week. About 2,442 meetings were organised at the village level to raise awareness about the banned SUP products and encourage residents to switch to plastics alternatives (Swachh Bharat Mission, 2023).

Sikkim introduce bans on single-use plastic products as the first Indian state

Sikkim was the first Indian state to ban plastic bags and target single-use plastic bottles (UNEP, 2018). In 2016, the use of styrofoam and thermocol disposable plates and cutleries was banned in the state. The tourism board of Sikkim announced the ban on SUPs including packaged drinking water in 2022. Fines were imposed on offenders in case of any violation of the plastic ban. With penalties and campaigns in place, most Sikkim locals opt for plates made of leaf, bagasse, and areca nut (**Figure 9.5**). In Sikkim, around 66% of shops use bags made of paper or newspapers, whereas around 34% use plastic bags including non-woven bags (UNEP, 2018). In addition, eco-friendly bamboo bottles serve as a replacement

Figure 9.5: Plates made from leaf, bagasse, and areca nut (Pasricha, 2019)

Figure 9.6: Bamboo bottles to replace plastic bottles in Sikkim (The Quint, 2020)

for plastic bottles. Lachen is the first town in Sikkim to completely ban packaged drinking water bottles and introduce bamboo bottles as an alternative (**Figure 9.6**). To support livelihood opportunities and income, residents were encouraged produce bottles from bamboo and other biodegradable material. Education campaigns in schools created awareness about the environmental harms caused by plastics to young children.

Garbage Café in Chattisgarh

In 2019, India's first 'Garbage Cafe' (**Figure 9.7**) was opened in the Ambikapur district of Chattisgarh (The Times of India, 2019). The garbage café provides food for citizens living below the poverty line in exchange for plastic waste. Cafe guests can order a full meal in exchange for one kilogram of collected plastic waste. In addition, people without

Figure 9.7: Garbage Cafe in Ambikapur (Times of India, 2019)

a fixed residence got free shelter against collected plastic items.

Plastic-free schools in Dehradun

'Plastic *Mukt Abhiyan*' (Plastic Free Mission) is a community-driven campaign for waste collection in schools, organised by the Social Development of Communities (SDC) Foundation in 2022 (SCBP, N.d.). SDC is a not-for-profit organisation based in Nagar Nigam Dehradun. Plastic *Mukt Abhiyan* operates under the tenets of the *Swachh Bharat* Mission to sensitise students to the challenges linked to plastic waste management and to implement a methodology to attain tangible results.

The *Abhiyan* also aims to contribute to a behavioural change amongst the students to discourage the use of SUPs and use safe substitutes like cloth bags, bamboo or paper straws, bagasse-made cutlery, paper cups, and steel/copper water bottles.

The programme was conducted over a two-month period between March and May 2022 and involved around 48,224 students of 6th standard and above from 105 schools in Dehradun, as well as teachers, staff, and their families (SCBP, N.d.). The programme

Figure 9.8: Collection of single-use plastics in schools (SCBP, N.d.)

was primarily focused on collecting SUPs and disseminating information on sustainable waste management practices to citizens. 'Plastic Banks' were set up in each school to collect segregated waste from students. A 'Plastic *Sangrakshak*' was appointed by the schools (mostly school Principals), along with 'Plastic *Yodhas*' (Senior Teacher/Staff) and Plastic *Prahris* (Plastic Class Monitors) to monitor and coordinate the activities of the programme. The programme became a 'jan-aandolan' with participation of 104 Plastic *Sangrakshaks*, 114 Plastic *Yodhas* and 1,429 Plastic *Prahris*, who not only segregated and collected the waste but also conducted additional *Swachhata* activities like street rallies, debates, and clean ups in their campuses. The segregated plastic was recycled through a chain of Nagar Nigam approved recyclers. Under this programme, 2,343 kilograms of SUP were collected and sent for recycling.

Reducing the use of plastic in packaging

Since 2021, the Indian e-commerce company Flipkart eliminated SUPs in its packaging throughout its supply chain, including such as eco-friendly paper shreds, recycled paper bags, carton waste shredded material and 2-ply roll (Figure 9.9). 'E-commerce ready packaging', is an initiative by Flipkart, wherein close to 15% of products were shipped without adding a secondary layer of packaging. The company aims to reduce the need for an outer packaging layer by collaborating with brands across apparel, electronics, and home furnishings to ship their products in the original brand packaging. Flipkart is also working towards packaging that are made from

Figure 9.9: Ecofriendly packaging materials by Flipkart (Flipkart, 2021)

recycled and alternative materials to help prevent deforestation (Flipkart, 2021).

Replacing single-use and virgin plastics in the beverage industry

By 2025, PepsiCo India aims to reduce plastics by using alternatives to make 100% of its packaging recyclable, compostable, or biodegradable, for its packaging to be composed of 24% recycled content, and to reduce the use of virgin plastics across its beverage portfolio by 35% (Pepsico, 2021):

Eliminating single-use plastics in hotels

The Taj Group of Hotels run by Indian Hotels Company Ltd (IHCL) has been reducing the usage of plastics in its day-to-day operations by replacing single-use plastic items with alternatives across their 100 hotels. The plastic wrappers were replaced with so-called oxo-biodegradable wrapping, plastic cutlery was replaced with cutlery made of corn starch or wood, and plastic straws were replaced with paper straws. However, it may be noted that there is a lack of evidence for oxo-biodegradable plastics to provide sufficiently advanced deterioration rates as an experiment with bags in different environments showed that none of them showed any deterioration over course of three years (Napper & Thompson, 2019). Other plastic wastes that were generated at the hotel premises is sent for recycling through authorised scrap traders.

Alternative livelihoods making sustainable alternatives to single-use plastic bags in Kerala

Ashoka Trust of Research in Ecology and Environment (ATREE), a Bengaluru-based environmental protection organisation, noticed that the declining fish population in the Vembanad Lake posed a threat to the local fishing community. To enable a source for sustainable and alternative livelihoods, women from the fishing community of Vembanad were engaged in making cloth bags from waste cloth, as an alternative to plastic bags (Figure 9.10). The cloth bags were sold under the name 'Muhamma cloth bags', which has now become a brand in Kerala and continues to bring business opportunities for women.

Figure 9.10: Women in stitching units making cloth bags (Rajendran, 2017)

'Recycle for Life Cycle' campaign in Tamil Nadu

In November 2019, Caritas India in partnership with Earth Day Network organised a recycling week in Tamil Nadu; 'Recycle for Life Cycle' brought together students from schools and colleges, women, and communities, making it a citizen engagement programme for promoting eco-friendly sustainable actions, reducing plastic waste and community recycling practices (Caritas India 2019). Under this initiative, Marthandam Integrated Development Society hosted an exhibition at St. Ephrem's Higher Secondary School in Kanyakumari district, where the school children exhibited models made of plastics, papers, as well as wastes from fruits and vegetables, tree leaves and wooden items (Figure 9.11). The exhibition gave a platform for the students to think differently about ways to reuse plastic products and other alternatives, thus supporting plastic reduction in the local area. As part of the campaign, Udhagamandalam Social Service Society organised an awareness generation session for the Women SHG members in Sathyamangalam, where the participants were educated of the demerits of using plastics and were encouraged to use cloth bags, aluminium mugs and buckets, wooden furniture instead of plastics and replacing 'Plastic *Kudam*' with silver vessels.

'Plastic Safari' education campaign

Hindustan Unilever Limited partnered with Xynteo to develop a behaviour change curriculum ('Plastic *Safari*'), in schools. The aim of this curriculum is to educate school children and residents of housing societies in Dahisar and Kolhapur districts of Mumbai about waste segregation and disposal. An interactive plastic recycling vehicle was taken to schools and housing societies to educate citizens on plastic waste management. While school children were expected to steer the pilot, it also reached out to teachers, parents, and housekeeping staff (HUL, 2020).

'Waste no more' digital curriculum

'Waste No More' is a digital curriculum for schools on the importance of waste segregation was launched in Kolhapur district in Maharashtra with the support of the Kolhapur Zilla Parishad. This unique curriculum had elements of storytelling, do-it-yourself activities, and real-life interviews that will give children an in-depth view into the world of waste management. During the academic year of 2019, more than 150 government school teachers contributed to the initiative as trainers and 100,000 participated in the initiative.

Figure 9.11: Exhibition by children of St. Ephrem Higher Secondary School as a part of Recycle for Life Cycle initiative (Caritas India, 2019)

9.3 Ongoing initiatives to recycle and recover plastic waste

Utilising plastic waste in road construction in Bengaluru

In collaboration with the Bangalore-based company, KK Plastic Waste Management Ltd., Bruhat Bengaluru Mahanagara Palika (BBMP) has used 12,000 tonnes of collected non-recyclable plastic waste in the construction of 3000 km of roads since 2002. The technology has been patented and certified by the Centre for Transportation Engineering (CTE) and the Central Road Research Institute (CRRI).

Plastic waste used to construct plastic tiles for pavements in Hyderabad

In Hyderabad, the 4,000 sq. ft. pavement was constructed out of 1,500 recycled plastic tiles outside a public park (Figure 9.12). The pavement was installed by Greater Hyderabad Municipal Corporation (GHMC) and Hyderabad-based start-up Bamboo House India. Each tile weighs up to 300 grams and is made of 600 polybags (MoHUA, 2019).

Micro compost centres in Trichy, Tamil Nadu

Trichy municipal corporation has set up 39 micro compost centres (MCCs) within the city for the collection of reusable and recyclable waste from residential and commercial establishments (**Figure 9.13**). Recyclable and reusable wastes such as clothes, plastic discards, toys, footwear, blankets, and old newspapers can be delivered at the nearest MCC, which are then weighed and segregated accordingly. The resource recovery centres also serve as exchange points for used goods, where good

Figure 9.12 Pavement constructed using recycled plastic tiles (MoHUA, 2019)

Figure 9.13: Resource Recovery Centre in Trichy collecting used plastics and other items (The Times of India, 2023)

quality goods can be collected from the centre by poor families.

Bottles For Change Programme

On the World Development Day (June 5, 2018), Bisleri, an Indian multinational beverage company, launched "Bottles For Change", a plastic recycling initiative focussing on the channelling used clean plastics for recycling. The programme is currently active in Delhi-NCR, Noida, Gujarat (Pansar village), Mumbai, Navi Mumbai, Panvel, Thane, and Chennai. The Bottles for Change Programme lays emphasis on educating citizens and bringing awareness about a habitual change in the correct way of plastic disposal and management of used plastics. They aim to create an opportunity for plastic agents and various stakeholders such as housing societies, schools, colleges, corporates, hotels, and restaurants to send their used clean plastics directly for recycling, thereby contributing to the overall reduction of plastic ending at the dump yards (**Figure 9.14**).

Figure 9.14 Bottles for Change Initiative (Bisleri, N.d)

Figure 9.15 Plastic Free Packaging by Amazon (Amazon, n.d.)

Amazon India

Since 2019, Amazon India has been collaborating with waste management companies and recycling facilities to eliminate SUP packaging. The company aims to collect plastics equivalent to all the plastic materials generated by its network at the national level. In December 2019, the company introduced paper cushions to replace plastic packaging materials such as bubble wraps and air pillows. The plastic packaging material in the form of corrugate boxes and paper cushions contains as much as 100% recycled content (**Figure 9.15**) (Amazon, 2020).

Collected and recycled post-consumer plastic waste

Dabur, a consumer goods company in India launched its Plastic Waste Management initiative in 2018, through which, post-consumer plastic waste including multilayer plastics (MLPs) was collected, processed, and recycled. The initiative was implemented in 45 cities in six states – Delhi, Uttar Pradesh, Maharashtra, Tamil Nadu, and Uttarakhand in 2018-2019, and was expanded to include 25 states in 2019-2020. Energy-recoverable waste and MLP are sent for processing at cement kilns or waste-to-energy plants, while recyclable PET is recycled into new products. From 2019 to 2020, Dabur collected, processed, and recycled over 12,110 million tonnes of post-consumer plastic waste. In 2022, the company collected, processed, and recycled around 27,000mt of post-consumer plastic waste from across the country.

"Well-Being Out Of Waste"

Imperial Tobacco Company of India Limited (ITC) has launched the 'Well-being Out of Waste' Programme to raise awareness and encourage waste segregation at the household level. It also aims at training waste pickers by providing a financial incentive to sell low-value plastics (LVP) and multi-layered laminates (MLL) waste at the Dry Waste Collection Centre. The LVP/MLL waste collected is sent to a cement kiln for energy recovery. The programme has been implemented in 786 wards in 10 cities, covering over 3.1 million households and educating 5.2 million school children along with 2,000 corporates.

The company claims to have become plastic-neutral in 2021-2022, collecting and sustainably managing more than 54,000 tonnes of plastic waste. ITC has launched recyclable paperboards and biodegradable paperboards as alternatives to plastic-coated containers, cups, and other materials used for deep-freeze applications. Sign-Up Green is ITC's laminated paperboard offering a sustainable alternative to plastic-based indoor advertising. ITC has also replaced plastic sticks in its earbuds with durable paper. The company has also introduced Cyber XLPac Anti-fungal paperboard packaging for soaps, which lessens the amount of plastic packaging used. As an alternative to SUP packaging, e-commerce players can opt for ITC's 100% recyclable 'Tough Pack' paper.

9.4 Identifying scalable and sustainable solutions

The above mentioned initiatives illustrate the different approaches adopted by various actors to reduce plastic pollution in Tamil Nadu and across India. These examples demonstrate that government-led efforts have prioritised educating the public and businesses on the need to reduce plastic waste, particularly single-use plastic packaging. Such measures can support top-down legislative interventions like bans on SUP products. It is evident that many businesses are also launching voluntary efforts to reduce plastic waste in their supply chain.

Research has shown that larger corporations with high public visibility are more inclined to undertake voluntary plastic control initiatives as part of their corporate social responsibility (CSR) policy, to avoid reputational damage (Pathak, 2021). Downstream in the waste hierarchy, the examples illustrate that efforts to recycle and recovered plastic waste have centred around end-of-life solutions that downcycles plastic waste into road construction and waste-to-energy. Sustainability concerns persists around the long-term viability of these types of solutions. To identify scalable solutions and avoid unintended consequences, it is necessary to assess the short-medium- and long-term environmental, social, and economic implications of commonly promoted solutions to end plastic pollution.


NIVA

CHAPTER 10
TACKLING PLASTIC POLLUTION THROUGH INCREASINGLY HOLISTIC AND JUST POLICIES AND PRACTICES: CHALLENGES AND WAYS FORWARD

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Rapidly escalating plastic pollution is a global concern, adversely impacting the environment, sustainable development, human health, and livelihoods across various socio-economic and geographic contexts. The entire lifecycle of plastics, from fossil and bio-based feedstock extraction to waste management and environmental remediation, contributes to significant pollution causing environmental and socio-economic impacts.

This report provides a comprehensive overview of plastic pollution in Tamil Nadu, including management efforts, socio-economic impacts, and environmental challenges. In this chapter, we delve more into the challenges identified throughout the report. We start by providing some reflections around key challenges and end by sharing key considerations that may contribute to holistically tackling plastic pollution in the future.

While recognising that plastic pollution must be tackled through a comprehensive approach that addresses the full life cycle of plastics, this report primarily focused on the downstream sources and effects of plastic pollution rather than considering leakages higher up in the plastics lifecycle. The focus on plastic pollution as a waste management issue largely reflects the national regulatory efforts and priorities in India.

Moving forward, actions to tackle pollution through strengthening waste management and bans on single-use plastics should be complemented by actions that reduce the quantities of plastics that is produced and consumed, phasing out of unsustainable, hazardous and non-essential plastics while that systems and technologies across the plastic value chain are sustainable, safe, essential and transparent.

Engaging with global policy developments related to the negotiations towards an international legally binding instrument to end plastic pollution should be considered to ensure policy coherence and readiness to effectively reduce plastic pollution from local to global scales.

India's position in the plastics treaty negotiations is largely aligned with countries considering waste management as the most critical tool to address plastic pollution, whilst being cautious towards any binding targets for reducing the production of primary plastic polymers. This is also reflected in national efforts, where the regulatory framework for managing plastic waste has advanced significantly over the last few years, particularly with the recent amendments to the Plastic Waste Management Rules in 2021 and 2022.

India has been one of the leading countries pushing for bans on SUPS, and has rolled out awareness campaigns to implement and enforce these across all states. The nationwide ban on SUPs marks a significant step towards more progressive legislation

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on plastic waste, yet indications are that the implementation and enforcement of the ban remains challenging.

When looking to SUP alternatives, it is essential to consider the potential environmental and socio-economic impact of substitutes, including measures to mitigate concerns raised by industries, businesses, consumers, and waste sectors. These may relate to the costs of adapting production and stock to new materials, the availability of additional recycling technologies and systems, and immediate impacts on marginalised livelihoods whose income may be impacted by fluctuations in the recycling market.

The use of bio-based and biodegradable alternatives to fossil-based plastics must also not compromise the necessity of reducing the production and consumption of all plastics. Instead, alternatives must be safe, sustainable, essential, meet biodegradability standards, and designed for reuse and recycling with clear labeling and available systems and technologies.

As alternative products are becoming increasingly accessible and used, there is a need for separate waste streams to avoid contamination of existing recycling streams and increase resource efficiency. In India, this remains a challenge due to factors including unclear or inadequate labelling system and limitations in source segregation. This can put additional strain on waste management systems, especially in regions with insufficient household waste segregation and weak or non-existent waste collection infrastructure.

Challenges to manage waste and pollution may be linked to the availability of financial resources, especially in countries like India where municipal authorities responsible for solid waste management often have limited budgets to cover the costs associated with the development of adequate waste collection, storage, treatment, and disposal systems. Limited financial and structural capacities to implement and develop systems and technologies of waste collection, segregation, and recovery hampers abilities to implement effective plastic waste management.

Coordination and collaboration across interconnected geographies are also challenged by differences in policies and regulations of states and Union Territories. Strengthening capacities to manage and reduce plastic waste through investments, training and awareness raising activities, monitoring of pollution sources and pathways, and engaging with a range of stakeholders including households, businesses, and local governments, may contribute to increasingly safe and sustainable solutions that promote a just transition to ending plastic pollution.

The following key considerations build on the knowledge and capacity gaps identified in the different chapters of this report. This summary is neither comprehensive nor exclusive of other challenges and may build upon experiences that are context-dependent and do not reflect the lived realities or experiences of others. The considerations mentioned below provide insights into challenges that require further dialogue, research, and cooperation to address the interlinked challenges of plastic pollution across diverse contexts.

1. Policy and regulations
   a. National and state-level regulatory frameworks, such as the Plastic Waste Management Rules and Extended Producer Responsibility Rules, are essential but face implementation challenges.
   b. Ongoing international developments will be significant in aligning national and local priorities with globally agreed goals to ensure a just transition towards ending plastic pollution.
2. Waste management infrastructure
   a. Investment in waste management infrastructure and practices in areas particularly prone to plastic pollution, like Tamil Nadu, is essential to reducing plastic pollution.
3. Data collection and monitoring methods:

   a. Harmonising international monitoring methods for plastic pollution can provide valuable insights for establishing effective monitoring systems in India.
   b. Identifying sources and impacts and developing effective mitigation strategies
   c. Use of agricultural plastics
   d. Understanding the use and impact of agriplastics in Indian agriculture to ensure long-term sustainability and minimise negative environmental effects.
4. Just transition
   a. Ensuring a just transition involves addressing the disproportionate impacts of plastic pollution on low-income and marginalised communities and recognising the role of waste pickers and other informal waste workers in reducing plastic pollution.
   b. A just transition calls for increased participation of affected rights- and knowledge-holders in relevant decision-making processes, safeguarding workers and human rights, and enabling increasingly safe and decent work opportunities when moving towards safe and equitable zero waste systems.
5. Circular economy
   a. Aligning circular economy principles with waste hierarchy goals is crucial for sustainable and scalable solutions to end plastic pollution, emphasising waste prevention, production and consumption reduction, and reuse systems.
6. Stakeholder engagement, awareness, and collaboration
   a. Addressing plastic pollution requires the engagement of diverse stakeholders, including households, consumers, businesses, industries, waste workers, civil society actors, research institutions, and local governments.
   b. All these stakeholders are key to contributing to public awareness and education on the impacts of plastic pollution and the importance of sustainable consumption and waste management practices.
   c. International collaborations and multi-stakeholder dialogue may enable the sharing of best practices across contexts and create locally relevant solutions to the plastic pollution problem.

The findings in this report draw on the best available scientific knowledge on plastic pollution and plastic waste management in Tamil Nadu and India. It incorporates an analysis of state and national plastic waste regulations and research, ongoing regulatory developments and initiatives, scientific sampling and monitoring methodologies, and insights from the first phase of the INOPOL project. Looking ahead, it will be crucial to conduct further research and establish baselines to assess pollution hotspots, sources, environmental impacts, and socio-economic drivers and effects of plastic pollution. This will serve as a foundation for building capacities, identifying challenges, and uncovering opportunities for reducing plastic pollution. The INOPOL project will collaborate with key stakeholders to generate science-based knowledge that can contribute to sustainable and equitable solutions for tackling plastic pollution, with a particular focus on the Cauvery River, which holds tremendous ecological and societal importance.

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Chapter 6

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