2021

INOPOL

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

BASELINE REPORT
PLASTIC POLLUTION IN INDIA

Norwegian Embassy
New Delhi

NIVA
Norwegian Institute for Water Research

MU GAMMA
Consultants Pvt. Ltd

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

Inopol (2021) Baseline Report on Plastic Pollution in India

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 toward promoting green development across India; The Energy and Resources Institute (TERI), India's leading institute that works towards sustainable energy and environmental management; 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 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.

Authors

Girija K Bharat, Hans Nicolai Adam, Emmy Nøklebye, Eirik Hovland Steindal, Rachel Hurley, Suneel Pandey, Smita Mohanty, Avanti Roy-Basu, Kofi Vondolia, Nina Buenaventura, Marianne Olsen, Girija Prasad, Twinkle Dev, Kaushik Chandrasekhar, Aruni Shajkumar, Valentina Elena Tartiu, Ingvild Skumlien Furuseth, Paromita Chakraborty, Abdullah Atiq, S K Nayak, Manisha Jain, Mary Abraham, Pallavi Gulati, Simi S Nair.

Copyright

Suggested Citation

INOPOL (2021) of Baseline Report - Plastic Pollution in India. India-Norway Cooperation Project on Capacity Building for Reducing Plastic and Chemical Pollution in India.

Disclaimer

Designed by

Paper Play, Delhi. E: care.paperplay@gmail.com

Norwegian Embassy
New Delhi

FOREWORD

Hans Jacob Frydenlund

Ambassador

The Royal Norwegian Embassy in New Delhi

Over two years have passed since India and Norway established a Joint Marine Pollution Initiative to tackle and prevent pollution from both land-based and offshore activities in India, in line with SDG 14 – Life Below Water. This bilateral cooperation blossoms by taking advantage of our nations' respective strengths in marine research, waste management, technology, environmental pollution and human health, to learn from one another and implement best practices for sustainable development.

The Royal Norwegian Embassy in New Delhi is pleased to support the launch of the INOPOL project's comprehensive baseline report on plastic pollution in India. The report highlights the important cooperation between India and Norway towards a sustainable blue economy; a joint effort which is continuously expanding in the fields of climate change, environmental research and ocean health.

The common challenges of marine litter and pollution demands global solutions and local actions. The close bilateral dialogue and transdisciplinary relationships developed as part of the INOPOL project will be key when we continue to explore the feasibility of establishing a new global agreement to combat plastic pollution. A robust scientific knowledge basis is pivotal when finding mutual grounds and developing effective measures on the multilateral arena.

At the Embassy, we are delighted to read the extensive baseline research conducted under the INOPOL project, which is a repository of knowledge. The report bridges important knowledge gaps on plastic pollution in the State of Gujarat and contributes to strengthen capacity to prevent and mitigate associated environmental threats, which in turn will benefit both policy makers and the wider public.

FOREWORD

Dr. Thorjørn Larssen
Deputy Managing Director,
Norwegian Institute for Water Research (NIVA)

Plastic and chemical pollution are key threats to the sustainability of our societies and environment. The interlinked challenge of plastic pollution and persistent organic pollution requires diverse solutions that are local, national and global in scope. One important measure is to identify and tackle the sources of plastic waste and chemical pollution. This is particularly important in countries lacking efficient monitoring systems, waste management infrastructure and capacity to manage plastic waste at pollution hotspots.

The INOPOL project is part of the India-Norway Marine Pollution Initiative, which is a bilateral collaboration aimed at combatting marine pollution. An important component in this strategy is to improve societal wellbeing as part of achieving the sustainable development goals (SDGs), in addition to preventing and significantly reducing marine pollution from land-based activities (SDG target 14.1). At NIVA, we are privileged to be working with leading Indian partner organizations and stakeholders to co-produce this important knowledge base.

NIVAs strategy towards 2030 aims to use our expertise in multidisciplinary water research to find solutions to environmental challenges at the local and national levels. International cooperation projects such as INOPOL are important elements in this strategy. We are delighted to share this report which provides a starting point for developing knowledge and capacity to reduce plastic and chemical pollution in India, the region and beyond.

The chapters of this report provide important insights into the Indian policy environment, pollution levels, existing monitoring practices, related health and environmental impacts, best practices and ways forward. This science-based knowledge forms the foundation of developing strategies and action plans to strengthen local and regional capacity towards significantly reducing the environmental and human threats posed by plastic and chemical pollution.

The preparation of this report would not have been possible without the contributions from many highly committed people. On behalf of NIVA, I want to thank the Royal Norwegian Embassy in New Delhi for support and the entire project team for their great efforts.

Table of CONTENTS

List of FIGURES

List of TABLES

Executive **SUMMARY**

This executive summary for the 'INOPOL Baseline Report on Plastic Pollution' introduces key themes covered in each chapter of the full report, including the INOPOL project background, description of catchment areas, regulations and policy status, plastic pollution levels, existing monitoring activities and methodologies, health and environmental impacts of plastic pollution, best practices, gaps and a way forward .

The India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India (INOPOL) aims to prevent and substantially reduce the scope of marine litter from sources in the catchment areas of rivers Tapi (Tapti) and Daman Ganga along the cities of Surat and Vapi in Gujarat State. These rivers are highly affected by petrochemical and industrial activities and are major receivers and transport routes for land-based plastic pollution. Tapi river flows through the metro-city of Surat, which has experienced significant economic growth and has been estimated to have the highest composition of municipal plastic waste generation of 60 Indian cities (CPCB 2015). Vapi is situated near the banks of Daman Ganga and is the largest industrial area in Gujarat, dominated by chemical and paper industries. Waste generation in both Surat and Vapi have been estimated to increase significantly over the next 10 years. **Chapters 1 and 2** presents the project background and description of pilot catchment areas.

Plastic production in India was estimated to 22 million tons in 2020. India's per capita consumption of plastics is about 12 kgs per person, which is much below the world average of 28 kgs. Being a densely populated country, this equates to the generation of 26,000 tonnes of waste per day (9.46 million tonnes/ annum). It is estimated that 60% (5.6 million tonnes) of this plastics waste is recycled, while 40% (3.6 million tonnes) is left uncollected or littered. Gujarat state is the second largest generator of plastic waste in India, with approximately 3,56,873 tonnes per annum in 2018-2019. Industrial and municipal plastic waste streams greatly affect marine ecosystems when reaching riverine systems. The catchment areas of Tapi and Daman Ganga rivers are rimmed with plastic debris attributed to large population concentrations, increased usage of single use plastics products, tourism, shipping and fishing activities. While meager estimates on plastic waste generation and recycling in the study areas exist, the baseline report found insufficient evidence to estimate the volumes of waste which is collected informally, landfilled and which remains uncollected in the environment (**Chapter 3**). There is a clear need for standardized methodology to measure plastic waste generation and leakage into aquatic and marine environments.

An assessment of regulatory frameworks, policies and predominant approaches to plastic waste management is presented in **Chapter 4**. Important policy developments here relate to the Plastic Waste (Management and Handling) Rules, 2011, superseded by the Plastic Waste Management (PWM) Rules, 2016, amended in 2018, and most recently notified for further amendments in 2021. We problematize the

rules outlining bans and required thickness of plastic carry bags, division of stakeholder responsibilities, and the phasing out multilayer plastics (MLP) and single-use plastics (SUP), amongst others. It is found that implementation and enforcement of the PWM Rules varies across different Indian states (MoEFCC, 2018-2019). The unregulated informal sector also plays a key role through its recycling of significant amounts of India's plastic waste. While estimates exist, lack of data, knowledge and recognition of the informal sector's role in plastic waste management forms persistent gaps in recycling estimates and strategies towards reduced plastic pollution. It also contributes to increased livelihood insecurities and socio-economic marginalization of informal recycling workers.

An important component of the project and future work are the development, assessment and application of national methods and standards for sampling and analyzing micro-and macro plastics (**Chapter 5).** The reviewed approaches and literature include spectroscopic sampling methods for stranded and floating macro-plastics, as well as a narrow scientific knowledge base on the extraction, identification and quantification of micro-plastics. There is a great need to study micro- and macro plastic pollution simultaneously, within a holistic approach to identify and quantify plastic inputs from land to river-systems and marine environments. Research attention has been particularly low in Gujarat State despite its industrial and political importance and its geographical connection to rivers and marine ecosystems. It is therefore significant that the INOPOL project develops knowledge and monitoring capacity particularly in these areas.

Monitoring of environmental plastic contamination is high on the international agenda, with policy instruments, monitoring programs, and action plans being developed with international organizations, working groups and initiatives, such as the UNEP Global Partnership on Marine Litter. Considering that there are no standardized methods for microplastic sampling and analysis, **Chapter 6** underlines the urgent need for harmonization of definitions, methods and materials. Furthermore, it presents four interlaboratory calibration exercises (ILCs) as tools to address the analytical component of microplastic studies. The adoption of ILCs as regular features of international projects and initiatives will improve harmonization between laboratories to review detection efficiency and comparability of results.

Toxic emissions from plastic production and inadequately disposed plastic waste pose significant threats to ecosystems and human health. In **Chapter 7,** attention is paid to this aspect by reviewing health, exposure and risks from plastics pollution, including the interlinkages between plastics and persistent organic pollutants (POPs). Plastic represents a risk to humans and the environment throughout its lifecycle from direct impacts such as causing disease and disrupting the endocrine system in humans, affecting ecosystem and organism health, as well as indirect impacts from poorly managed waste disposal causing floods and loss of revenue for tourism or fishers. Microplastic and POPs need to be studied in tandem to draw conclusions about their interlinkages and potential solutions for management of both. Considering the limited research for plastic-POPs interlinkages, the INOPOL project will provide a comprehensive and holistic view of both types of pollutants.

The report also discusses case studies on plastic waste collection practices, plastic recycling schemes, and policy measures to reduce plastic waste and pollution at local, national and regional levels (**Chapter 8**). Source segregation and waste collection practices with color coded bins are reviewed as a success factors in the Indian cities of Panjim, Indore, and Ambikapur and Mundukkarai. In the two latter cases, segregated waste is collected by women self-help groups rather than corporations before being brought to material recovery facilities. Furthermore, national and international case studies highlight innovative and technological interventions which contributes to minimize the harmful effects of plastic waste, including recycling plastics into craft products, beverage container recycling schemes, and down cycling of plastics into road making and energy generation. While co-processing and waste-to-energy initiatives generally have been considered good practices towards a circular economy, these end-of-life initiatives are not optimal from a resource utilization perspective if materials can be reused or recycled. Moreover, there is limited evidence available on the wider implications of co-processing of waste, particularly in the Indian context. This research gap will require closer examination before promoting these strategies to reduce unmanaged waste.

Despite emerging research and growing attention, limitations and challenges within monitoring and assessment methodologies of plastic particles and plastic waste management approaches and capacities exists. The report discusses these with an emphasis on the project case study areas in India (**Chapter 9**). We chart out how the INOPOL project aims to address these gaps by providing science-based approaches, knowledge exchange, training and policy input to strengthen local and national capacity to ultimately mitigate the environmental threats posed by plastic and chemical pollution. The impacts of Covid-19 on the waste management sector are also discussed, highlighting challenges around the unprecedented growth in biomedical waste generation and the disruptive effects of nationwide lockdowns on municipal waste management systems, particularly on livelihoods and waste handling capacity in the informal recycling sector.

The final chapter (**Chapter 10**) focuses on how the INOPOL project will make result-oriented contributions to reduce chemical, marine litter and microplastics pollution in India. The comprehensive baseline report for land-based sources of plastic pollution, including both micro and macro plastics, provides a strong knowledge base for upcoming project activities; The baseline will be followed by the development of a data collection strategy, a sampling and analysis strategy, a monitoring strategy for plastic waste, policy notes and a plastic waste strategy report for Gujarat, and capacity building and training programs for key stakeholder groups, such as policy makers, industry, technical experts, laboratory personnel, community groups and civil society.

Chapter 1
PROJECT BACKGROUND

The report is a documented summary of the baseline assessment report of plastic pollution prepared as a part of the India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India (INOPOL). This report presents a gist of various chapters covered as a part of the baseline report that includes analysis of the current situation, description of the study sites including socio-economic context, regulations covering the policy status, pollution levels, existing monitoring activities and data, knowledge about health and environmental impact, and best practices relating to plastic waste management. The report focuses on India more generally, and more specifically, the study areas of Surat and Vapi in the catchment areas of rivers Tapi (Tapti) and Daman Ganga in Gujarat State. Furthermore, the report also assesses the existing data gaps that the INOPOL project will contribute to fill. There are numerous ongoing activities and initiatives in India and the context is rapidly developing, hence, note that the present report merely represents a snapshot of the situation, building on the secondary data available to the authors during preparation of this report.

1.1 INOPOL project at a glance

The INOPOL initiative is a collaboration project between Indian and Norwegian institutions with the objective to build knowledge and capacity to tackle plastic and chemical pollution from major sources within industry, public sector, and the civil society in India.

Key features

The key features of the INOPOL project are encapsulated in **Table 1.**

Table 1: Table describing the key features of the project

Time frame:	January 2019- June 2022
Funding:	The Norwegian Ministry of Foreign Affairs/ NORAD
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 Toxics Link
Case studies:	▪ Surat, river Tapi (Tapti) ▪ Vapi, river Daman Ganga
Key outcomes:	▪ Establish baselines on use and release ▪ Strengthen monitoring capacity and standardization ▪ Assess social drivers and impacts, and identify sustainable solutions ▪ Develop sound management tools

The project will contribute to building a stronger scientific knowledge base which will support India's ambitious domestic targets to reduce plastic releases and enhance its efforts to achieve international commitments, such as the UN Clean Seas, the Basel Convention on hazardous waste and the implementation of the Stockholm Convention on Persistent Organic Pollutants (POPs).

The Norwegian government launched a new development program to combat marine litter and microplastics in 2018, "The Norwegian development program to combat marine litter and microplastics". The main objective of the program is to "prevent and greatly reduce the extent of marine litter from large sources in developing countries", with a focus on populous and economically fast-growing countries in Asia. INOPOL was granted funding support under the program in 2019 to develop coherent systems for data collection and analysis in India.

Building on the project team's strong experience within environmental monitoring and management, the project will produce the following key outcomes:

a. Establish baselines on use and release of plastic
b. Strengthen monitoring capacity and standardization
c. Assess social drivers and impacts, and identify sustainable solutions
d. Develop sound monitoring and management tools

The final combined products of these efforts are

a. Sector-specific road maps for reduced marine-litter and microplastic pollution (land-based), and
b. a basis for a State-implementation plan on POPs.

The plastic waste component of the INOPOL project is led by the Norwegian Institute for Water Research (NIVA) (Project Lead), in close collaboration with The Energy and Resources Institute (TERI), Central Institute of Petrochemicals Engineering & Technology (CIPET) and Mu Gamma Consultants Pvt. Ltd. (MGC).

1.2 Objectives and outcomes

By applying a knowledge-based scientific approach, INOPOL will investigate land-based sources, social and economic drivers, river fluxes and ocean input of plastic and POPs pollution. Based on these project outcomes, the project will identify effective reduction and control measures. The project seeks to synergize with and enhance ongoing efforts by key stakeholders (e.g., ministries, scientific institutions, NGO's) to reduce pollution in the State of Gujarat.

The project will develop a pilot for Gujarat state that subsequently may be used to scale up of efforts at national level. Key goals and ambitions (**Figure 1**) are to build knowledge and capacity of different groups of stakeholders, experts, and civil society to help reduce the releases and impacts of plastic pollution and the 'new' POPs listed under the SC and developed by the Government of India. Monitoring, data collection and modelling are key activities in combination with local and regional awareness raising to support development of a management tool and sector-specific road maps aimed to reduce releases of litter and plastic waste. Identification of social and economic drivers and impacts of measures will feed into the development of management tools and activities related to capacity building and awareness generation.

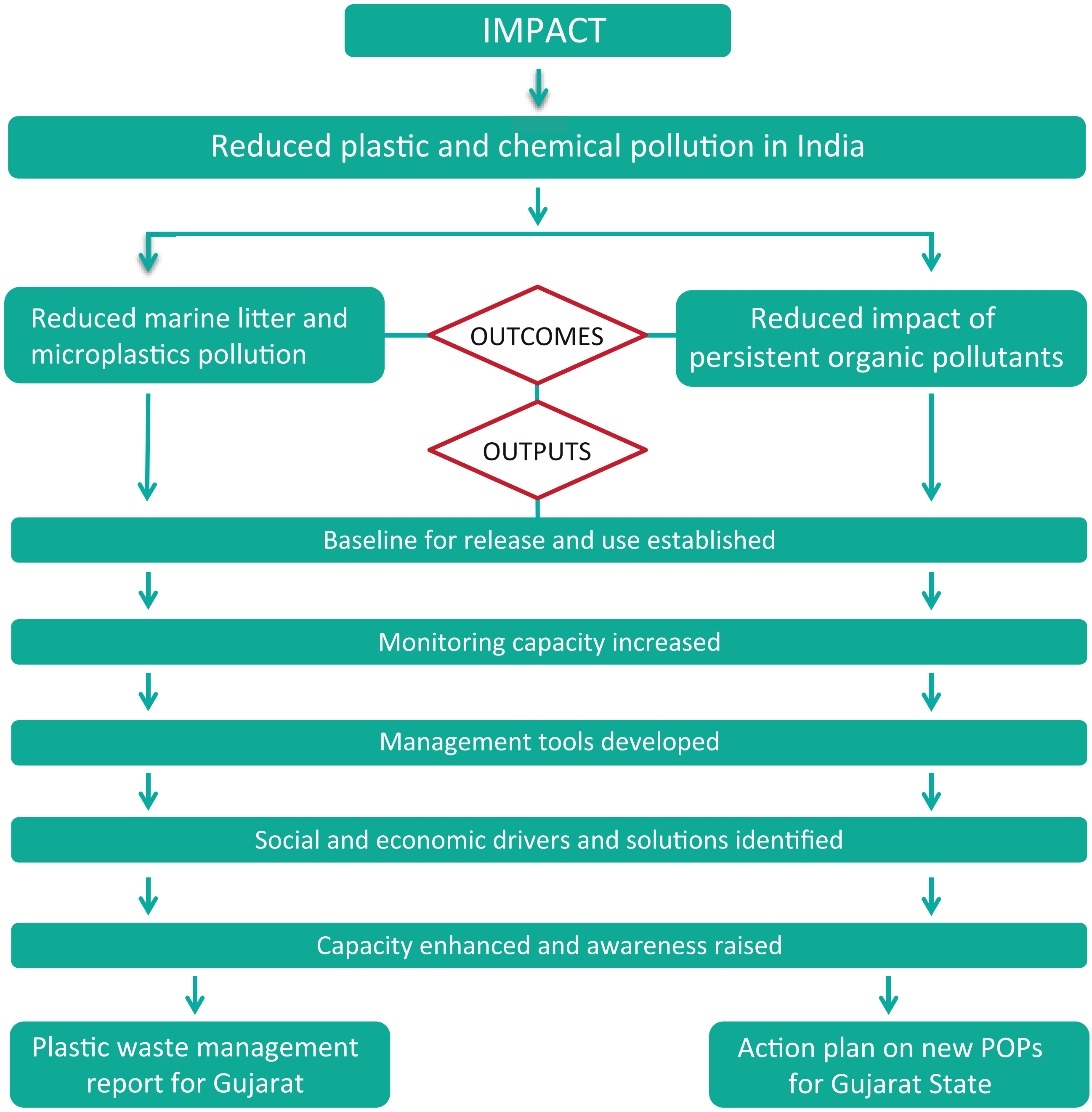


Figure 1: Overview of the INOPOL project's goal hierarchy

Chapter 2
DESCRIPTION OF PILOT CATCHMENT AREAS

2.1 Project Study Areas

To execute the different project activities and develop a knowledge base for plastic pollution and POPs issues, two catchment areas in the State of Gujarat are selected – Tapi river catchment with the city of Surat as main urban industrial centre and Daman Ganga catchment with Vapi as main industrial centre. Both these rivers drain into the Arabian Sea.

Plastic waste leakage from land-based sources is significant in areas where a large number of plastic packaging and manufacturing industries are located near the coast, and in coastal residential, commercial and institutional areas (Jambeck et al., 2015). Littered plastic waste may also become a major concern when accumulating in drains leading to blockage and flooding (NPC & UNEP, 2019). The case study areas have been selected because of their socio-economic, physical and ecological profiles making these areas hot-spots for marine plastic pollution.

2.1.1 Surat

The city of Surat is located along the coast in Gujarat between the latitudes 21.112° North and longitude of 72.814° East and spreads over an area of 326.515 km^2 **(Surat Urban Development Authority, 2017)**. The rivers Tapi and Mindhola flow through the city, both of which drain into The Gulf of Khambat (Cambay). Surat is a low-lying city with an elevation of 13 m above sea level. Surat experiences tropical climate with an average annual rainfall of approximately 60 inches (1525 mm). As per 2011 census, the population of Surat was approximately 4.6 million, with a population density of 13,680 people per km^2. Surat Municipal Corporation (SMC) is the administrative body in the city. Surat is a highly industrialized city with an abundance of diamond and textiles industries. The city has an estimated GDP of $59.8 billion – 9th largest amongst Indian cities. Surat urban agglomeration consists of SMC area, SUDA area and the town of Hazira (extended SUDA area). Surat urban agglomeration is shown in **Figure 2**.

The figure shows that the area under SMC is densely populated, Hazira is heavily industrial and the area beyond SMC limit is predominantly agricultural. This is within the catchment of rivers Tapi and Mindhola. The catchment also consists of mangroves that go by the name Hazira Mangroves. The details of the catchment area are presented in **Table 2**.

Plastic waste generation in Surat

Surat is one of the major cities in India and was recently selected in the 'Smart City Mission' launched by the Indian Ministry of Urban Development. Due to the economic and social conditions of this metro city, Surat generates a significant amount of waste. As reported by SMC in 2018-2019, Surat generated a total of 2200 tonnes of solid waste per day at a rate of 0.45 kg per capita. Owing to the importance of Surat in the Indian context, there have been several national studies in order to assess and characterize the

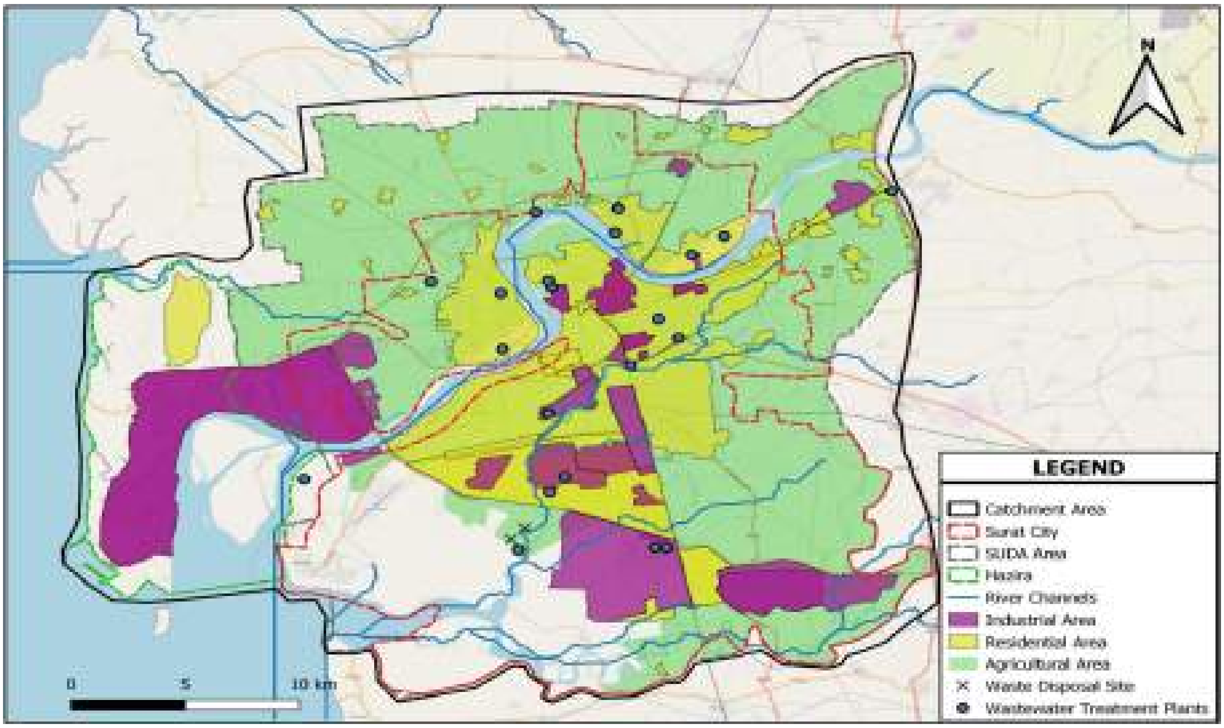


Figure 2: Surat urban agglomeration

Table 2: Surat catchment details

Details	Catchment details
Area of catchment	715 km^2 (approx.)
Number of inhabitants	4,805,101
Names of rivers flowing	Tapi and Mindhola
Number of urban clusters	05
Number of industries	41,300 (approx.)
Number of registered plastic recyclers	03
Number of WWTPs/CETPs	05

generated waste within the city. The most recent study is the CPCB-CIPET study of 2015 **(CPCB, 2015)** that characterized and assessed plastic waste generated in 60 Indian cities. According to this study, Surat had the highest composition of plastic within the generated MSW at 12.47%. A breakdown of the different types of plastic waste is illustrated in **Figure 3**.

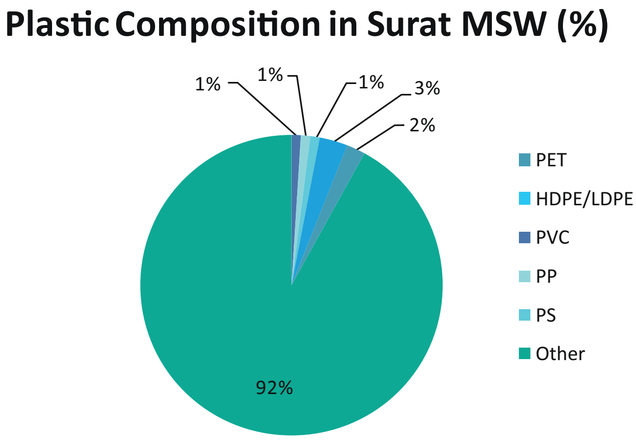


Figure 3: Breakdown of plastic composition in Surat's MSW

2.1.2 Vapi

Vapi is the second largest city of southern Gujarat, situated in Valsad District, along the bank of River Daman Ganga. The city has an area of 22 km^2 and is located between latitude 20.385˚ north and longitude 72.91˚ east. Vapi has an elevation of 27 meters above sea level. Vapi is surrounded by the Union Territories (UTs) of Daman & Diu and Dadra & Nagar Haveli. The UT of Daman & Diu is divided into two parts by Daman Ganga River – 'Moti' Daman (Big Daman) and 'Nani' Daman (Small Daman). Another river called Kolak flows through both, Vapi and Daman. Just like Surat, Vapi also experiences a tropical climate with heavy rainfall during the monsoon season, with average rainfall being about 90 inches (2279 mm). This city falls under the jurisdiction of Vapi Municipality. The last recorded census of 2011 stated that Vapi has a population of 163,630, with a density of 7292 people per km^2. Vapi is one of the most industrialized towns in the state of Gujarat, courtesy the establishment of Gujarat Industrial Development Corporation (GIDC) Industrial Estate in the city. The industrial sector of Vapi is majorly dominated by chemical and paper industries. Vapi is

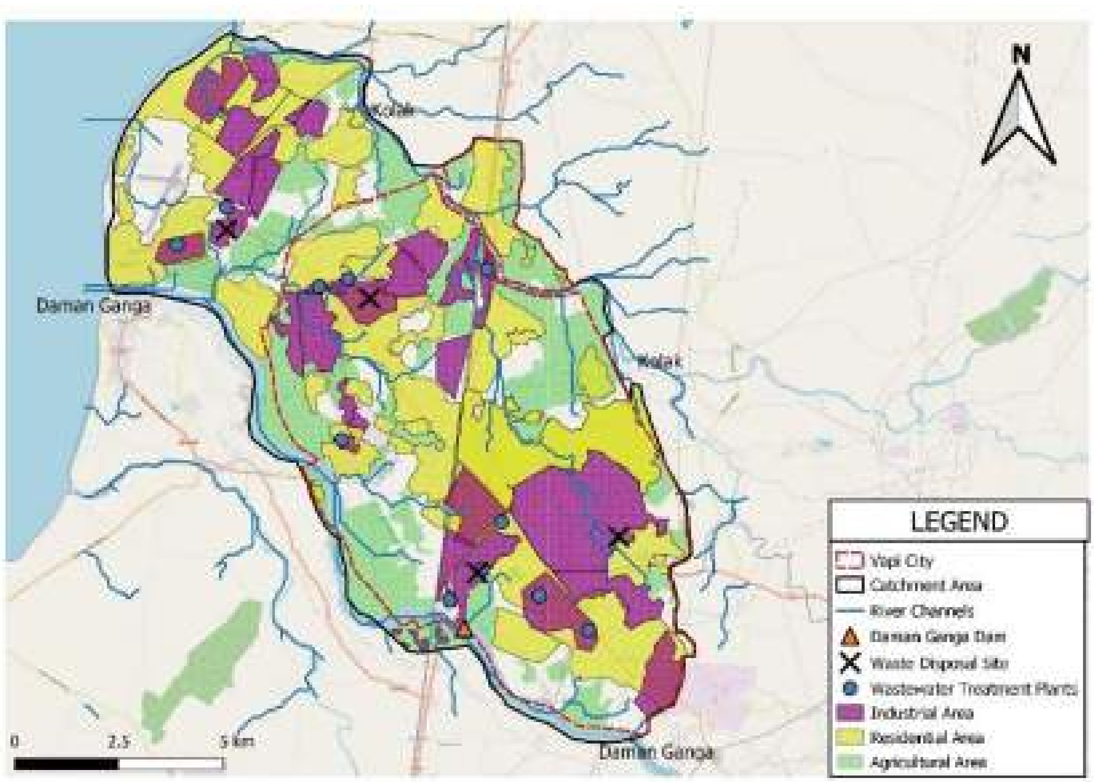


Figure 4: Vapi agglomeration

Table 3: Vapi catchment details

Details	Daman Ganga catchment
Area of catchment	22 km^2 (approx.)
Number of inhabitants	163,630 (approx.)
Names of rivers flowing	Daman Ganga and Kolak
Number of urban clusters	02
Number of industries	12,000 (approx.)
Number of registered plastic recyclers	18
Number of WWTPs/CETPs	11 (approx.)

also home to one of Asia's largest Common Effluent Treatment Plant (CETP), which is administered by Vapi Municipality.

Figure 4 above depicts the land use map of Vapi agglomeration. For this project, Vapi City and Nani Daman have been considered in the Daman Ganga catchment area. The rationale has been to include the highly industrialized zones of Vapi and Nani Daman owing to its proximity to the coast where Daman Ganga drains into the Arabian Sea. The lower boundary of the catchment is marked by the boundary of Vapi Municipal Corporation area, whereas the upper boundary is marked by the coast. The catchment also includes a dam, which goes by the name Daman Ganga Dam, commonly called Madhuban Dam. Specific details regarding Vapi agglomeration have been tabulated in **Table 3** below.

In 2019, Vapi generated 50 TPD of solid waste, out of which 1 TPD was plastics – equaling to a plastic composition of 2%. However, waste quantification and characterization studies of Vapi have not been conducted at a central level. In order to predict the characteristics of Vapi's plastic waste generation, data information for Daman is being used due to its close proximity to Vapi (~11 km) and similar populations of the two cities (Daman has a population of 191,173 while Vapi has a population of 163,630 as per census 2011). It is important to note that Daman's plastic waste composition data

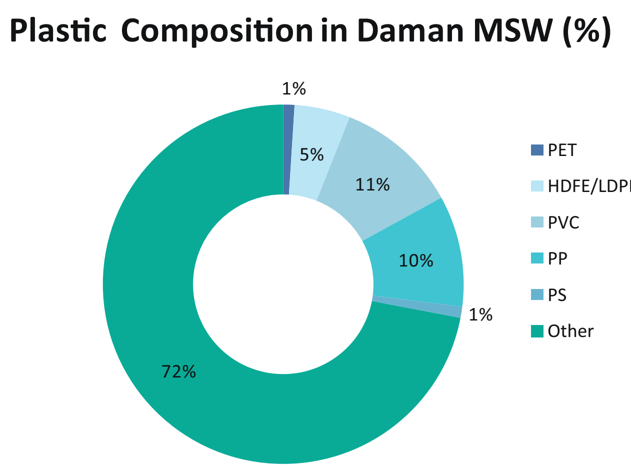


Figure 5: Breakdown of Daman's plastic waste composition

is only considered to estimate the characteristics of Vapi's plastic waste scenario, and for the quantification of waste generation in Vapi, official municipality data will be used. Daman was one of the 60 cities that was assessed in CPCB-CIPET study of 2015 **(CPCB, 2015)**. The breakdown of Daman's plastic waste generation is presented in **Figure 5**.

2.2 Waste generation Projections in the study area

Future waste generation estimations for Surat and Vapi have been prepared and tabulated in **Table 4** and individually visualised in **Figures 5** and **Figure 6**,

Table 4: Decadal estimation of waste generated in Surat and Vapi

Year	Surat				Vapi			
	Population	Per capita waste (kg/ capita/day)	Solid waste (TPD)	Plastic waste (TPD)	Population	Per capita waste (kg/ capita/day)	Solid waste (TPD)	Plastic waste (TPD)
2011	4591246	0.261	1200	149.64	163360	0.242	39.6	0.792
2021	7651367	0.297	2276	283.82	336145	0.276	92.72	1.854
2031	12751092	0.338	4315	538.08	690542	0.314	216.73	4.335
2041	21249845	0.385	8183	1020.42	1418580	0.357	506.63	10.133

respectively. The detailed methodology for estimating the future waste projections of Surat and Vapi is provided in Annex 1 of Chapter 2 of the Baseline Assessment Report.

From **Figure 6**, it is evident that Surat's waste generation is estimated to rise almost 8 folds by the year 2041.

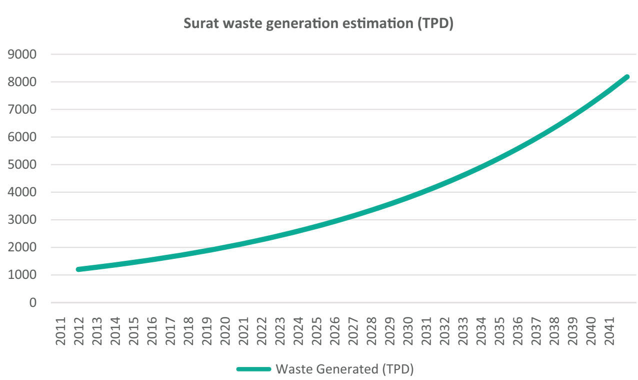


Figure 6: Surat waste generation estimation

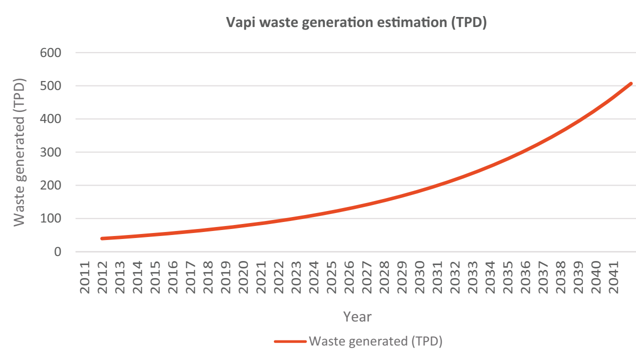
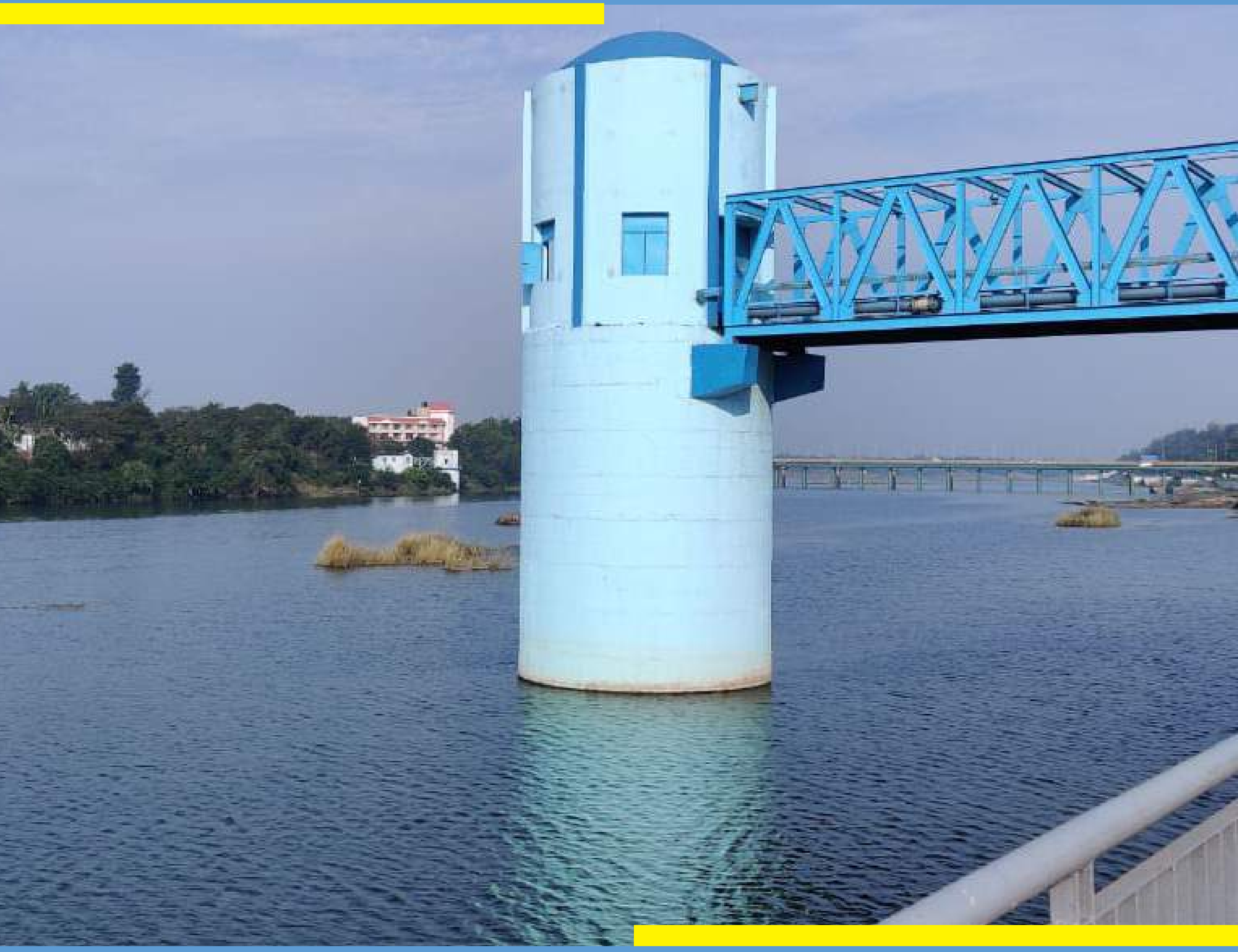


Figure 7: Vapi waste generation estimation

Figure 7 illustrates Vapi's predicted waste generation and it can be deduced that in 2041, Vapi will be generating nearly 500 TPD, which is more than 10 times the generation witnessed in 2011, i.e. 40 TPD.



Chapter 3
REGULATORY FRAMEWORK, POLICIES AND PROGRAMS FOR PLASTIC WASTE MANAGEMENT

Plastic is an essential material owing to the host of benefits it offers, such as convenience, flexibility, lightness, durability and water-resistance. This chapter focusses on the predominant approaches to legal regulations and outlines the role of linked circular economic thinking that are important to prevent plastic leakage into land and marine environment.

3.1 Relevant policies and programs in PWM (International, National, State, ULBs)

3.1.1 Global Governance

To manage the menace of unmanaged plastic waste release at the international level, about 127 countries **(World Resources Institute, 2019)** have adopted some form of legislation to regulate plastic pollution, mainly against plastic bags. Ban orders have been effective in raising global awareness against single-use plastics, the main constituent of plastic waste. Some global efforts are listed below.

- The **Global Partnership on Marine Litter (GPML)** was launched at the UN Conference on Sustainable Development (Rio+20) in June 2012 that focused on the prevention of marine litter and microplastics (SDG 14.1).
- The **2030 UN Agenda for Sustainable Development** (2015) **(WasteAid, 2016)** provides a "shared blueprint for peace and prosperity for people and the environment" through achieving 17 Sustainable Development Goals (SDGs) that can be achieved once we recognize PWM as a powerful driver of sustainable development.
- At the UN Environment Assembly (UNEA 2) of the UN Environment Programme (Nairobi, Kenya, May 2016), a **draft resolution on Marine Plastic Debris and Microplastics** was drawn up.
- UN Environment launched the **Clean Seas Campaign** in February 2017, that contributes to the goals of the GPML and aims to engage governments, general public, and the private sector to manage marine plastic pollution.
- At the UNEA-3 (Nairobi, Kenya, December 2017), efforts to address global plastic pollution took a step forward as countries agreed to establish a specialist group aimed at assessing different options to combat marine plastic pollution.
- **The Circular Economy and Plastics Strategy of the European Union (European Commission, 2018)** was adopted in January 2018. Plastic products are aimed to be better designed, have higher plastic waste recycling rates, and boost a better market for recycled plastics. The Strategy focuses on six key areas

and targets ten single-use plastic products found on Europe's beaches and seas, which comprise 70% of all marine litter items including lost and abandoned items **(Kerscher, 2019)**.

- The **Basel Convention** is an international treaty to reduce the movements of hazardous waste between nations, and specifically from developed to less developed countries. In 2019, as many as 187 countries of the Convention included plastic waste in a legally binding framework, by making global plastic waste trade more transparent and better regulated, and a new partnership on Plastic Waste with various stakeholders was established.
- In 2019, the governments of India and Norway signed a Memorandum of Understanding on **India-Norway Ocean Dialogue** and established a Joint Task Force on Blue Economy for Sustainable Development. In 2020, the two Governments reviewed the progress made under this MoU, including the establishment of the Marine Pollution Initiative (**Norway in India, 2020**).
- In May 2020, the UN Economic and Social Commission for Asia and the Pacific (ESCAP) and the Government of Japan initiated the **'Closing the Loop' project'** (**UN-ESCAP, n.d.**) to minimize the impacts of plastic waste pollution on the riverine and marine environment of South East Asia. The project will be piloted in Kuala Lumpur (Malaysia), Surabaya (Indonesia), Nakhon Si Thammarat (Thailand) and Da Nang (Vietnam), and supports the existing 'ASEAN Framework of Action on Marine Debris' and the 'G20 Osaka Blue Vision' to manage plastic waste (towards achieving SDGs 11, 12 & 14).

Policies and programs of top plastic producing countries

- *Germany* (**DW, 2018**): In 2015, Germany introduced a 5-point plan aimed at managing the dependency of single-use plastic and taking steps in adopting a sustainable system. The overall objective was to become less of a "throwaway society".
- *Brazil* (**Global Recycling. 2020**)*:* In 2019, about 1,055 Brazilian cities were reported to have a recycling program. Project 'ProteGEEr' of GIZ supports the implementation of the National Policy for Solid Waste towards climate protection in Brazil, which ends in 2021.
- *China:* In 2020, China presented a major plan to reduce single-use plastics across the country, including a ban on non-degradable bags in major cities by the end of 2020 and in all cities and towns by 2022 (**BBC News, 2020**).
- *USA:* In February 2020, USA introduced a Bill for a legislation to phase out single-use plastic products nationwide, from January 1, 2022 onwards. The Break Free from Plastic Pollution Act of 2020 is the only federal legislation that addresses the issue through source reduction and extended producer responsibility. At present, several US states have imposed ban on single-use plastic bags (**NCSL, 2021**).

3.2 The National Perspective: India

Plastics production in India is estimated to grow to 22 million tons a year by 2020. To facilitate plastic recycling, the Society of the Plastics Industry, Inc. introduced its resin identification coding system in 1988 that defines seven types of plastics (PET, HDPE, PVC, LDPE, PP, PS, and other miscellaneous plastics).

3.2.1 Plastic Waste Management Rules

The Government of India notified Plastic Waste Management (PWM) Rules, 2016, amended in 2018, superseding Plastic Waste (Management & Handling) Rules, 2011. The Rules require carry bags made of virgin or recycled plastic to be minimum 50 microns in thickness. The Rules also clearly define the roles and responsibilities of different stakeholders (Institutional waste generators, and event organizers, ULBs, Gram Panchayat, Producers/

Importers/Brand Owners, State Pollution Control Boards, Urban Development Department, District Magistrate/Deputy Commissioner).

In 2018, the 2016 rules were amended to phase out the manufacture and use of multi-layered plastic (MLP), which are "non-recyclable, or non-energy recoverable, or with no alternate use".

Further, in March 2021 Ministry of Environment, Forests and Climate Change (MoEFCC) notified the draft Plastic waste management Rules 2021. The amendment documents the inclusion of a few key definitions such as 'Single Use Plastic', 'Plastic waste processing' and 'Non-woven plastic bag'. The Ministry has also proposed to increase the thickness of carry bags made of virgin plastic to 120 microns. Another notable addition is the proposed ban on the manufacture, import, stocking, distribution, sale and use of specific single-use plastic from January 1, 2022. The amendment is currently in the draft stage and is open for public comments.

Enforcement of Plastic Rules in different Indian states **(MoEFCC, 2018-2019)**

- *Enforcement of the Plastic Rules at the state level:* While 22 States/UTs have imposed complete ban, seven States/UTs have imposed partial restriction/ prohibition of plastic carry bags or other single-use plastic products. Rest of the States/UTs have not imposed any additional restrictions (other than enforcing the PWM Rules) **(MoEFCC, 2019)**. Action plans for implementation of PWM Rules has been submitted by 12 states/UTs **(Financial Express. 2019)**.
- *Actions against violators:* As per provision '12' of PWM Rules, 2016, as many as 21 States/UTs have imposed fines, issued notices and closure directions to the defaulters, and seized materials in their respective States/UTs.
- *Use of properly marked and labeled plastic carry bags:* Rule '14(1)' of PWM Rules require shopkeepers/retailers to use properly marked and labeled plastic carry bags. Most of the States/UTs (except a few like Gujarat and Nagaland) are not following the proper practice of plastic carry bag labelling, especially the street vendors and small retailers.
- *Enforcement in Gangetic towns and cities:* The Central Pollution Control Board has issued directions to the Commissioners of 46 Million-plus cities, 20 State Capital cities and 118 towns located on bank of Ganga river to prohibit manufacturing and use of sub-standard plastic bags **(MoEFCC, 2019)**.
- *Gujarat's policies:* The state of Gujarat has brought out specific action plans for PWM in urban areas **(SBM-U, Gujarat, n.d.)** for different stakeholders like Brand Owners, Producers and ULBs.

Few other special provisions and programmes

- *Plastic Free Protected Areas:* In 2018, the Wildlife Division of the Ministry of Environment Forest and Climate Change (MoEFCC) issued directions to all States & UT Governments to organize awareness generation programs to declare all Protected Areas **(MoEFCC, 2018-2019)** as "Plastic Free Zones". Protected Areas in States like West Bengal, Odisha, Delhi, Uttarakhand etc. have complied.
- *Plastic free schools and colleges* **(MoEFCC, 2018-2019)***:* The MoEFCC advised that Eco-club of schools and colleges to declare their institutions plastic-free and certificates were issued for those who complied.
- *Swachh Bharat* Mission (SBM) *2.0 to tackle plastic waste:* In October 2019, the Government of India announced that its flagship program, SBM will aim to eliminate single use plastic by 2022 (SBM Part 2), and aims to achieve it by deploying a set of strategies towards recycling and managing plastic waste.

3.2.2 Current management practices in India

Waste management practices

As per a 2015-study by the CPCB on the assessment and quantification of plastics waste generation in 60 major cities in India, the demand for plastic raw materials has doubled mainly due to rapid urbanization and growing consumerism. Some of the most common problematic practices of managing plastic waste in India have been discussed in this chapter. According to the PWM Rules, 2016 (amended 2018) and based on available information from 14 SPCBs/Pollution Control Committee (PCC), the Central Pollution Control Board developed a report in 2018-2019. Some of the successful plastic waste management practices in Indian cities of Hyderabad and Bengaluru, and a few cities in Gujarat, namely Surat, Vadodara, Ahmedabad, Dwarka, Gandhinagar and Rajkot have been discussed in this chapter.

Existing Plastic manufacturing/recycling units

Rule '13(1)' of PWM Rules, 2016, requires all plastic manufacturing/recycling units to be registered with the concerned SPCBs/PCCs. There were 4773 (4294 –Plastic Mfg., 7-Compostable Mfg., 287-MLP Mfg. & 185- Recycling) Registered units in 30 States/UTs and there are no registered plastic manufacturing units in Andaman and Nicobar Islands, Arunachal Pradesh, Bihar, Lakshadweep & Sikkim. The Gujarat Pollution Control Board has made it mandatory for manufacturers to implement an action plan for safe disposal/recycling of plastic waste. A total of 1016 units (1002 plastic manufacturing/recycling units, 4 Compostable units and 10 multi-layered plastic units) are registered in Gujarat State. (**CPCB Annual Report 2018-19**).

3.3 Existing capacity/ expertise of PWM

- *Utilization of Plastic Waste in Road Construction:* In November 2015, the Union Ministry of Road Transport & Highways made it mandatory for road developers to use waste plastic along with bituminous mixes for road construction. India has built 1,00,000 kilometers of plastic roads in at least 11 states (**Swachh India, 2018**). Roads made of plastic are durable against extreme weather conditions, are cost-effective and pothole resistant. Chennai, Bengaluru, and Hyderabad are few of the cities who have taken initiatives on road construction from plastic waste.
- *Building material, roads and other items made of plastic waste:* CSIR-NPL of India has developed a sustainable and patented technology to manufacture tiles from plastic waste and will manufacture these tiles on a commercial scale. They plan to set up a recycling unit, which will have the capacity to produce 5 lakh tiles per month. Plastic waste has also been used for the construction of a children's school in New Delhi, a parking shelter at Miyapur Metro Station, as well as garbage bins in Hyderabad,
- *Conversion of PET bottle waste into textile products:* A petro-chemical company is collecting PET bottle waste from across India; it has tied up with 150 vendors in India to provide PET bottle bales for processing into textile products.
- *Recycling of used beverage cartons:* Tetra Pak, the carton packaging company, has set up collection centers for managing Used Beverage Cartons (UBCs) in India (**TERI, 2018-2019**). The UBCs are collected and recycled or upcycled into different products and interventions like school desks, sheets used for making mobile toilets, material recovery facilities etc., and the recycling rate has increased from 29% in 2011 to 54% in 2019.
- *Co-processing of plastic waste in cement plants:* CPCB has prescribed guidelines on the co-processing of plastic waste as an alternate fuel. Gujarat, Madhya Pradesh, Meghalaya transport their plastic waste to cement plants for co-processing. The co-processing of plastic waste in cement industries in Gujarat is dependent on the availability and demand from cement plants.

- *Refuse derived fuel (RDF) from plastic waste:* In October 2017 **(CPHEEO, 2018)**, an Expert Committee of the Ministry of Housing and Urban Affairs (MoHUA) prepared "norms for RDF from MSW for its utilization in cement kilns, waste to energy plants and similar other installations" for enhancing the use of MSW based RDF in various industries. The key objective was to present guidelines and propose regulatory/fiscal incentives for the industrial use of RDF, as per the requirements of SBM.
- *Bio-based polymers:* Lab samples of these bio-based plastics are developed by The Energy and Resources Institute **(Deepthi et al., 2018)**. New formulations of natural fiber reinforced completely bio-based thermoplastic composites have been developed by the MoEFCC in collaboration with industrial partners for injection in molded consumer goods products. These composites are expected to be completely compostable under specific conditions making them more environment friendly **(MoEFCC, 2018-2019)**.

3.4 Existing infrastructure

Budget of PWM

The investment required for managing India's plastic waste over the 20-year period (2011-2012 to 2031-2032 at 8% of MSW) has been estimated at ~USD 5.1 billion **(RaboResearch, 2018)**. The Government of India allocated a budget of Rs. 12,294 crores (One crore is equal to 1,00,00,000) for 2020-2021 for SBM that is now aimed to achieve a *Swasth* and *Swachh* India; the allocation for SBM *Gramin and Urban are* Rs 9,994 crore, and Rs 2,300 crore, respectively. The focus will be on solid waste collection, source segregation and processing, including plastic waste management. In 2019, the Indian government initiated a plan for one-time funding Rs 6 crores each to develop PWM Centers in the cities of Surat (Gujarat), Patna (Bihar), Bengaluru (Karnataka) and Varanasi (Uttar Pradesh) **(Indian Express, 2019)**. For 2020-2021, the Government of Gujarat has made a provision of Rs.200 crores under SBM (Urban). A new scheme 'Gujarat Clean and Plastic free' with an allocation of Rs.56 crores **(Government of Gujarat, 2020)** was announced wherein rag pickers collecting dry/plastic waste will be given financial assistance. Also, a provision of Rs.803 crores was made under *SBM* (*Gramin)* wherein Rs.88 crores will be provided to all *Gram Panchayats* for monthly grant of Rs.4/person for door-to-door collection of solid waste (including plastic waste).

Infrastructure of PWM

Many states lack the technology and infrastructure for managing plastic waste in a cost- and resource-efficient way. Some states and cities have taken the lead in empowering municipalities and in developing the required infrastructure. The Government of India has committed support to developing plastic waste management infrastructure through *SBM*.

- *Swachhta Kendras in Urban India* **(UNDP, 2018-2024)***:* The UNDP with other corporate partners, are implementing PWM Programme (2018-2024) that will help to institutionalize Material Recovery Centers or *Swachhta Kendras* focusing on technology-supported knowledge management through promotion of cloud-based traceability, accountability, and digital governance along waste value chain. About 17,000 metric tons of plastic have been collected and processed **(UNDP, 2018-2024)**. So far, 22 *Swachhta Kendras* have been established in 20 cities and is expected to expand to 50 cities and towns.
- *PWM units in Rural India:* A plastic waste management unit for collection and recycling of plastic waste will be set up in each of the 8,000 Administrative Blocks **(The Economic Times, 2019)** (SBM 2.0). With a focus on recycling, every village will be needed to start waste segregation and send its plastic waste to the block level PWM unit. The unit will work at converting the aggregated waste into bales, shred and transport them to aggregators for recycling. A deadline of 2021-2022 has been set with a target of

one storage facility per village. Until May 2020 **(SBM-G, n.d.)**, 48,655 PW storage facilities have been established in Indian villages.

3.5 The role, practice and organization of the informal sector in PWM

For a long time in India, a large informal workforce has been involved in collecting, dismantling, sorting, shredding, cleaning, compounding, pellet making, and manufacture, sale and use of new products. The informal recycling sector fills the void left by the lack of formal waste management systems i.e due to lack of infrastructure, resources, and capacity in the current systems, contributes to waste and cost reduction, and recovers valuable materials. It is estimated to contribute to divert 4.7 million tons of plastic per year from the public waste collection system **(WBCSD, 2017)**. Plastic waste passing through the informal sector, however, has its challenges as 15–25% of it is unsuitable for further recycling. **Delhi** is one of the main recycling hotspots that generates 5% of plastic waste but produces roughly 25% of recycled plastics in India. In Tikri Kalan, a trading and sorting cluster, around 1900 tons of materials are traded every day. The **Surat** Municipal Corporation segregates plastic waste before going into the dumping ground and employs rag pickers for the segregation of value-added plastics. The primary segregation of plastic waste is carried out at the waste collection site and secondary segregation is done at the transportation site **(CPCB, 2015)**. The **Government of India** has made concrete efforts to institutionalize the informal sector. *Swachhta Kendras* has reached out to 1,756 *Safai Sathis* (workers) and provided social security to them by giving assistance with creating bank accounts, obtaining *Aadhar* cards, availing health check-up, and providing personal training sessions **(HCCB & UNDP, 2018-2024)**. Such efforts need to be scaled up across the country, as it will be a win-win for both the people involved and the environment.

Chapter 4
STATUS OF LITTER AND PLASTIC POLLUTION

Increased use of disposable plastic goods constitutes the major fraction of waste that causes river and/or beach pollution all over the world. Marine sources like fishing fleets contribute between 20-30 percent of ocean plastics, while the land-based sources contribute significantly to the tune of 70-80 percent **(Our World in Data, 2018)**. The average global plastic production crosses 150 Million tonnes per annum with its applications ranging from packaging, films, wrapping materials, shopping and garbage bags, fluid containers, to clothing, toys, household and industrial products, and building materials (**Figure 8**).

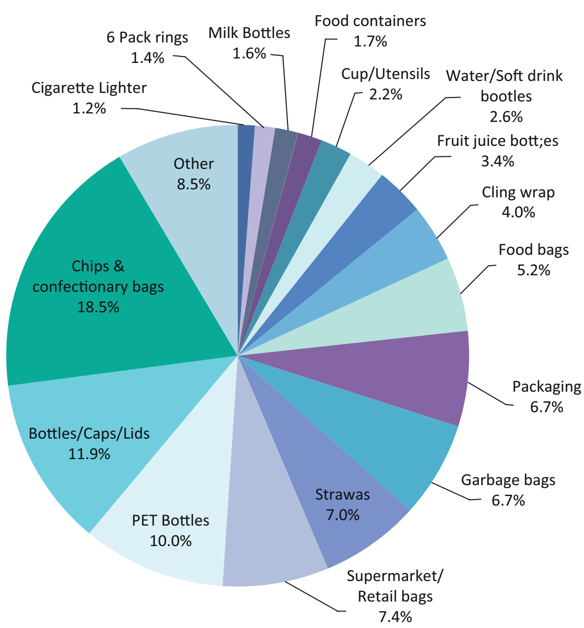


Figure 8 *Contribution of different daily-use commodities in a plastic waste generation (Kurniawan et al., 2017)*

In India, the per capita consumption of plastics is about 12 kgs per person, which is much below the world average per capita consumption of 28 kgs per person. Being a densely populated country, 26000 tonnes of wastes are generated per day (9.46 million tonnes/annum), from which 5.6 million tonnes (60%) plastics wastes are recycled and 3.6 million tonnes/annum are left uncollected or littered. Different survey reports have quantified the amount of plastic waste (in tonnes per annum) generated by different states in India. Among the various states, Maharashtra tops the list with generation of 469,098 tonnes of plastics waste per annum followed by Gujarat (2,69,294), Tamil Nadu (1,50,323), Uttar Pradesh (1,30,777) and Karnataka (1,29,600) respectively (CPCB Annual Report 2015-16). Gujarat, being a major industrial and commercial hub of India, hosts 1002 registered plastic manufacturing/recycling units, four compostable units, and 10 multi-layered plastic units **(CPCB Annual Report 2018-2019)**. The state comes second in contributing to India's plastic waste generation with approximately . 3,56,873 tonnes per annum in 2018-2019 **(CPCB Annual Report 2018-2019)**. Apart from industries, single-use plastic (SUP) wastes and littering during religious procession also add to the rise in plastic waste dumped into the state (**UNEP, 2018**). Domestic wastes such as empty water bottles, garbage bags, carry bags, snack and confectionery packets are examples of SUP that adds to the build-up of plastic waste in the state. These types of plastic waste originating from cities and villages greatly affect marine ecosystems when reaching riverine systems.

4.1 Catchment Areas of Tapi and Daman Ganga

Tapi river flows through the plains of Surat and Daman Ganga through the industrial town of Vapi are rimmed with plastic debris attributed to huge population, increased usage of single use plastics products, and an increase in tourism, shipping and fishing activities. Surat generates around 1,50,000 kg per day of plastics waste **(Swachh India, 2017)** as major industries in this city are textile industries which contributes to 40% of the country's synthetic production **(Surat District Profile, 2011)**. Moreover, the total amount of plastic waste generated in Surat is 149.62 Metric Tonnes/ day **(CPCB, 2015).** An average resident of the city disposes 33.5g of waste per day which contributes to 149.62 MT wastes per day. In the city of Vapi, 70% of the industries are from pharmaceuticals and chemical sectors. The city generates 3500-4500 MT waste per month from paper mills itself. Nonetheless, Alang-Sosiya ship wrecking yard where an average of 180 ships from around the world is dismantled every year build huge plastic wastes which also contributes in effecting the marine ecosystem.

4.2 Plastic waste generating industries in the catchment

The state of Gujarat generated 10,145 MT/day of solid waste, as of November 2017 (**MNRE India, 2018**). The collection, transportation, segregation processing and disposal of municipal solid waste are catered by the respective municipal corporation under state government enforced regulatory policies. From the eight leading Municipal corporations, Ahmedabad and Surat generated the highest amount of waste followed by Vadodara and Rajkot (**CPCB Annual Report, 2018-2019**).

As per provision '5(b)' of PWM Rules, 2016 (amended 2018), approximately 86555 MT of plastic waste has been used for co-processing in cement plants (**CPCB Annual Report, 2018-2019**). Further, the use of plastic carry bags is completely banned in the city of Gandhinagar (**CPCB Annual Report, 2018-2019**).

Groups of chemical, petrochemicals, drugs and pharmaceuticals and textile industries are concentrated along coastal districts such as Surat and Vapi. These industries are significantly contributing to water pollution putting pressure on the marine and coastal ecosystem (**Gujarat ENVIS, n.d.**).

Packaging waste is the most common type of plastic waste generated from the industrial clusters of Surat and Vapi. Major industries in the coastal regions of Gujarat such as the dyestuff, manufacturing and engineering, textiles, chemicals and petrochemicals, pharmaceuticals, and diamond processing, contribute to plastic waste. The geographical location of Surat and Vapi makes it imperative to stop plastic leakage at the source prior to its entry into waterways and thereby prevent negative effects throughout the source-to-sea system.

The Government of Gujarat has started a new initiative **"Save river Tapi"** to improve water quality and save the river from plastic pollution. Attempts have been made to ensure public awareness of the implementation of strict restrictions for littering of waste and disposing wastes into the river. The state government has also initiated co-processing of wastes under which the wastes generated from the paper mills industry of Vapi can be used to fire the cement plants in the city. Further, another initiative called "Clean E-Waste Channel" has been initiated by the state government. This initiative ensures the proper recycling of the discarded plastics parts which are otherwise incinerated that result in the accumulation of plastic debris. Under this venture, awareness has been spread amongst the recyclers' community about the consequences of improper dumping of plastic waste.

4.3 Plastic Waste Collection and Recycling

Surat Municipal Corporation has planned to collect and separate plastic wastes at the disposal sites to prevent it from going into landfills. In association with Ecovision Environmental Resources LLP, a recycling plant has been established to treat 5000 kgs of plastic wastes with a plan to increase the recycling capacity to 1,00,000 kilos. Also, they are gearing up to convert shredded plastic waste to produce diesel (**Swachh India, 2017**).

Considering the high calorific value of plastic wastes when compared to coal, the Gujarat Pollution Control Board has taken necessary actions for co-processing through use of plastic waste materials as alternative fuels or raw material to recover energy or resource Since the state has many cement plants, plastic wastes can be used to fire the cement kilns. However, there are several challenges; 70% of plastic waste contains high moisture which prevents its use as a fuel; lack of incentives to cement industries to use plastic wastes; the unwillingness of industrialists to adopt non-conventional methods; and difficulties in transport and storage etc. (**Shah, 2018**). Despite the odds, there are many advantages in co-processing of plastic waste, including reduction of conventional fuels or raw materials, reduction of overall emission of greenhouse gases, utilization of waste, etc. To overcome the problem of waste generation and recycling, industries should be made aware of the advantages of recycling and co-processing, and it is equally important to sensitize the public about the harmful impacts of littering and careless dumping, urging them to reduce its consumption to reduce environmental pollution.

Chapter 5
ENVIRONMENTAL MONITORING (INDIA)

Accumulation of plastics in water bodies constitutes an emerging scientific and societal concern, owing to their ubiquity, high persistence and improper management by effluent and wastewater treatment procedures. Surveys and research results reveal that most of our oceans and coastal areas show vast presence of plastic waste, ranging from *macro* to *nano* sizes. Certain lightweight and smaller plastic products are not being collected effectively in many countries, and these linger in both the terrestrial and aquatic/marine environments. The microplastics in the range from few micrometers and up to 5 mm are formed by the fragmentation of the larger plastics by photo-oxidation or other mechanical forces that enter aquatic bodies and into food chains. The group of particles termed as microplastics differs in in physico-chemical properties such as size, shape, colour, density and polymer type. Microplastics do not degrade easily and has become a particular concern as these can reach high densities and can interact with biotic and abiotic environment. Microplastics are the cause of death of many zooplanktons, marine animals, and sea birds, and may travel up the food chain to become accumulated in human bodies. Therefore, it is deemed very important to understand and shed more light on monitoring and analyzing these plastic pollutants. This will contribute to identify sources of pollution and controll the efficiency of pollution prevention measures. Understanding and implementing monitoring measures also generates social awareness which may prompt stricter enforcement and implementation of regulations and policies which protect the environment and human health,

This chapter documents existing monitoring methods, standards, sampling, and analysis of micro and macro plastics. The chapter reviews approaches to macro-plastic monitoring such as that of *stranded macro plastics and that of floating macro plastics* and also reviews studies assessing the abundance of macroplastics in India. The chapter further explores different approaches to monitoring of micro plastics. This includes processes such as sampling, extraction, identification and quantification employing essential tool and techniques. **Figure 9** demonstrates the overall methodology for microplastic assessment.

Scientists and researchers have been working on detailed environmental monitoring of plastics pollution for a sustainable blue economy. The first approach for microplastics involves the pretreatment and sampling method which is essential to separate and identify microplastics. The prevalent methods of sampling include selective sampling, volume reduced sampling and bulk sampling. Selective sampling is done by collecting visible samples from surface of water and sediments, but only specific items based on certain criterion are considered for volume reduced sampling. Under bulk sampling technique, the entire volume of sample is used without any reduction in volume. The pre-treatment method is done either by biological digestion or through density separation. In biological digestion, the samples are treated enzymatically or chemically to remove organic substances from the collected samples. The density separation method involves the fractionation of low-density and high-density natural particles. The visually identified microplastics are then exposed to various spectroscopic techniques such ATR-FTIR, Raman spectroscopy for the identification of compositional characteristics of microplastics. Thermal analysis such as DSC, TGA, Pyro GC-MS may also be employed for the identification of microplastics based on thermal stability and degradation characteristics.

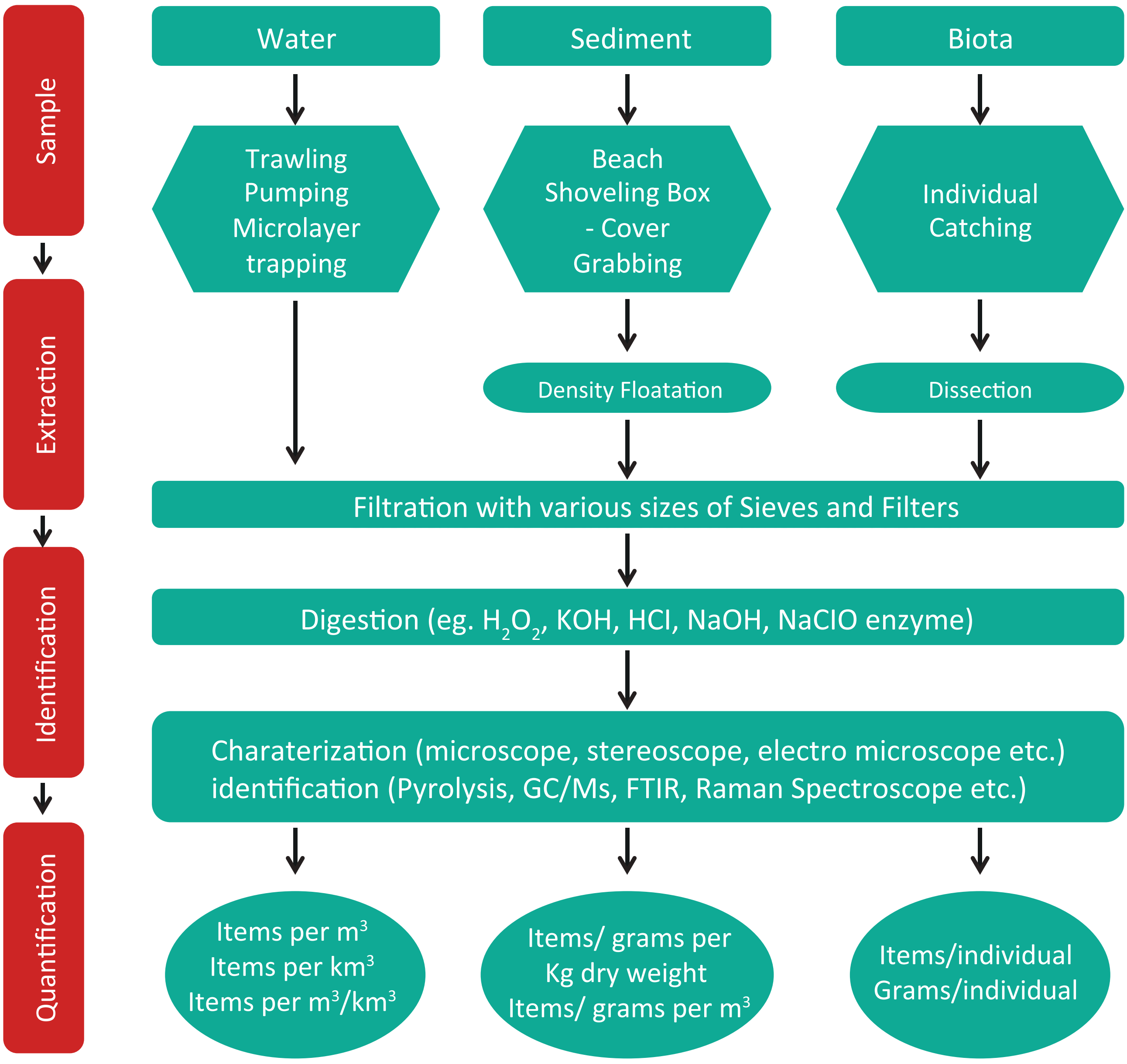


Figure 9 *Overall methodology of microplastics assessment*

Chapter 6
ENVIRONMENTAL MONITORING (INTERNATIONAL)

6.1 Environmental monitoring of plastics of Macro- and Microplastics

Monitoring of environmental plastic contamination is high on the international agenda. UN Member States, Regional Seas Conventions, and International Organisations are currently ratifying policy instruments and implementing monitoring programs in response to several international directives. Several regional, national, and local action plans for marine debris have now been developed under the UNEP Global Partnership on Marine Litter. There are a range of national and international monitoring programs and surveys that are commissioned by national environment agencies or conducted as part of collaborative research projects spanning different environments (marine, riverine, lacustrine, terrestrial), matrices (water, sediment, biota, soils), and plastic types (microplastic, macroplastic, litter). The chapter outlines the environmental monitoring activities conducted by several international organisations, working groups, and initiatives that focus on the marine environment and floating litter, beach litter, and microplastics. It also summarises internationally funded collaborative research projects (current and future) related to the monitoring of macro-, micro-, or nanoplastics in the environment.

Due to the relative infancy of environmental monitoring efforts related to plastics and a lack of harmonised methodologies or standards, much of the current activities have taken the form of establishing technical guidelines or undertaking baseline or 'one-off' surveys. There has been a lack of monitoring activities that extend across large spatial or temporal scales making it difficult to conclude about the relative contributions from different sources of environmental contamination, and the different controls on the accumulation or transport of plastic, such as hydrological or meteorological conditions. Appropriate, validated, and harmonised approaches should be developed amongst the different actors to ensure that forthcoming activities are efficient, meaningful, scientifically robust, and comparable at an international scale.

6.1.1 Macroplastic

Early monitoring efforts focused largely on plastic contamination in the 'macro' range (>25 mm), under the remit of surveying marine litter. Large efforts have been made since 2000 by OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic) to harmonise methods for recording plastic waste collected during beach cleans for the North East Atlantic region **(OSPAR Commission 2007; OSPAR Commission 2010)**. Beach monitoring has also been conducted in many global regions, under different local, national, and international schemes. In addition to beach litter, macroplastics floating in the open ocean and in the Great Lakes of North America have been surveyed by international organisations.

Projects initially focussed primarily on macroplastic contamination (2013-2016), but recently, macroplastic monitoring has dropped from the focus of these international research projects. However, the work of developing, refining, and harmonising methods for macroplastic sampling and analysis is reflected in the work programme of the EUROqCHARM project, which addressed a specific European Commission H2020 call related to the improvement and standardisation of methods across the spectrum of environmental plastic contamination.

Macroplastic has also received renewed focus in the international research papers that estimated significant volumes of plastic waste released from rivers into the ocean (**Jambeck et al. 2015**); monitoring of riverine transport of macroplastics and develop methods for measuring plastic flows **(van Emmerik et al. 2018; Geraeds et al. 2019)**. This work must now begin to identify and quantify source inputs and establish the controls on macroplastic transport and accumulation.

6.1.2 Microplastic

Guidelines for microplastics (or 'microlitter') monitoring have been developed by several international organisations and working groups **(Michida et al., 2019).** Monitoring surveys have been already undertaken by NOAA (National Oceanic and Atmospheric Administration), HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission), and CPPS (Permanent Commission for the South Pacific). This is also supplemented by a suite of monitoring programmes conducted across the world, operated by national research councils, environmental protection agencies, or non-governmental organisations, such as on mapping microplastic distributions, and have progressed towards solutions for reducing releases or mitigating contamination.

International collaborative research projects on microplastics initially focussed on establishing baseline assessments and developing sampling and analytical methodologies (e.g. BASEMAN, BLASTIC) and has progressed to include a wider range of environments (e.g. terrestrial environments covered in IMPASSE), smaller particle sizes (e.g. ANDROMEDA, FACTS), and greater harmonisation of monitoring approaches (e.g. EUROqCHARM). As observed for macroplastic monitoring, these international collaborative research projects remain largely European in focus and the findings from these projects should be adapted for wider geographic contexts, including specific regional settings, except one-off or baseline surveys of microplastic contamination presented in the scientific literature. The scientific literature is also expanding to consider more advanced research questions within the monitoring of riverine microplastic contamination. These developments currently exist for isolated examples. A holistic approach to future riverine microplastic monitoring should address several of these points within a single coordinated programme.

6.2 Sampling and analysis of Macro- and Microplastics

6.2.1 Macroplastic

Some guidelines have emerged from international working groups that review and assess methods for monitoring macroplastic in riverine environments. Several approaches have now emerged and been applied in the scientific literature: visual observation of floating or visible sub-surface macroplastic along all or part of a river cross-section **(van Emmerik et al. 2019b);** use of unmanned aerial vehicles or cameras to assess floating or visible sub-surface macroplastic along all or part of a river cross-section; use of nets to collect macroplastic that is close to the water surface or suspended in the water column; use of booms or trash racks to physically intercept floating or subsurface macroplastic across the whole or part of the river cross-section; use of data from waste collection schemes that are already in operation as part of river cleaning activities **(Rech et al. 2015; Lahens et al. 2018; Kiessling et al. 2019)**. As of now, no single approach to sampling and analysis of macroplastic in rivers has emerged as the optimum strategy.

The above approaches do not represent a 'perfect' solution for gaining a complete, representative snapshot of riverine macroplastic contamination. Hence, it is likely that multiple methods should be utilised within a monitoring programme to capture the full range of macroplastic contamination. Also, there is a need for more complete validation of the monitoring methods and better integration of quality assurance and quality control (QA/QC) in monitoring and reporting. Further, one of the primary issues associated with the analysis of macroplastic contamination in the marine environment has been the heterogeneity in categorisation and data formats or handling **(Addamo et al. 2018)**. This should be addressed through thorough training of analysts undertaking the monitoring activities, the use of harmonised procedures and materials for data collection and analysis, and validation of the successful identification and categorisation of macroplastics using simultaneous deployment of a physical interception method to confirm results.

6.2.2 Microplastic

No standard methods exist for investigating microplastic contamination. Standardisation of approaches to microplastic sampling and analysis can be challenging, given the scales involved; variations necessitate a different suite of methods for sampling, sample preparation, and analysis. It is certain that no single standardised methodology will emerge as the optimum approach for all microplastic monitoring. Tailored methods suitable for specific applications or research questions can co-exist, relying on thorough reporting of methodological detail to allow for comparability and reproducibility **(Cowger et al. 2020)**. Several optimised and validated methods have now been published in the scientific literature for different components of microplastic sampling and analysis **(Courtene-Jones et al. 2017; Quinn et al. 2017; Hurley et al. 2018)**. Common approaches to the sampling of microplastics in monitoring activities include the use of nets, pumping systems, grab or scoop samplers, and cores. These should be selected based on the specific research questions and may also be further adapted to ensure collection of a representative sample. There are often trade-offs to consider **(Liedermann et al. 2018, Lindeque et al. 2020)**. It is also important to maintain good contamination control practices during sampling, because up to 15% of microplastic fibres in a sample can derive from the apparel of those involved in taking the samples **(Scopetani et al. 2020)**.

Although there is no single standard method for analysing microplastic samples, there are some commonalities in the approaches to microplastic analysis. Techniques for removing or reducing organic material include alkaline hydrolysis (e.g., 10% KOH at 40°C), Fenton's reagent, peroxidation (e.g. 30% H_2O_2 at 40°C), or enzymatic digestion (e.g. proteinase, cellulase, chitinase, etc.), depending on the type of organic material present in the sample. All methods are generally adjusted to account for sample type, sample size, expected microplastic concentrations, and the associated research questions.

The chapter summarizes the studies that have critically reviewed the approaches to the sampling and analysis of microplastics in the scientific literature and compiled recommendations for ensuring a high standard of quality in all stages of investigation. Representativeness of sampling and subsampling, appropriateness of methods for sampling and analysis, reduction or prevention of extraneous sample contamination (e.g., from background or laboratory contamination sources), and inclusion of QA/QC practices are important.

The need for harmonised definitions, methods, and materials for microplastic analysis has been highlighted by several international working groups and researchers. The chapter puts together four interlaboratory calibration exercises (ILCs) as a tool to address the analytical component of microplastic studies. To maintain good QA/QC practices and ensure harmonisation between different laboratories, ILCs should become a regular feature of projects and international initiatives to review detection efficiency and comparability of results.

Chapter 7
HEALTH, EXPOSURE AND RISKS FROM PLASTIC POLLUTION: A REVIEW

7.1 Routes of exposure (micro, macro, plastic-borne chemicals)

Plastic has found a place in households across all socio-economic strata as well as all geographical landscapes. As a result, subsequent quantities have been accumulated in the natural environment and landfills. It is estimated that plastic comprises 10% of the municipal waste stream **(Barnes et al., 2009).** Accounts of plastic pollution range from contamination of soil and agricultural lands by the spread of sewage sludge and irresponsible disposal in surrounding areas **(Piehl et al, 2018**), accumulation of plastic in waterfalls and riverine tributaries **(Mukhopadhyay et al, 2020**), plastic pollution on mountain tops **(Allen et al, 2019**), and transport to sea by rivers, rainwater and flood events **(Lebreton, 2017**). However, accounts of the effect and quantities of plastic in terrestrial habitats and freshwater are limited and most information available is from the domains of natural and marine sciences.

7.1.1 Macroplastics

There are various sources for accumulation of plastic in the environment, including direct dumping and dropping of litter on land or at sea, overflow from landfill sites, open drains, and loss in transport and accidents. Large rivers release a substantial amount of plastic debris to the marine environment because of high flow rate and strength of the current at the bottom. As reported, 40-80% of mega and macro marine debris items are plastic, included carry bags, packaging items, footwear, sports equipment, etc. **(Barnes et al., 2009).** The scale and pattern of distribution of large plastic fragments in the ocean environment depends on the wind and current conditions and the coastline geography. Gujarat is found to have the third highest mean quantity of beach litter among Indian States with a recorded 90.56 g/m, that be correlated with heavy industrial activity in the state **(Kaladharan et al., 2017).** Macroplastic and microplastic accumulation hotspots in the ocean, known as gyres, comprise plastic debris originating from both sea and land-based sources and subsequently transported to subtropical waters (**Li et al., 2016). Lebreton, Egger and Slat (2019**) developed a global model of ocean plastics from 1950s to 2015, to better understand the accumulation pattern of plastic waste. They deduced that a vast majority – 82 million tons of macroplastics and 40 million tons of microplastics - is present along the world's shorelines. Ingestion of plastic has been documented for at least 233 marine species, including all marine turtle species, more than one-third of seal species, 59% of whale species, and 59% of seabirds **(Kühn et al., 2015).**

7.1.2 Microplastics

Microplastics comprise of either manufactured plastics of microscopic size below 5 millimeters in length, such as scrubbers and industrial pellets that serve as precursors for manufactured plastic products (primary sources), or fragments or fibers of plastics derived from the breakdown of larger plastic products (secondary sources). These particles are degraded by UV light, oxidation and physical abrasion into 'micro' particles. Variable factors that influence the formation of microplastic by degradation are environmental exposure conditions, polymer properties such as density and crystallinity and the type and quantity of chemical additives (**Lambert et al., 2018**). Microplastics are tiny plastic pieces, barely visible to the naked eye. A 2017 study by the United Nations Environment Programme (UNEP) concluded that 1.5 million tons of microplastic enters the oceans every year.

Plastic polymers persist in the environment due to resistance to micro-organismic degradation. Their distribution in the marine environment is influenced by the density of the particles, location of the sources and conveyance with ocean currents and waves. Some microplastics tend to sink, and some are likely to float in marine waters. The buoyant and persistent nature of microplastics allows them to become easily and widely dispersed via hydrodynamic processes and ocean currents. This is a major hindrance in effective management and understanding of microplastics, as their sources remain difficult to trace (**Auta et al., 2017**).

7.1.3 Plastic borne chemicals

It has been documented that organochlorine pesticides such as dichlorodiphenyl trichloroethane (DDTs), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) are found on microplastics sampled from the sea. Heavy metals such as aluminum (Al), copper (Cu), silver (Ag), zinc (Zn), lead (Pb), iron (Fe) and manganese (Mn) have also been detected on plastic production pellets sampled in the seawater (**Auta et al., 2017**). The extent of chemical pollution via microplastics can be evidenced by data, which suggests that global concentrations of POPs in marine plastic pellets range between 1–10,000 ng g^{-1} (**Ogata et al., 2009**). Adsorption of hydrophobic chemicals on plastic substrates leads to the formation of concentrated mass of debris. These aggregates act as a 'sink' for other chemicals, thus providing a protective niche for microorganisms and adsorbed pathogens. Given that Sewage Treatment Plant (STPs) release partly treated effluents into sea in the coastal areas, this leads to further accumulation of disease-causing pathogens and micro-organisms. This combination of both microbial and chemical agents onto plastic potentially increases the risk to consumers if fish, crustaceans, or shellfish are contaminated and then consumed (**Waring et al., 2018**). Chronic exposure to these chemicals takes place majorly via dietary routes by consumption of foods such as fatty tissues of animals and edible oils.

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

7.2.1 Environmental Risk

The environmental effects of plastic pollution in the marine environment may be irreversible. Plastics/ microplastics are a heterogeneous class of pollutants with a wide range of individual characteristics such as particle size, material type, and shape. These diverse material characteristics make them available to a broad range of species like neustonic, pelagic or benthic species. This enables microplastics to penetrate aquatic food webs at multiple trophic levels and ecological niches. Microplastics, upon ingestion by marine organisms, may cause physical and chemical harm. The consumption of microplastics by marine organisms may cause mechanical effects such as attachment of the polymer to the external surfaces thereby, hindering mobility and clogging of the digestive tract, or chemical effect such as inflammation, decreased growth and hepatic stress. It can also lead to reduced food consumption due to satiation (malnutrition or even starvation) **(Auta et al., 2017).** Plastics serve as an effective substrate for sessile species (e.g. tube worms, barnacles and bivalve molluscs) as well as a temporary platform or raft for motile organisms. Plastic has been found to host viruses, harmful algal bloom species, and microbial communities, increasingly recognized as the 'Plastisphere'. It is a vector for transport of alien invasive species and POPs that may be ingested in concentrations much higher than the ambient seawater. Colonization of algae and bacteria (on a plastic substrate) allows them to travel across biomes thus potentially increasing their bio-geographical range. As a result, each plastic particle, regardless of its size has the potential to transport living organisms and to redistribute harmful substances, altering ecosystem functioning, composition and genetic diversity **(Villarrubia-Gómez et al., 2018) (Beaumont et al., 2019).** Ecological processes, from sub-cellular to ecosystem level, can be impacted in many ways by marine plastics. High microplastic intake has been found to have adverse outcomes on fecundity, energy allocation and reproduction (among other impacts) in oysters and copepods.

7.2.2 Human Risk

Before plastic reaches consumers, and long before it reaches the environment, severe human health effects are evident in the initial stages of the plastic lifecycle—fossil fuel extraction and transport. Harmful pollutants emitted from oil and gas operations such as drilling, piping, and transportation is believed to impact the respiratory, circulatory, reproductive, neurological, immune, and digestive systems, in addition to the eyes and skin. 37% of the chemicals used in the pre-production process called 'fracking' are suspected endocrine disruptors such as benzene, toluene, ethyl benzene, and xylenes.

The main routes of human exposure to microplastics are as follows: a) Microplastics from cosmetics, paints, coatings, inks and tyres that are ingested by various marine organisms. b) Microplastics from soil and freshwater including in locations used as a source of drinking water is particularly concerning if plastic particles can pass through the filtration systems of wastewater treatments. c) Humans can get exposed to microplastics through direct consumption of food items containing them such as honey, beer, salt or indirect consumption of toothpaste or scrubs. d) Fibers from clothes and fragments from abraded plastic sheets and tyres form a major part of airborne plastic pollution. These microplastic particles may be inhaled by humans and transported to the lungs with concerning yet unknown health impacts.

Less visible but more severe is the pollution generated in the process of production of plastic resin and polymers. During polymerization of ethylene, the reactive mixture is scrubbed with dilute aqueous caustic solutions that become high-volume pollutants. Major emissions from plastic production processes include sulfur oxides, nitrous oxides, methanol, ethylene oxide, and volatile organic compounds. Workers involved in the production are exposed to these chemicals largely through the process of heating materials to make them more pliable for creating plastic products. Chemicals released include hazardous monomers such as styrene, vinyl chloride, acrylonitrile, bisphenol A (BPA), and formaldehyde. These chemicals have been labeled as carcinogens or endocrine disrupting chemicals (EDCs); their exposure can lead to liver damage, mammary gland tumors, lung cancer, ovarian cysts, endometriosis, and breast cancer, among others. Further additives, including plasticizers, flame retardants, and metals, used in plastic production have similar carcinogenic and endocrine-disrupting health impacts. Diseases resulting from these chemicals are often diagnosed years after exposure and are thus not reflected in industry reports to the government **(CIEL, 2019)**.

Consumers of plastic products are also susceptible to exposure to toxic elements. Most of the plastic additives are not bound to the polymer matrix, and due to their low molecular weight, they easily leach out of the polymer into the surrounding environment, including air, water, food, or body tissues. Migration of chemicals from food packaging into food and beverages is considered the main source of human exposure to contaminants associated with plastic. Common migrant chemicals from food packaging plastics are DEHA, BPA, Phthalates, Styrene, 4-Nonylphenol. *Orb Media* conducted a study on tap and bottled water; the tap water study showed 83% contamination with 98% of the particles being microfibers while bottled water revealed 93% contamination with only 13% of the particles being categorized as microfibers.

7.2.3 Societal Risk

Marine workers and tourists are susceptible to injuries due to plastic pollution such as getting entangled in nets, cutting themselves on sharp debris and being exposed to unsanitary items. (**Beaumont et al., 2019**) Charismatic species such as turtles, sea birds and cetaceans (whales, dolphins) hold a significant emotional and cultural importance to humans; just their safety and presence are found to be linked to human well-being. As a result, accounts of sub-lethal effects of plastic on these species in the media and spending time at littered coastlines has also been demonstrated to be detrimental to the mental health and mood of humans **(Beaumont et al., 2019).** Studies also point to consequent economic effects of plastic pollution, such as income loss for fishermen due to plastic debris, loss of tourism revenues and damage to marine industries, which subsequently have socio-economic consequences (**Kramm et al., 2018**).

This chapter address the toxic chemical additives like Bisphenol A, Acrylonitrile, Cadmium, Flame retardants, Phthalates, Styrene (also known as Vinyl Benzene), Vinyl Chloride, Lead and Perfluorinated Substances (PFAS), the products in which they are found, and their impacts on society.

7.3 Overview: Inter-linkages between plastics and POPs

Plastic resin pellets in oceans and seas around the world have been found to contain different POPs, such as HCHs and DDTs **(Ogata et al. 2009).** Electronic and electrical waste recycling in many developing countries like India is another major source for the release of plastic associated POPs such as flame retardants or dioxins (**Chakraborty et al., 2017; 2018**). Plastics associated with electronic items are either discarded or burnt to recover valuable metals and in general mishandled, leading to the emission of POPs from e-waste into the environment **(Chakraborty and Sampath et al., 2018**) **(Figure 10**). Particularly, liquid and gaseous emissions of these compounds occur simultaneously upon crude recycling of e-waste (**Sepúlveda, Schluep et al. 2010).** After plastic materials are released into the environment, they are highly persistent **(Thompson, Olsen et al. 2004**).

Plastic as a matrix can contain various types of POPs because of any combination of the following:

- Chemicals added directly to the plastic during the production process to give it a certain property (additives such as flame retardants, UV stabilizers, etc.)
- Unintentional chemicals from production processes including monomers which may originate from UV irradiation of the plastic.
- Chemicals that arise in the plastic recycling process
- Hydrophobic chemicals that are adsorbed onto the surface of the plastic from ambient environmental pollution in water bodies.

Microplastics have previously been assumed to act as a vector for hydrophobic organic compounds (HOCs) within natural environments through the sorption of these contaminants to the microplastics which can release additives. As per **VKM Report (2019)**, contaminant transfer is bi-directional and

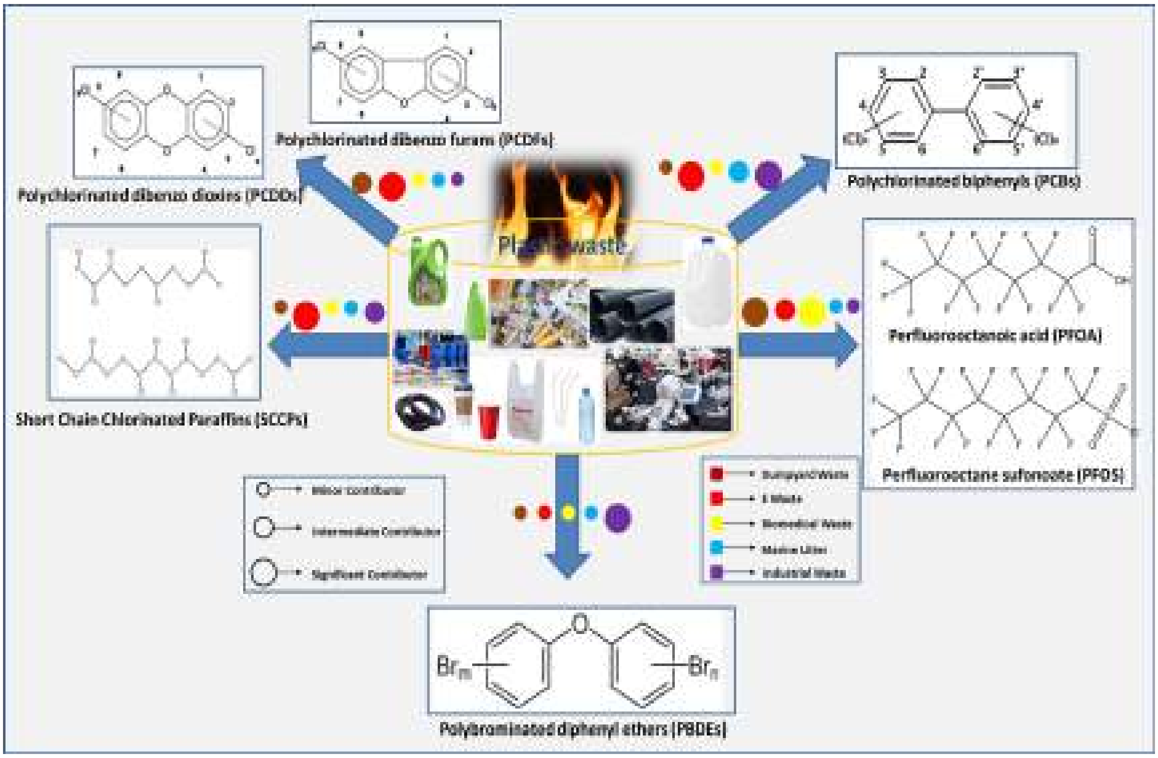


Figure 10: *Linkage between POPs and plastic waste*

can alter (increase or decrease) contaminant body burden depending on polymer type, environmental conditions and chemical fugacity gradients. The relative importance of nano- and microplastics as carrier of HOCs is estimated to be low compared to other media. Whatever be the origin, plastics do contain POPs and they should be viewed as vectors that may carry POPs to faraway places via long range transport. These tiny particles of plastic are readily mobilized by air as well as water. These are the causes that have led to a growing number of studies that are exploring the link of plastics as a source of POPs pollution in the ocean.

Given the existing studies on improper disposal and management of plastic waste, POPs arising from plastic as a medium have been condensed under 5 major categories (dumpyard waste, e-waste, biomedical waste, marine litter and industrial waste) based on the major sources of plastic waste (like PET, HDPE, LDPE, PVC, PP, PS, HIPS, ABS, PC). The chapter illustrates the various types of POPs associated with some of their common use in different commercial and industrial products.

7.4 Human, societal, and environmental risks associated with plastic and chemical interlinkages

Typically, in developing countries, except for marine litter, uncontrolled burning/incineration remains the key factor for some of the harmful effects from typical waste categories like dumped, electronic, biomedical, and industrial wastes. Given the ubiquitous nature of plastic, it invariably ends up in the waste and when poor waste management systems aided with a complex waste stream, mishandling happens. For example, emissions of PCDD/Fs as a result of informal e-waste recycling has been established **(Chakraborty and Selvaraj et al., 2017)**. Persistent organic pollutants and other chemicals released from plastics pose a threat to the environment and human health. Open burning of dumped waste, untreated wastewater and storm-water are reported to be the main sources of both BPA and PAEs in riverine sediments **(Mukhopadhyay et al., 2020)**. Effluent outfall from STPs, untreated wastewater discharge from industries and domestic sources were related to higher percentage of Non-steroidal Anti-inflammatory Drugs (NSAIDs) and preservatives in urban and suburban sites **(Chakraborty et al., 2018)**. The sheer number of additives that can be added to plastic and the lack of a universal production process makes it extremely difficult to predict the chemical makeup of plastic. With this uncertainty, there is a possibility of human exposure to even more harmful yet unknown compounds. This chapter presents the plastic and associated chemicals like PVC, DEHP, DINP, PC, PS, PE, PET, PP, Polyurethane Foam, Acrylic, and Tetrafluoro-ethylene, their usage, and health impacts.

Chapter 8
GOOD PRACTICE IN PLASTIC WASTE MANAGEMENT: INDIAN AND GLOBAL CASE STUDIES

8.1 Objective

The chapter aims to document a range of case studies from India and best practices globally within the domain of plastic waste management, ranging from collection to recycling including policy measures to curb plastic litter at a local, regional and national levels. The international best practices documented are carefully chosen to be relevant to the Indian waste management context. The chapter covers case studies on plastic waste collection practices, plastic recycling schemes and good practices, and policy intervention to reduce plastic waste and pollution at a regional and country level, as illustrated in Figure 8.

8.2 Case Studies on Plastic waste collection practices

The section provides descriptive case studies of the best practices adopted in 4 Indian cities – Panjim, Ambikapur, Indore and Madukkarai and reports them in detail. In addition to these Indian examples, the chapter explores waste collection practices in Hernani City in Spain and in San Francisco in United States of America.

In India, accelerated urbanization has posed serious challenges to waste management. Many Municipal corporations in the country are still grappling with identifying the right approach to its sustenance. One of the major problems has been to operationalize source segregation that is one of the most obvious yet pertinent steps towards handling waste effectively. Its implementation has been challenging and limited to a few cities considering vast expanse of area, population and social diversity. Despite these challenges, source segregation at household level in India is nearly 74.82% in the year 2020 according to "Swachhata Sandesh Newsletter" (Cleanliness Message), by the Ministry of Housing and Urban Affairs (MoHUA) **(Singh, 2020)**.

The 4 Indian cities documented in this section have achieved 100% source segregation by implementing vigorous waste collection practices. In Panjim, waste is collected after five-way segregation with the help of colored bins. Collection of waste in Indore is also carried out in 3 segregated streams. In Ambikapur and Madukkarai, segregated waste is collected by women self-help groups, rather than the corporation itself like in the case of former two cities. In all four cities, the segregated dry waste is sent to material recovery facilities where it is further segregated and sold to waste aggregators for recycling.

The two global case studies include that of Spanish city Hernani and San Francisco in USA. The rationale behind including these cities was their relevance

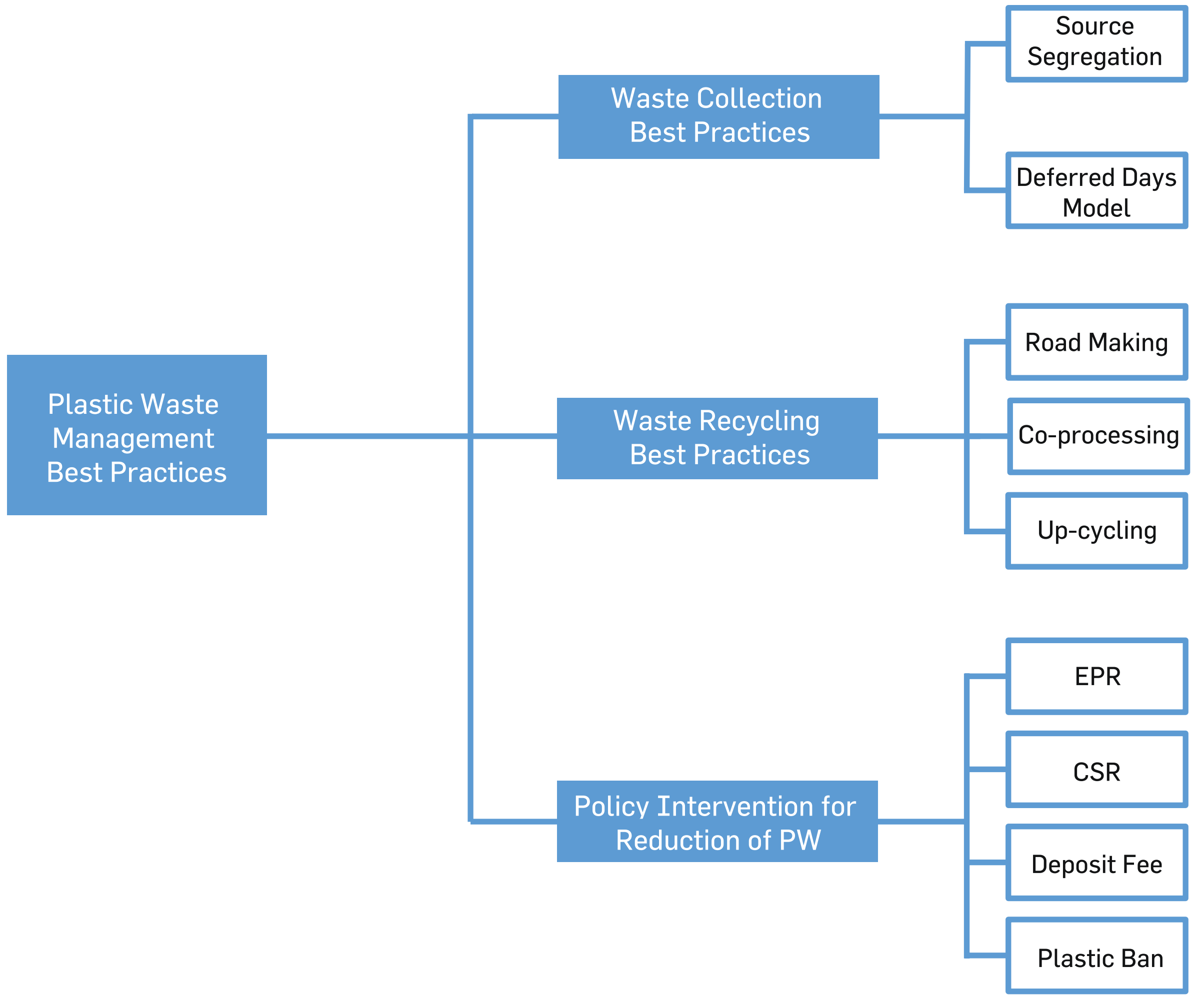


Figure 11: Overview of best practices covered in this chapter

to the Indian context. Hernani, being a small town, has achieved excellent segregation levels, courtesy their unique waste collection strategy of designating different days for the collection of different waste streams. San Francisco, being a metropolitan city has adopted a different approach of waste collection by partnering with a private waste management company called Recology. The waste is segregated into 3 streams at source and the collected dry waste is sent to a material recovery facility (MRF) where it is further segregated into 27 categories. Both these cities have successfully curbed the amount of plastic being littered through improving their waste collection process.

8.3 Plastic waste recycling schemes and good practices

This section of the chapter explores innovative ideas along with technological interventions that have been adopted in Indian and global scenarios to minimize the harmful effects of plastic waste. The various technological interventions include down cycling of plastics into road making and energy generation. Innovative ideas include recycling plastics into craft products and many more.

In India, plastic road making has been strongly advocated which requires bitumen to be mixed with 6-8% of plastic (**Ministry of Railways, 2019**). This not only provides an effective way of managing refused plastics, but also increases the durability and resistance of roads. Similarly, plastic co-processing in cement kilns has also been mandated by the Government of India. According to the Central Pollution Control Board (CPCB), 65 cement plants have been authorized for co-processing plastic and other hazardous wastes (**CPCB Annual Report, 2018-2019**). Along with technological interventions, several social enterprises have developed social inclusion programmes within waste management services, particularly focused on dry waste collection, recycling and livelihood generation. For example, Hasiru Dala is a Bengaluru based social impact organization works with waste pickers and other waste workers to ensure dignified livelihoods. It has launched several innovative and technological interventions such as the Fair Trade Plastic Recycling Initiative with The Body Shop and the Plastic for Change mobile app to name a few. Hasiru Dala's innovations provide circular and responsible waste management solutions for the disposal of urban waste while empowering waste pickers (**Business India, 2020**). SAAHAS is another non-profit organization that focus on source segregation and decentralized waste management. SAAHAS provides waste-to-resource solutions to waste management by collecting and transporting segregated dry waste which is sold to recycling companies. Both these initiatives have achieved decentralized waste management in their cities and hence make a notable case study, which can be replicated in other parts of the country as well.

While selecting the global case studies for this section, emphasis has been on including schemes that facilitate innovative handling of plastic waste and also the ones that avoid marine plastic littering. Marine litter is a grave concern and a massive threat to our ecosystem. Several projects have been launched to improve the situation of marine littering. One such project is the Project STOP – a project with multiple partners (The Alliance to End Plastic Waste, Borealis, SYSTEMIQ, Nestlé, Government of Norway, NOVA Chemicals and Borouge) launched in Indonesia to curtail plastics from entering the water bodies. This project has adopted a "System Change Scenario" to avoid the leakage of plastics into the marine ecosystem (**World Economic Forum, 2020**).Another project to minimize the menace caused by plastics in marine systems is witnessed in Gambia. Launched by WasteAid and UK Aid, this project has helped the coastal town of Gunjur, Gambia to capture nearly one million plastic bags in a month and upcycle it to make floor tiles out of them (**WasteAid, 2019**). In Tunisia plastic packaging waste is collected with the help of a national public system called ECO-LEF. Under this system, plastic waste is collected by small companies who buy this from informal collectors and immediately pay them on the basis of weight. These smaller companies then sell the recyclables to authorized recyclers. In 2018, 3,400 tonnes of plastic waste were collected and recycled under this program in Tunisia (**Chaabane et al., 2019**). The city of Kamikatsu in Japan has established a plastic waste recycling scheme called Kuru-Kuru Shop (Circular Shop), where locals can drop off items they no longer require and pick any of the items already present in the shop free of cost, enabling source reduction. Furthermore, they have also established Kuru-Kuru Craft Center where residents make products out of discarded materials and sell for a very low price (**GAIA, 2019**).

8.4 Case Studies to reduce plastic pollution at area, regional and country level

This section primarily focuses on interventions to mitigate plastic pollution at the country, regional and area levels. National and global case studies included in this section reflect the collaborations and efforts of public and private sector to minimize the plastic waste pollution.

In India, the Ministry of Environment, Forest and Climate Change (MoEFCC) has laid down Plastic

Waste Management Rules, 2016 (a. 2018) that provided the national framework for the management of plastic waste. The rules states that all plastic bags are required to comply with the minimum 50-micron thickness levels. The rules also define the role of extended producer responsibility (EPR) in managing plastic waste in India. The guidelines to implement EPR was released by the same Ministry in 2020, excerpts of which have been broadly included in the chapter. At regional level, several Indian states have independently taken measures to limit the generation of plastic waste. As many as 29 Indian states and UTs have imposed complete/partial plastic ban **(CPCB Annual Report, 2018-2019)**. This chapter talks about two Indian states (Sikkim and Maharashtra) that have implemented such bans and how the citizens of those states reacted to these bans.

Globally, one of the best practice recorded in this segment is that of Palau – a small island of Micronesia. This country has not only improved the condition of plastic waste management, but also financially benefitted from it; courtesy their Beverage Container Recycling Regulation. Under this regulation, they charged a deposit fee of 10 cents on every imported beverage bottle/container, which was redeemable by the consumers upon depositing the bottle to the material recovery facility. This program has helped Palau retrieve 90% of the used beverage containers in 2018 **(Bureau of Public Works, 2019)**. Another international case study on reducing plastic waste is from USA, where beverage giants are exercising CSR by collaborating with the federal government under the "*Every Bottle Back Initiative*". The primary aim of this initiative is to reduce the usage of virgin plastics and upscale the collection and recycling of PET bottles **(American Beverage. n.d.).** Commissioned by American Beverage Association, this initiative forces the collaboration of fiercest beverage rivals – Coca-Cola, PepsiCo and Keurig Dr Pepper, along with World Wildlife Fund (WWF).

Chapter 9

GAP ANALYSIS IN THE BASELINE REPORT

This chapter highlights the existing limitations and challenges within monitoring and assessment methodologies of plastic particles (macro and micro), as well as plastic waste management approaches and capacities, with an emphasis on the project case study areas in India. The INOPOL project aims to address some of these gaps by providing state-of-the-art science-based approaches, knowledge exchange, training and policy input to strengthen local and national capacity to ultimately mitigate the environmental threats posed by plastic and chemical pollution. The identified gaps have been compiled within analytical themes to demonstrate key areas where INOPOL may contribute to reducing gaps through knowledge generation, exchange and capacity building. This gap analysis report is structured as follows: Data limitations, knowledge gaps, policy and regulatory gaps, infrastructure and capacity gaps, technological gaps and socio-economic impacts. Due to the unprecedented and dynamic impacts of COVID-19 pandemic, the INOPOL project also engages with the impacts of the pandemic on the plastic waste management scenario.

9.1 Data limitations

- The data from the Central Pollution Control Board (CPCB) are based on information provided by State Pollution Control Boards (SPCBs). SPCBs capacity to collect and produce reliable data varies from State to State. The INOPOL baseline study was not able to access the data collection procedure in the different States. There was insufficient evidence to estimate volumes of collected and uncontrolled waste going to landfills and remaining uncollected. Likewise, in the case study site, Gujarat, scientific evidence on plastic waste dumped in landfills is not known. Some studies from Surat (2011) showed that industries in Surat are major contributors to the city's plastic waste generation, but evidence is scarce on the volume of waste going into the recycling stream, dumped in landfills and/or ending up unmanaged in the environment. In Vapi, there was limited availability of evidence on waste generation (Chapter 4).
- The most common mechanisms to measure the amount of plastic waste generated by a city is through the amount received by the urban local bodies (ULBs) own collection channels which includes street sweeping and door to door household collection. This approach does not capture plastic waste that leach into the environment by being inadequately disposed of, including waste being illegally burned or openly dumped in the environment.
- Though the last population data is of Census 2011, the population and waste estimation figures have been mathematically projected to arrive at near realistic estimation which would make a considerable difference in estimations.
- The informal sector is responsible for recycling significant amounts of waste in India, yet there is limited data and knowledge of informal recycling

structures' role and significance for plastic waste management (Chapter 3). Moreover, the waste generation data of SPCBs does not fully capture plastic waste collected and recycled through informal recycling channels. These factors form a persistent gap in estimates of national plastic waste generation and recycling (Chapter 2).

- The Plastic Waste Management Rules 2016 obligates recycling units of plastic material to register with the SPCB in their operating State. There are 1080 unregistered plastic manufacturing/recycling units running in 12 States/UTs, namely; Assam, Bihar, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Puducherry, Punjab, Tamil Nadu & Uttar Pradesh. (Chapter 4).
- Our baseline research found an inconsistency amongst sources in their interpretations of plastic waste collection and recycling data. In some instances, official estimates of waste generation per capita are not representable to reflect the rapid growth in plastic consumption and waste generation. While waste generation and recycling data are important parts of forming a baseline for further research, large grey areas need to be accounted for when interpreting numerical data on plastic waste generation, recycling and management. Standardised methodology for measuring plastic waste generation needs to be developed, including capturing unmanaged plastic waste that leaks into aquatic and marine environments. The INOPOL project addresses this gap by employing thorough experimental validation and assessment to interpret and quantify marine plastic litter (Chapter 4).

9.2 Knowledge gaps

- Standardised methods to record and register stranded macro-plastics exists and are mainly conducted through spectroscopic methods. In contrast to larger, visible types of plastic waste which can be subject to structural identification, sinking and invisible micro-plastics have received limited monitoring.
- Previous studies have sampled macro- and micro plastics from various beaches in Maharashtra, Karnataka, Goa, and Tamil Nadu. Ganga river and Vembanadu lake (in Kerala) have also received scholarly attention. However, there exists limited holistic knowledge on macro- and micro-plastic pollution (Chapter 5).
- Research attention has been particularly low in Gujarat State despite its industrial and political importance and its geographical connection to rivers and marine ecosystems. It is therefore significant that the INOPOL project works on developing knowledge and monitoring capacity particularly in these areas. Sample collection and analysis have been carefully developed by a team of researchers who hold expertise in sample methodology within the geographical scope of the project. Baseline data forms an important phase for the successful monitoring of plastic waste, which in turn, can drive the necessary political momentum and public awareness to reduce plastic pollution (Chapter 5).
- A shift in the research focus of the scientific community has been seen from macro-plastic (2013-2016) to micro-plastic (2016-2020) as the emerging contaminant of concern. However, there is a need to study both micro- and macro-levels of contamination simultaneously within a holistic approach to identify and quantify plastic inputs from land to river-systems and marine environments. There are few previous accounts of studies on macro- and micro-plastic contamination in India's lakes, rivers and marine environments. The need for a coordinated and comprehensive study in the Indian domain that deciphers the highly complex and dynamic riverine system and develops monitoring tools for plastic contamination has been recognized. The INOPOL project attempts to pervade this space with the aim to build knowledge and capacity to strengthen monitoring and management capacity

that prevents marine litter and microplastics pollution (Chapter 5 and 6).

- Microplastic and persistent organic pollutants (POPs) need to be studied in tandem to draw conclusions about their interlinkages and potential solutions for management of both. Considering the limited research for plastic-POPs interlinkages, the INOPOL project will provide a comprehensive and holistic view of both types of pollutants (Chapter 7).

9.3 Policy and regulatory gaps:

- The current regulatory and political systems in India have limited scope for improving waste management through market-based instruments. Perform, Achieve and Trade (PAT) for accelerating energy efficiency improvements has been highly beneficial in energy intensive industries. A similar scheme needs to be incorporated within the waste sector to strengthen compliance with ambitious yet achievable targets. Since supply and demand market mechanisms play a vital role in plastics, a systematic approach may lead to better management and increased revenue generation (Chapter 3).
- Circular economy solutions including concepts of EPR are increasingly gaining grounds within waste management strategies in India. Considering these concepts have been primarily developed in North America and Europe, these strategies may require adaptation to be applicable to suit waste management scenarios with a large presence of informal sector stakeholders (Chapter 3).
- Policy interventions are required to stimulate demand for recycled plastics to ensure viability of recycling streams and close the loop of the value chain. Current circular economy implementation focuses on select materials, products instead of suggesting the desired system changes to the economy (Chapter 3).
- Significant gaps between implementation strategies pursued within different waste handling policies in India has been identified. For example, the provision for EPR within the Solid Waste Management Rules (SWM Rules), 2016, and the Plastic Waste Management Rules (PWM Rules), 2016 (2018) differ; While the SWM Rules state that manufacturers and brand-owners shall provide financial assistance to local authorities for establishing waste management systems to fulfil their EPR, the PWM Rules do not mention the financial contribution to local authorities but direct manufacturers and brand-owners to collect waste through their distribution channel or the local body concerned. Such discrepancies pave the way for loopholes in enforcement of rules for better management of waste (Chapter 8).

9.4 Infrastructure and capacity gaps:

- The waste management system in India can be characterised by inefficiency, epitomised by the mass of plastic waste which is not reused, recycled nor effectively disposed. Waste dumpsites are commonly located near riverbanks making them particularly prone to release plastic pollution into the environment. The unavailability of environmentally sound collection and disposal points builds up under inadequate waste management infrastructure.
- Inefficient plastic waste disposal is often a consequence of inadequate infrastructure for segregation and collection. Many municipal corporations do not have adequate systems for plastic waste segregation and collection, and lack access to the technology and infrastructure needed to dispose of plastic waste in a cost efficient and resource efficient manner (Chapter 3).
- There are very few organised facilities for plastic waste management and recycling in India. Most cities lack a proper waste treatment system,

such as processing plants and sanitary landfill sites. This adds to the accumulation of large quantities of unsegregated waste (Chapter 5).

- The INOPOL project could play a key role in strengthening capacity to manage waste, particularly in developing monitoring tools, training programmes, raising awareness, and proposing waste management strategies, which can be utilized by the CPCB, SPCBs and ULBs to improve waste handling practices (Chapter 4).

9.5 Technological gaps:

- Co-processing of waste to energy plants has generally been emphasised as a success story for plastic waste recycling towards a circular economy. Technological challenges to this approach include plastic waste which is unsuitable for fuel use due to being contaminated by organic wastes. Co-processing efficiency is therefore highly dependent on the local waste management system which facilitates and incentivises segregation at source. While this is increasingly recognised as an important step to increase recycling **(Henam and Bandela 2020)**, this baseline report recognises a considerable need to change consumer behaviour and engage with industry to make long-term sustainable changes to plastic waste production and disposal. Activities and research under the INOPOL project will contribute to generating knowledge, awareness and capacity building. It should also be recognised that there are limited numerical data and evidence available on the wider implications of co-processing of waste, particularly in the Indian context. This research gap will require closer examination before promoting co-processing as a way forward for reducing unmanaged wastes. Particularly in the context of visions of a circular economy, co-processing of waste has commonly been promoted as a circular economy strategy, yet co-processing of waste is not considered optimal resource utilization (Chapter 3 and 4).
- There is a need to develop highly technological and locally applicable Circular Economy solutions to align socio-economic Sustainable Development Goals with plastic waste management strategies in India and other developing countries largely characterised by labour-intensive informal recycling environments.
- Bio-based polymers are gaining popularity as an alternative to single-use plastics. However, there are limited guidance on requirements and standardisation of what can be classified as biodegradable plastic alternatives. For example, more research is needed to understand if products labelled as 'biodegradable' will degrade properly under normal environmental conditions, and whether biodegradable items may adversely impact recycling process of normal plastics if mixed (Chapter 3).
- The amendment of PWM rules in 2018 included phasing out Multi-layered packaging (MLPs) on account of their non-recyclable nature. However, it is observed that replacement technologies are not available to manufacturers of products which use such packaging. Efforts are being made by industries all over the world to make MLPs recyclable without compromising on their properties to preserve food and maintain hygiene (Chapter 8).

9.6 Socio-economic impacts:

- Informal waste workers are vulnerable to livelihood insecurities and socio-economic marginalization. It has been recognized both globally and nationally that steps need to be taken to better protect the livelihoods of informal waste workers of this sector (Chapter 3). A significant part of reducing unmanaged plastic waste and pollution will be to find ways to sustainably bridge the gap between informal and formal recycling sectors (Chapter 4). There is particularly a need to better understand the material dimension of the informal sectors' role within plastic waste management, as well as how socio-economic impacts involved with informal plastic waste management in India are perceived and experienced at the lowest level of the recycling chain.

- Toxic emissions from plastic production processes and disposal mechanisms such as incineration may pose significant threats to ecosystems and human health. The adverse impacts of POPs associated with inadequately managed plastic waste is also a key concern. The interlinkages between plastics and POPs and its effects on the environment and human health is also a key issue of concern. Particularly, immediate and long-term livelihood risks must be explored and mitigated within the informal waste sector who work in direct contact with waste or live-in areas exposed to potentially hazardous emissions from inadequately disposed plastic waste (Chapter 7).

9.7 COVID-19 impacts:

- SARS 2-COVID 19 severely impacted every aspect of economy, environment and society in India. The waste management sector has been particularly affected, as cities have experienced an unprecedented growth in biomedical waste generation. At the same time, prolonged nationwide lockdowns have had disruptive effects on municipal waste management systems, particularly on its informal component which was prevented from operating during the lockdown.
- In the absence/shortage of informal plastic collection and recycling structures, larger quantities of unsegregated waste have been sent to landfills while livelihoods dependent on this type of work have been severely affected. At the same time, it is significant to recognize how informal workers and waste management networks have been weakened, as these play an important role as conduits of efficient plastic value chains and reduce the amount of unmanaged and landfilled recyclable waste and plastic pollution.
- Structural challenges that affect livelihoods in the informal waste sector workers have been particularly highlighted during the COVID-19 pandemic. These results suggest need for enhanced engagement with the informal sector assessing their exposure of economic and environmental risks, social recognition and visibility.

Chapter 10
WAY FORWARD

IThe INOPOL project will make result-oriented contributions to reduce chemical, marine litter and microplastics pollution in India. The researchcommencedby developing a comprehensive baseline for land-based sources of plastic pollution, including both micro and macro plastics. The compilation also gatheredexisting knowledge, data and research while identifying gaps within the spheres of plastic pollution and waste management, thereby providing rich material that has and will be used in project related activities. The baseline research will be followed and complemented by the following activities:

- Developing a data collection strategy
- Developing a sampling and analysis strategy
- Developing a monitoring strategy forplastic waste
- Developing policy notes and a Plastic Waste Strategy Report for Gujarat
- Capacity building and training

Developing a data collection strategy

The data collected during the secondary research stage will be fine-tuned and updated in accordance with inputs from stakeholder consultations. Primary data willalso be gathered throughinterviews, surveys andcollection of quantitative and qualitative environmental data.

Developing a sampling and analysis strategy

A standardized sampling and analysis strategy is important to collect data which is representable for the environments under investigation. The project aims to establish standard operating procedures (SOPs) for plastic pollution sampling. The project will also develop training materials to build knowledge and capacity for relevant stakeholders (e.g scientists, policy makers) to conduct microplastic sampling and analysis, including quality control and assurance measures.

Developing a monitoring strategy forPW

Monitoring is a critical component in the management of macro and micro plastic pollution and isa high priority issue with respect to both capacity building and implementation in India. The project will contribute to strengtheningmonitoring protocols, guidelines, and analytical methodologies,as well as training laboratory staff withinthe government and academic institutions in India.Existing macro-plastic monitoring contributes to understand the presence microplastic particles in the environment. The development of analytical methods for microplastics provides reliable data for their environmental and biological occurrences, and therefore plays an important role in the investigation of their distribution, temporal and spatial trends, environment fates and potential sources. Such quantitative analysis-based monitoring not only helps stakeholders to share responsibility according to the polluter-pays principle, but also provides vital information required by regulators. The project will develop manuals and guidance documents for macro- and microplastics monitoring and analysis,ready for application by government laboratories and other relevant stakeholders.

Developing a Plastic Waste Strategy Report for Gujarat

The accumulated knowledge arising from the project will be transformed into a format that is accessible and relevant for decision makers, thereby building capacity, awareness and providing actionable input to policy. This will continue throughout the project, with various publication formats for different target audiences (policy briefs, scientific commentaries etc.). The results will be ultimatelysynthesized into a plastic waste management strategy report for Gujarat state.The final combined products of these efforts will be a sector-specific road map for reduced marine-litter and microplastic pollution from land-based sources.

Capacity building and training

The key goal of the project is to build knowledge and capacity of different stakeholder groups, including experts and civil society, to reduce the releases of plastic and manage the impacts fromplastic pollution better.Adequate knowledge and awareness on plastic waste and microplastic pollution will be generated through the project's training and capacity building programs. To ensure maximum outreach, the major project stakeholders have been divided into three different groups which will be targeted separately:

1. Policy makers, industry, and enterprise managers, may need to take action against plastic pollution and new POPs and therefore must have a strengthened knowledge about different aspects of plastic and POPs pollution. *I.e. SPCB, CPCB, MoEFCC, MoES, ULBs, industry associations and specific enterprises*.
2. Technical experts involved in the project or working with related projects. Particularly important are laboratory personnel (especially in SPCB and CPCB laboratories), who must have sufficient knowledge about the challenges in plastic and POPs analyses and state of the art knowledge,as well asexperts working with environmental assessments, who need sufficient knowledge to evaluate the extent of a given problem (e.g. a contaminated site or an emission source). *I.e. SPCB, CPCB, MoEFCC, ULBs, NEERI, IIT Gandhinagar, research institutes, universities and private laboratories*
3. The community who will benefit immensely from science-based and balanced information about plastic pollution, POPs and related concerns. *I.e. NGOs, informal workers and civil society in general*. Furthermore, engagement and co-produced research with stakeholders like NGOs, informal workers, government, industry and civil society is important to map plastic waste networks, as well as identifying social and economic drivers, impacts and sustainable solutions.

Aspects such as environmental occurrences, source identification, fate, and behavior of macro and micro plastics in different environmental matrices will be included with case studies from India. Current research initiatives like the identification of cost-effective monitoring techniques and clean-up programs for contaminated sites will also be included.The training and capacity building programs will contributeto cover these aspects, to enhance capacity of stakeholders holistically on the ways and means to tackle plastic pollution and its impacts.

The INOPOL project will contribute to prevent and substantially reduce the scope of marine litter from sources in the catchment areas of rivers Tapi and Daman Ganga in the State of Gujarat, which are highly affected by petrochemical industries, refineries, thermal power plants, cement and rayon factories, and ship-breaking industries. It is also a major receiver and transport route for land-based plastic pollution. The knowledge and capacity of stakeholders, experts, and civil society would be built for reduction of releases and of the impacts of plastic pollution and the chemicals listed under the Stockholm Convention. By preventing and reducing marine pollution and hazardous waste in India, the project will improve infrastructure and systems for plastic waste management from land based sources; clean up and properly managewaste from the selected rivers; ensure sustainable production, use, and responsible waste management within the private sector; and strengthen national and regional instruments to prevent marine litter and microplastics. The project will thus also make a contribution in the pathway towards the SDGs, including goals 6, 9,12,14 and 17.

REFERENCES

1. 18 states have completely banned plastic bags: CPCB to NGT. Financial Express. 2019. Retrieved from: https://www.financialexpress.com/india-news/18-states-have-completely-banned-plastic-bags-cpcb-to-ngt/1655004/ last accessed on May 1, 2020
2. A European Strategy for Plastics in a Circular Economy. European Commission. 2018. Retrieved from: https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf last accessed on May 6, 2020
3. Addamo, A.M. et al. 2018. Marine litter database. Lessons learned in compiling the first pan-European beach litter database
4. Allen, S., Allen, D., Phoenix, V.R. et al. Atmospheric transport and deposition of microplastics in a remote mountain catchment. Nat. Geosci. 12, 339–344 (2019). https://doi.org/10.1038/s41561-019-0335-5
5. Annual Report 2018-2019. Ministry of Environment, Forest & Climate Change (MoEFCC). Retrieved from: http://moef.gov.in/wp-content/uploads/2019/08/Annual-Report-2018-19-English.pdf last accessed on May 1, 2020
6. Assessment & Quantification of Plastics Waste Generation in Major Cities. Central Pollution Control Board (CPCB). January 2015. Retrieved from: http://www.indiaenvironmentportal.org.in/files/file/Assessment%20and%20Quantification%20of%20Plastics%20Waste.pdf last accessed on May 8, 2020
7. Auta, Helen & Emenike, Chijioke & Fauziah, Shahul Hamid. (2017). Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions. Environment international. 102. 10.1016/j.envint.2017.02.013.
8. Barnes, D. K. A., Galgani, F., Thompson, R. C. & Barlaz, M. 2009 Accumulation and fragmentation of plastic debris in global environments. Phil. Trans. R. Soc. B 364, 1985–1998.
9. Beaumont NJ, Aanesen M, Austen MC, Börger T, Clark JR, Cole M, Hooper T, Lindeque PK, Pascoe C, Wyles KJ. Global ecological, social and economic impacts of marine plastic. Mar Pollut Bull. 2019 May;142:189-195. doi: 10.1016/j.marpolbul.2019.03.022. Epub 2019 Mar 27. PMID: 31232294.
10. Brazil: Challenges for the Future. Global Recycling. 2020. Retrieved from: https://global-recycling.info/archives/4155 last accessed on November 2, 2020
11. Bureau of Public Works. (2019). Solid Waste Management in Palau. Koror: Ministry of Public Infrastructure, Industries and Commerce. Retrieved January 10, 2021
12. Central Pollution Control Board (CPCB). (2019). Annual Report for the Year 2018-2019 on Implementation of Plastic Waste Management Rules. New Delhi Retrieved from: https://cpcb.nic.in/uploads/plasticwaste/Annual_Report_2018-19_PWM.pdf clast accessed on March 1, 2021
13. Chaabane, W., Nassour, A., Bartnik, S., Bunemann,

A., & Nelles, M. (2019). Shifting Towards Sustainable Tourism: Organizational and Financial Scenarios for Solid Waste Management in Tourism Destinations in Tunisia. Sustainability, 11(13). Retrieved January 8, 2021

14. Chakraborty P, Mukhopadhyay M, Sampath S, Ramaswamy BR, Katsoyiannis A, Cincinelli A, Snow D. Organic micropollutants in the surface riverine sediment along the lower stretch of the transboundary river Ganga: Occurrences, sources and ecological risk assessment. Environ Pollut. 2019 Jun;249:1071-1080. doi: 10.1016/j.envpol.2018.10.115. Epub 2018 Oct 29. PMID: 31146313.
15. Chakraborty P, Sampath S, Mukhopadhyay M, Selvaraj S, Bharat GK, Nizzetto L. Baseline investigation on plasticizers, bisphenol A, polycyclic aromatic hydrocarbons and heavy metals in the surface soil of the informal electronic waste recycling workshops and nearby open dumpsites in Indian metropolitan cities. Environ Pollut. 2019 May;248:1036-1045. doi: 10.1016/j.envpol.2018.11.010. Epub 2018 Nov 5. PMID: 31091636.
16. Chakraborty P, Selvaraj S, Nakamura M, Prithiviraj B, Cincinelli A, Bang JJ. PCBs and PCDD/Fs in soil from informal e-waste recycling sites and open dumpsites in India: Levels, congener profiles and health risk assessment. Sci Total Environ. 2018 Apr 15;621:930-938. doi: 10.1016/j.scitotenv.2017.11.083. Epub 2017 Dec 18. PMID: 29223911.
17. Closing the Loop- Scaling up Innovation to Tackle Marine Plastic Pollution in ASEAN Cities. United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP). n.d. Retrieved from: https://www.unescap.org/projects/closing-the-loop last accessed on May 6, 2020
18. CPCB report on compliance of Plastic Waste Management Rules, 2016. Central Pollution Control Board (CPCB). 12 October 2020. Retrieved from: http://www.indiaenvironmentportal.org.in/content/468734/cpcb-report-on-compliance-of-plastic-waste-management-rules-2016-12102020/ last accessed on April 6, 2021.
19. Courtene-Jones, W. et al. 2017. Optimisation of enzymatic digestion and validation of specimen preservation methods for the analysis of ingested microplastics. Analytical Methods 9(9), pp. 1437–1445. doi: 10.1039/C6AY02343F.
20. Cowger, W. et al. 2020. Reporting Guidelines to Increase the Reproducibility and Comparability of Research on Microplastics. Applied Spectroscopy, p. 000370282093029. doi: 10.1177/0003702820930292.
21. Deepthi, M V; RRN, Sailaja; Khan M, Ameen; Roy, Pratik; Chandrasekhar, Kaushik. (2018). TERI Analysis on Challenges and opportunities - Plastic Waste Management in India.
22. Development Plan 2035. Surat Urban Development Authority, 2017. Retrieved from: https://www.sudaonline.org/development-plans/development-plan-2035/ last accessed on April 5, 2021.
23. Excell, Carole. World Resources Institute (WRI). 2019. 127 Countries Now Regulate Plastic Bags. Why Aren't We Seeing Less Pollution? Retrieved from: https://www.wri.org/blog/2019/03/127-countries-now-regulate-plastic-bags-why-arent-we-seeing-less-pollution last accessed on May 6, 2020
24. Generation of Solid Waste. MNRE India. 2018. Retrieved from: http://www.indiaenvironmentportal.org.in/files/file/GENERATION%20OF%20SOLID%20WASTE.pdf last accessed on March 3, 2021.
25. Germany unveils 5-point plan to reduce plastic waste. DW. 2018. Retrieved from: https://www.dw.com/en/germany-unveils-5-point-plan-to-reduce-plastic-waste/a-46455503 last accessed on November 2, 2020
26. Global Alliance for Incinerator Alternatives (GAIA). (2019). Small Town, Big Steps: The Story of Kamikatsu, Japan. Quezon City: GAIA.

Retrieved January 6, 2021

27. Government of Gujarat, Budget Estimates. 2020. Retrieved from: https://financedepartment.gujarat.gov.in/Documents/Bud-Eng_1005_2020-2-26_199.pdf last accessed on May 11, 2020
28. Guidelines on Usage of Refuse Derived Fuel in Various Industries. Central Public Health and Environmental Engineering Organisation (CPHEEO), Ministry of Housing and Urban Affairs. October 2018. Retrieved from: http://cpheeo.gov.in/upload/5bda791e5afb3SBMRDFBook.pdf last accessed on May 12, 2020
29. Hasiru Dala Innovations provides responsible solutions for urban waste disposal. Business India. February 14, 2020. Retrieved from: https://businessindia.co/climatechange/hasiru-dala-innovations-provides-responsible-solutions-for-urban-waste-disposal last accessed on April 6, 2021
30. Henam, Sonia Devi & Bandela, Dinesh Raj. 2020. Recycling Plastics. Centre for Science & Environment (CSE). Retrieved from: https://www.cseindia.org/recycling-plastics-9713 last accessed on April 6, 2021
31. How the Indian state of Gujarat is taking on plastic pollution; UNEP, 2018; Retrieved from: https://www.unenvironment.org/news-and-stories/story/how-indian-state-gujarat-taking-plastic-pollution last accessed on March 1, 2021.
32. Hurley, R.R.; Lusher, A.L.; Olsen, M.; Nizzetto, L. Validation of a method for extracting microplastics from complex, organic-rich, environmental matrices. Environ. Sci. Technol. 2018, 52, 7409–7417
33. Impact of plastic waste on environment. Ministry of Environment, Forest & Climate Change (MoEFCC). 2019. Retrieved from: http://www.indiaenvironmentportal.org.in/files/file/Impact%20of%20Plastic%20Waste%20on%20Environment.pdf last accessed on May 4, 2020
34. Indian and Norwegian Ministers of Environment commit to explore a Global Agreement to stop Plastic Pollution. Norway in India, 2020. Retrieved from: https://www.norway.no/en/india/norway-india/news-and-events/new-delhi/news/indian-and-norwegian-ministers-of-environment-commit-to-explore-a-global-agreement-to-stop-plastic-pollution/ last accessed on May 2, 2020
35. Informal approaches towards a circular economy - learning from the plastics recycling sector in India; November 28, 2017; World Business Council for Sustainable Development (WBCSD), World Resources Forum (WRF), & Swiss Federal Laboratories for Materials Science and Technology (EMPA).
36. Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Law, K. L. (2015, February 13). Plastic waste inputs from land into the ocean. Science, 347(6223), 768-771.
37. Kaladharan, P and Vijayakumaran, K and Singh, V V and Prema, D and Asha, P S and Sulochanan, Bindu and Hemasankari, P and Edward, Loveson and Padua, Shelton and Veena, S and Anasu Koya, A and Bhint, H M (2017) Prevalence of marine litter along the Indian beaches : A preliminary account on its status and composition. Journal of the Marine Biological Association of India, 59 (1). pp. 19-24.
38. Karelia G. Road To A Plastic Free City: Surat Aims To Produce Diesel Out Of Plastic Waste. Swachh India. 2017. Retrieved from: https://swachhindia.ndtv.com/road-plastic-free-city-surat-aims-produce-diesel-plastic-waste-9665/ last accessed on March 3, 2021.
39. Karelia, Gopi. The Times of India. Swachh India. October 26, 2018. One Lakh Kilometres Of Roads In India Are Being Made From Plastic Waste, Is This The Solution To End Plastic Crisis?. Retrieved from: https://swachhindia.ndtv.com/plastic-waste-roads-one-lakh-kilometre-india-20274/ last accessed on May 8, 2020.
40. Kiessling, T., Knickmeier, K., Kruse, K., Brennecke,

D., Nauendorf, A., & Thiel, M. (2019). Plastic pirates sample litter at rivers in Germany–Riverside litter and litter sources estimated by schoolchildren. Environmental Pollution, 245, 545–557.

41. Kerscher, Ulrich. (2019). Towards a Sustainable Future? The EU Policies Concerning Plastics and Their Didactical Potential for Primary and Secondary Teaching. Discourse and Communication for Sustainable Education. 10. 47-62. 10.2478/dcse-2019-0005.
42. Kramm, Johanna and V€olker, Carolin. 2018. Understanding the Risks of Microplastics: A Social-Ecological Risk Perspective. Freshwater Microplastics, Hdb Env Chem 58, DOI 10.1007/978-3-319-61615-5_11
43. Kühn, S., Rebolledo, E. L. B., & van Franeker, J. A. (2015). Deleterious effects of litter on marine life. Marine Anthropogenic Litter (pp. 75-116)
44. Kurniawan et al. 2017. Current Issues in Applied Biology. February 2017. Retrieved from: https://www.slideshare.net/edy0kurniawan/plastic-waste-management-72541520 last accessed on March 1, 2021.
45. Lahens L, Strady E, Kieu-Le TC, Dris R, Boukerma K, Rinnert E, Gasperi J, Tassin B. Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. Environ Pollut. 2018 May;236:661-671. doi: 10.1016/j.envpol.2018.02.005. PMID: 29438952.
46. Lambert, Scott and Wagner, Martin. 2018. Microplastics Are Contaminants of Emerging Concern in Freshwater Environments: An Overview. Freshwater Microplastics. Hdb Env Chem 58, DOI 10.1007/978-3-319-61615-5_1
47. Lebreton, L., Egger, M. & Slat, B. A global mass budget for positively buoyant macroplastic debris in the ocean. Sci Rep 9, 12922 (2019). https://doi.org/10.1038/s41598-019-49413-5
48. Lebreton, Laurent & Van der Zwet, Joost & Damsteeg, Jan-Willem & Slat, Boyan & Andrady, Anthony & Reisser, Julia. (2017). River plastic emissions to the world's oceans. Nature Communications. 8. 10.1038/ncomms15611.
49. Lenkiewicz, Zoë. The Gambia: Plastics recycling training update. WasteAid. May 26, 2019. Retrieved from: https://wasteaid.org/the-gambia-plastics-recycling-training-update/ last accessed on April 6, 2021.
50. Lenkiewicz, Zoë. WasteAid. May 11, 2016. Waste and the Sustainable Development Goals. Retrieved from: https://wasteaid.org/waste-sustainable-development-goals/ last accessed on April 30, 2020.
51. Liedermann, M.; Gmeiner, P.; Pessenlehner, S.; Haimann, M.; Hohenblum, P.; Habersack, H. A Methodology for Measuring Microplastic Transport in Large or Medium Rivers. Water 2018, 10, 414. https://doi.org/10.3390/w10040414.
52. Lindeque, Penelope & Cole, Matthew & Coppock, Rachel & Lewis, Ceri & Miller, Rachael & Watts, Andrew & Wilson-McNeal, Alice & Wright, Stephanie & Galloway, Tamara. (2020). Are we underestimating microplastic abundance in the marine environment? A comparison of microplastic capture with nets of different mesh-size. Environmental Pollution. 265. 114721. 10.1016/j.envpol.2020.114721.
53. Manuja, Sourabh. Used Beverage Carton management study for India. The Energy & Environment Institute (TERI). 22 November 2018 to 21 March 2019. Retrieved from: https://www.teriin.org/project/used-beverage-carton-management-study-india last accessed on May 7, 2020
54. Ministry of Railways. (2019). Guidelines on use of Plastic Waste in Road Construction. New Delhi: Government of India. Retrieved January 6, 2021
55. Mukhopadhyay, Moitraiyee & Sampath, Srimurali & Muñoz-Arnanz, Juan & Jiménez, Begoña & Chakraborty, Paromita. (2020). Plasticizers and bisphenol A in Adyar and Cooum riverine

sediments, India: occurrences, sources and risk assessment. Environmental Geochemistry and Health. 42. 10.1007/s10653-020-00516-3.

56. National Productivity Council (NPC) and United Nations Environment Programme (UNEP). (2019). Plastic Leakage Pathways Report.
57. Ogata, Y., Takada, H., Mizukawa, K., Hirai, H., Iwasa, S., 2009. International pellet watch: global monitoring of persistent organic pollutants (POPs) in coastal waters 1 initial phase data on PCBs DDTs and HCHs. Mar. Pollut. Bull. 58, 1437–1446
58. Our new initiative: Together, we're committed to getting every bottle back. American Beverage. n.d. Retrieved from: https://www.innovationnaturally.org/plastic/ last accessed on April 6, 2021.
59. Piehl, S., Leibner, A., Löder, M., Dris, R., Bogner, C., & Laforsch, C. (2018). Identification and quantification of macro- and microplastics on an agricultural farmland. Scientific reports, 8(1), 17950. https://doi.org/10.1038/s41598-018-36172-y
60. Plastic & Health: The Hidden Costs of a Plastic Planet; Center for International Environmental Law (CIEL); February 2019
61. Plastic Waste Control in India—Is it Really Happening?. RaboResearch, Rabobank. February 2018. Retrieved from: https://research.rabobank.com/far/en/sectors/fa-supply-chains/Plastic-Waste-Control-in-India.html last accessed on May 1, 2020
62. Plastic Waste Management Programme: A Partnership. Hindustan Coca-Cola Beverages Pvt Ltd. (HCCB) & United Nations Development Programme (UNDP). 2018-2024. Retrieved from: https://www.undp.org/content/dam/india/docs/human-development/HCCB.pdf last accessed on April 30, 2020
63. Plastic waste management: Surat among four cities chosen for central project. Indian Express. November 20, 2019. https://indianexpress.com/article/india/plastic-waste-management-surat-among-four-cities-chosen-for-central-project-6127752/ last accessed on May 12, 2020.
64. Quinn, B.; Murphy, F.; Ewins, C. Validation of density separation for the rapid recovery of microplastics from sediment. Anal. Methods 2017, 9, 1491–1498.
65. Rech, S., Macaya-Caquilpán, V., Pantoja, J. F., Rivadeneira, M. M., Jofre Madariaga, D., & Thiel, M. (2014). Rivers as a source of marine litter—A study from the SE Pacific. Marine Pollution Bulletin, 82, 66–75.
66. Ritchie, Hannah and Roser, Max. Our World in Data, 2018. Plastic Pollution. Retrieved from: https://ourworldindata.org/plastic-pollution last accessed on April 6, 2021.
67. Scopetani C, Esterhuizen-Londt M, Chelazzi D, Cincinelli A, Setälä H, Pflugmacher S. Self-contamination from clothing in microplastics research. Ecotoxicol Environ Saf. 2020 Feb;189:110036. doi: 10.1016/j.ecoenv.2019.110036. Epub 2019 Dec 9. PMID: 31825795.
68. Sepúlveda, Alejandra & Schluep, Mathias & Renaud, Fabrice & Streicher, Martin & Kuehr, Ruediger & Hagelüken, Christian & Gerecke, Andreas. (2010). A Review of the Environmental Fate and Effects of Hazardous Substances Released from Electrical and Electronic Equipment During Recycling: Examples from China and India. Environmental Impact Assessment Review. 30. 28-41. 10.1016/j.eiar.2009.04.001.
69. Shah S. 2018, How Gujarat succeeded in co-processing plastic waste in cement kilns and promoting circular economy; Down To Earth. 03 September 2018. Retrieved from: https://www.downtoearth.org.in/blog/environment/how-gujarat-succeeded-in-co-processing-plastic-waste-in-cement-kilns-and-promoting-circular-economy-61518 last accessed on March 1, 2021
70. Singh, Satpal. (2020). Solid Waste Management

in Urban India: Imperatives for Improvement. New Delhi: Observer Research Foundation. Retrieved January 9, 2021

71. Single-use plastic: China to ban bags and other items. BBC News. 2020. Retrieved from: https://www.bbc.com/news/world-asia-china-51171491 last accessed on May 6, 2020
72. Skåre, Janneche Utne; Alexander, Jan; Haave, Marte; Jakubowicz, Ignacy; Knutsen, Helle Katrine; Lusher, Amy; Ogonowski, Martin; Rakkestad, Kirsten Eline; Skaar, Ida; Sverdrup, Line Emilie; Wagner, Martin; Agdestein, Angelika; Bodin, Johanna Eva; Elvevoll, Edel O.; Hemre, Gro Ingunn; Hessen, Dag Olav; Hofshagen, Merete; Husøy, Trine; Krogdahl, Åshild; Nilsen, Asbjørn Magne; Rafoss, Trond; Skjerdal, Olaug Taran; Steffensen, Inger-Lise; Strand, Tor A; Vandvik, Vigdis; Wasteson, Yngvild. (2019). Microplastics; occurrence, levels and implications for environment and human health related to food. Scientific opinion of the Scientific Steering Committee of the Norwegian Scientific Committee for Food and Environment. VKM report 2019:16, ISBN: 978-82-8259-332-8, ISSN: 2535-4019. Norwegian Scientific Committee for Food and Environment (VKM), Oslo, Norway.
73. State Plastic Bag Legislation. National Council for State Legislatures (NCSL). 2021. Retrieved from: https://www.ncsl.org/research/environment-and-natural-resources/plastic-bag-legislation.aspx last accessed on May 6, 2020
74. Status of Industrial Environment in Gujarat; Gujarat ENVIS, n.d., Retrieved from: http://www.gujenvis.nic.in/PDF/soe-industrial.pdf last accessed on March 1, 2021.
75. Surat District Profile, January 2011. Retrieved from: https://www.slideshare.net/ourvibrantgujarat/surat-district-profile, 2011 last accessed on March 1, 2021.
76. Swachh Bharat Mission – Grameen (SBM-G). n.d. Retrieved from: https://sbm.gov.in/slwmodfplus/Index.aspx last accessed on May 8, 2020
77. Swachh Bharat Mission, Urban (SBM-U)– Gujarat. n.d. Retrieved from: http://sbmu-gujarat.in/downloads/ last accessed on May 11, 2020
78. Thompson, Richard & Olsen, Ylva & Mitchell, Richard & Davis, Anthony & Rowland, Steven & John, Anthony & Mcgonigle, D.F. & Russell, Andrea. (2004). Lost at Sea: Where Is All the Plastic?. Science (New York, N.Y.). 304. 838. 10.1126/science.1094559.
79. van Emmerik, T. et al. 2018. A Methodology to Characterize Riverine Macroplastic Emission Into the Ocean. Frontiers in Marine Science 5. Available at: https://www.frontiersin.org/articles/10.3389/fmars.2018.00372/full [Accessed: 21 August 2019].
80. van Emmerik, T. et al. 2019b. Seasonality of riverine macroplastic transport. Scientific Reports 9(1), pp. 1–9. doi: 10.1038/s41598-019-50096-1.
81. Villarrubia-Gómez, Patricia & Cornell, Sarah & Fabres, Joan. (2017). Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle. Marine Policy. 96. 10.1016/j.marpol.2017.11.035.
82. Vishnoi, Anubhuti. 29 October 2019. The Economic Times. 8,000 block level plastic waste management units on anvil. Retrieved from: https://economictimes.indiatimes.com/news/politics-and-nation/8000-block-level-plastic-waste-management-units-on-anvil/articleshow/71805811.cms?from=mdr last accessed on May 6, 2020
83. Waring RH, Harris RM, Mitchell SC. Plastic contamination of the food chain: A threat to human health? Maturitas. 2018 Sep; 115:64-68. doi: 10.1016/j.maturitas.2018.06.010. Epub 2018 Jun 20. PMID: 30049349
84. World Economic Forum. (2020). Radically Reducing Plastic Pollution in Indonesia: A Multistakeholder Action Plan National Plastic Action Partnership. Geneva: World Economic Forum. Retrieved January 5, 2021

INOPOL

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

Norwegian Embassy
New Delhi

NIVA
Norwegian Institute for Water Research

MU GAMMA
Consultants Pvt. Ltd

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