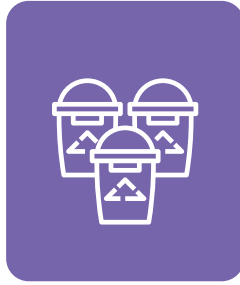


# Plastic Waste Leakage Assessment

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TRAINING MANUAL





# Plastic Waste Leakage Assessment

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## TRAINING MANUAL

ClimateSmart Cities Assessment Framework  
Waste Management

## **Plastic Leakage Assessment Toolkit**

Training module

### **Developed by:**

Climate Centre for Cities, NIUA in association with National Productivity Council (NPC),  
United Nations Environment Programme (UNEP)

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# Executive Summary

National Productivity Council (NPC) is pleased to present to you the “**Plastic Leakage Assessment Toolkit**” developed under the Flagship project of UNEP’s “Promotion of action against marine plastic litter in Asia and the Pacific (CounterMEASURE II)”. This toolkit has been developed especially for all the stakeholders involved in the generation, collection, storage, transportation, and treatment of plastic waste. This toolkit may also be utilized by researchers and academic institutions.

The toolkit has 8 sections broadly classified under Introduction, sources of plastic leakage into environment, approach & methodology specifying the tools & techniques for assessment of plastic leakage, aspects of plastic value chain, details of Macro plastic assessment on land & micro plastic assessment in water body, plastic leakage characterization, a case study of city Prayagraj and conclusion in line with the NIUA format. It provides useful tips, dos and don’ts, methods and practices that should be followed for assessment of plastic leakage.

This toolkit has been brought together by a team of professionals based on actual field studies and primary data generated during the execution of the CounterMEASURE project. Usage of GIS application for reconnaissance study and ground-truthing has also been highlighted. The toolkit illustrates various layers and maps created under the study for the benefit of the toolkit users, which has been carefully reviewed by the subject matter experts.



The overall purpose of the toolkit is to provide guidance towards scientific assessment of plastic waste.

NPC hopes that this publication would be useful to all stake holders and would emerge as the trusted source for the methodology for plastic waste assessment. NPC remains thankful to the UNEP, NIUA, ULBs and all the concerned stake holders who extended tremendous support in the process.

National Productivity Council Team





Who is the training manual designed for?



What is the focus of the training manual?



How to make use of this manual?



What are the Learning outcomes of the training?



Scope and limitations of the training



The training module on the indicator Plastic Leakage Assessment is intended for Urban Local Bodies (ULBs), specifically the solid waste management departments, safaikaramcharis, ragpickers, and other officials of Department of Environment, SPCBs, and CPCB involved in solid waste management, and in developing and implementation of policies related to plastic waste management. A basic understanding in solid, plastic waste management in urban areas is a prerequisite for various stakeholders.

This training manual focuses on understanding the methodology for undertaking plastic waste leakage from the mismanaged solid waste in urban areas. It highlights the various steps that are required towards estimating plastic waste generation, identification of sources of plastic waste leakage, undertaking macroplastic assessment in the city, undertaking microplastic survey etc. Through this training manual, methodologies that may help the decision makers to identify the areas which are vulnerable for plastic leakage is also outlined. Based on the assessment, strategies/action plans/policies need to be formulated for effective management of plastic waste.

This manual is to be used as a technical reference material which delves into details touched upon in the presentation with references to additional reading material to aid participants in the following training sessions.

The learning outcomes of this training for cities is to develop a better understanding of plastic leakage assessment, to introduce, and identify the areas which are vulnerable to plastic leakage which needs to be addressed on priority. This training module would also equip the cities in conducting macroplastic assessment, and microplastic surveys to understand the characteristics of plastic waste and its sources of generation, based on which strategies, action plans and policies can be formulated and implemented.

As the training module is designed and developed as a 2-hour online training session with interactive exercises for city officials its scope is limited to establish a basic understanding of plastic waste management as per the Plastic Waste Management Rules 2016, and the requirements of the CSCAF indicator of waste minimization initiatives undertaken by the cities.



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## Abbreviations

CPCB	Central Pollution Control Board
DEM	Digital Elevation Map
DPI	Domestic Plastic Import
DPP	Domestic Plastic Production
EPI	Product Embodied Plastic Import
EPR	Extended Producer Responsibility
EVOH	Ethylene Vinyl Alcohol
FICCI	Federation of Indian Chambers of Commerce & Industry
FPE	Foreign Plastic Export
FTIR	Fourier Transform Infrared Spectroscopy
GHG	Green House Gas
GIC, AIT, Bangkok	Geoinformatics Center, Asian Institute of Technology, Bangkok
GIS	Geographic Information System
GPS	Global Positioning System
GPS	Global Positioning System
HDPE	High Density Polyethylene
HPI	Hidden Plastic Leakage
IUCN	International Union for Conservation of Nature
LCA	Life Cycle Assessment
LDPE	Low Density Polyethylene
MFA	Material Flow Analysis
MFA-LCA	Material Flow Analysis- Life cycle Assessment
MLP	Multi Layer Packaging
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing & Urban Affairs
MP	Micro Plastic
MRF	Material Recovery Facility
NAPCC	National Action Plan on Climate Change
NIUA	National Institute of Urban Affairs



NPC	National Productivity Council
NRSC	National Remote Sensing Centre, Hyderabad
PDL	Plastic Dissipative Loss
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polyester
PVAL	Polyvinyl Alcohol
PVB	Polyvinyl Butyral
PVC	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride
PW	Plastic Waste Import
PWE	Plastic Waste Export
PWL	Plastic Waste Leakage
QR Code	Quick Response Code
RDF	Residue Derived Fuel
SPCB	State Pollution Control Board
ULB	Urban Local Body
UNEP	United Nations Environment Programme



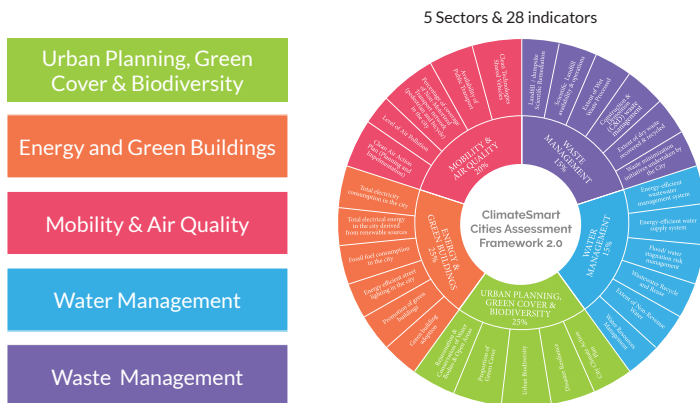
# 1

## Introduction and Goals for the Training

### Introduction

Rapid urbanisation is exerting pressure on the urban environment, services, infrastructure provisions and public health. According to NIUA 2020, India accounts for about 6.5 percent of the global greenhouse gas (GHG emissions). In order to combat this climate change, Government of India launched 8 missions under the National Action Plan on Climate Change (NAPCC) in 2008 which is spear-headed by the Ministry of Housing & Urban Affairs (MoHUA). To advance the actions of the said mission, MoHUA has launched the “Climate smart Cities Assessment Framework” in February 2019 for 100 Smart cities.

Figure 1.1: Climate Smart City Assessment Framework, Adapted from- NIUA Climate Centre for Cities<sup>1</sup>



<sup>1</sup><https://www.niua.org/csc/assessment-overview.htm>



The framework has been developed across 5 categories as mentioned below: -

- Energy and Green Buildings
- Urban Planning, Green Cover & Biodiversity
- Mobility and Air Quality
- Water Management
- Waste Management

One of the important categories of this Framework is Waste Management which comprises of solid, plastic, biomedical, e-waste, hazardous waste etc. Indiscriminate disposal of plastic waste on land and water is creating a threat to the environment, human health, flora & fauna. In order to address plastic pollution and identify the leakages along the plastic value chain, the given Plastic Leakage Assessment Methodology has been adapted from the Life Cycle Assessment (LCA) and Plastic Footprint Methodology (Peano et.al, 2020 Boucher & Friot, 2017). This methodology focuses more on the leakage pathway and provides guidance for quantifying micro- and macro-plastic leakages throughout the life cycle, with more emphasis on waste management sector. The benefits of a standardized approach include verifiability, relevance, and consistency of results. Plastic leakage is defined as a quantity (in grams) of plastic leaving the technosphere and ending up in the natural environment (Peano et.al., 2020).

### Goals for the Training

- To develop the tool kit to serve as guidance document/ training material to target audience including major stakeholders like ministries/ departments at national and state levels, policy makers, ULBs, research institutions etc.
- To identify, develop and implement the road map/interventions to address city/ national based marine litter and plastic pollution including countermeasures.

# 2

## Sources of Plastic Waste Leakage into the Environment

Various sources of plastic waste leakage into the environment as represented in Figure 1 (Key stages of the leakage modelling) are as follows: -

- 1. Loss** - It can be during the product manufacturing, transportation or mismanaged waste. This stage is constituted by the fraction of plastic materials that is detached from the product during manufacturing, use or transport (for microplastics), or mismanaged waste (for macroplastics), i.e., the fraction leaving the technosphere. In India, The Central Pollution Control Board (CPCB) estimated that in 2019, Indian cities generated about 9506.246 metric tonnes per day of plastic waste out of which 40%, remains uncollected (CPCB, 2021).
- 2. Transfer:** Different types of transfer pathways lead from loss to release. Transfer pathways represent the main routes through which plastics are released from the technosphere to a nature compartment. Various transfer pathway have been represented with the help of Fig 2 as given below (Peano et.al, 2020):-
  - i. wastewater (e.g., laundering of synthetic textiles),
  - ii. road runoff (e.g., tire abrasion)
  - iii. air (e.g., microplastics released from synthetic textiles)
  - iv. uncollected waste (e.g., littered waste, fly tipping)
  - v. poorly managed waste (e.g., non-sanitary landfill, illegal dumping)
  - vi. direct pathway (e.g., macroplastic waste dumped in rivers)
- 3. Initial Release** compartment is the environmental medium to which the plastic is released through a single pathway or a combination of multiple pathways.
  - i. Plastic released to oceans.
  - ii. Release to fresh water represents the initial release to rivers or lakes.

- iii. Plastic released to soil, for instance via the spreading of sewage sludge on agricultural soils.
- iv. Release to terrestrial environment such as plastic deposited and stored in dumpsites, plastics deposited on buildings or trees, and littered plastic packaging.
- v. Release to air such as plastic dust from tire abrasion or synthetic textiles (although this latter type is not included in the methodology due to lack of data).

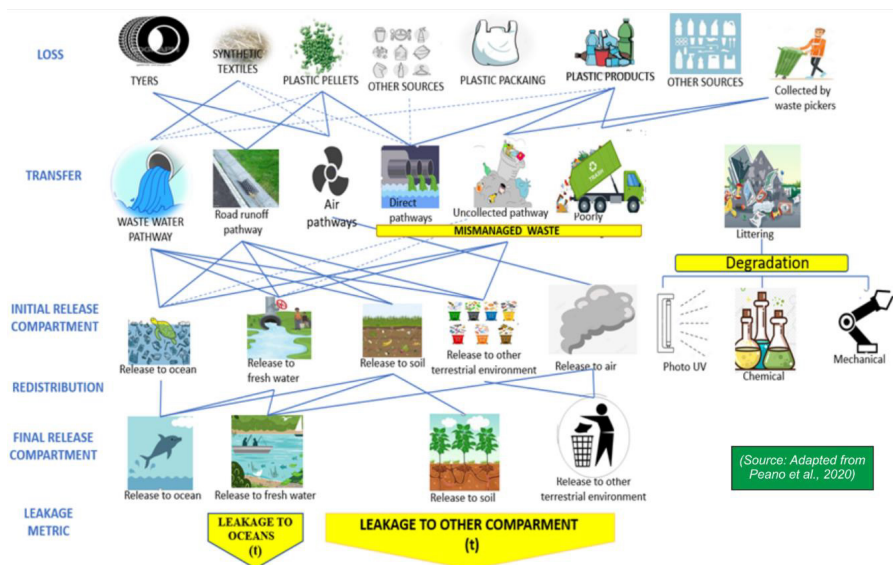
4. **Redistribution:** The redistribution of plastic from an initial compartment to its final compartment: -

- i. The transport of plastic by rivers, as it is expected that microplastics may be partly transferred in oceans and partly deposited in river sediments.
- ii. The redistribution of microplastic emitted by air onto fresh water and soil.

5. **Final Release** compartment is the final medium to which plastic is transferred after the redistribution stage. Following compartments are considered in methodology: -

- i. Release to ocean
- ii. Release to freshwater
- iii. Release to soil
- iv. Release to terrestrial environment

Figure 2.1: Key Stages of the Leakage Modelling- Adapted from Peano et.al, (2020)<sup>1</sup>



## Objectives of Plastic Leakage Assessment

### Context

The United Nations Environment Programme (UNEP), the International Union for Conservation of Nature (IUCN), and the Life Cycle Initiative have co-developed a harmonised methodological framework which broadly categorises and highlights the course of action from identification to deploying appropriate strategies which are as follows: -

- **A hotspot** is defined as a component of the system that directly or indirectly contributes to plastic leakage and its associated impacts, and that can be acted upon to mitigate this leakage.
- **An intervention** is defined as a tangible action that can be taken to mitigate the leakage from a given hotspot or reduce its impacts.
- **An instrument** is defined as a practical way to implement an intervention and enable progress through specific regulatory, financial or informative measures.

Guidance notes for hotspots, interventions and instruments are given in Additional Reading<sup>1</sup>.

<sup>1</sup> <https://incp.org.co/Site/publicaciones/info/archivos/Guia-Plastic-Leak-Project-17042020.pdf>

## **Objective**

The objective of the Plastic Leakage Assessment is to identify, characterize & quantify plastic leakage. In this context, this training manual has been developed to help quantifying plastic leakage & characterizing plastic in terms of plastic products & polymers. The output of this toolkit may help in designing the interventions, for example, establishment of MRF Facility, plastic collection scheme, disposal and recycling of plastics etc. Overall goal is to integrate plastic pollution factors to perform a plastic leakage assessment for providing data on existing hotspots. This will assist to identify specific countermeasures, which can tackle and address plastic pollution both in the short and long term.

# 3

## Approach and Methodology

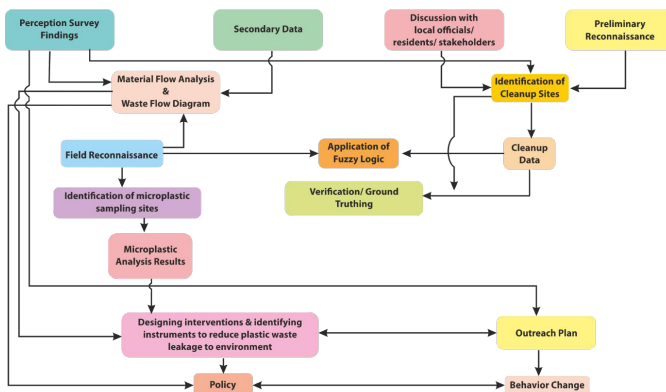
### Background

A conceptual approach has been adopted based on a combination of Systemiq/ road map and UN Environment/ IUCN methodologies (Peano et.al,2020 & Boucher J & Friot D, 2017) covering all the salient features (Guidance Notes for Key Features of the Systemiq / road map and UN Environment/ IUCN methodologies is provided in Additional Reading 2. This will help to design and identify interventions and instruments required to reduce the land-based plastic litter. Plastic Hot-spotting and identification of leakage pathways form the backbone of this approach within a geographical context.

### Methodology: Tools & Techniques

Fig 3.1 indicates schematic methodology for plastic leakage assessment.

Figure 3.1: Schematic methodology for plastic leakage assessment, Adapted from- NPC, (2020a)<sup>1</sup>



<sup>1</sup><https://www.npcindia.gov.in/NPC/Uploads/file%20upload/Plastic%20Leakage%20Assessment%20Toolkit%20-%2020240520.pdf>

Various stages of plastic waste leakage assessment can be classified into the following: -

1. Leakage Source identification & quantification: Tools and techniques to be used are as follows: -
  - i. Perception Survey
  - ii. Collection of Secondary Data
  - iii. Reconnaissance Survey (Field Survey)
  - iv. Material Flow Analysis (MFA): Input-Output Tables
  - v. Fuzzy Logic Approach to identify plastic leakage areas
  - vi. Verification/ Ground truthing
  - vii. Organization of Stakeholder's Consultation Workshop
  
2. Plastic Leakage Characterisation
  - i. Macro-plastic Assessment Study/ Cleanup Study
  - ii. Fields Reconnaissance (To identify representative site)
  - iii. Cleanup Study
  - iv. Micro-plastic Survey in water-body
  - v. Fields Reconnaissance (To identify representative site)
  - vi. Micro-plastic Sampling & Analysis

# 4

## Plastic Value Chain

### A. Leakage Source identification & quantification

- 1. Perception Survey:** Various stakeholders like producer and recyclers, restaurant owners, households, street vendors, junk-dealers/ ragpickers (kabadiwalas), grocery shopowners, religious institutions, waste management authorities, Policy & Regulatory bodies, Institutions, businesses, and communities can be surveyed using a number of tools like questionnaire, face-to-face interactions, focused group discussions, workshops/ conferences to identify hotspots and leakage pathways. This technique covers the complete plastic value chain and different stages or combination of stages as well. It can capture all types of hotspots and is extensively used in Indian component of the project. Output of the Perception Survey shall indicate the awareness level among various stakeholders, sources of waste generation, types of hotspots which can also indicate range of waste generation levels from different sources found.
- 2. Collection of Secondary Data:** Secondary data collection on plastic production, plastic consumption, plastic waste generation & management and waste disposal may be undertaken from various departments/ agencies such as ULBs, industry associations, department of industries, pollution control board, plastic recyclers etc. Additional information pertaining to drainage networks, wastewater discharge, land-use/ land-cover, demography, rainfall etc should be collected. Annual Reports of the State Pollution Control Boards should reflect the plastic waste statistics. Detailed template for secondary data collection is placed in **Additional Reading 3**.



Figure 4.1: Visuals from Perception Survey, Adapted from NPC Fieldwork Study



Secondary data on plastic waste generation/ consumption/ composition/ management needs to be collected from the departments as well as through Fields reconnaissance survey as per the following format-

Table 4.1: Template for collection of waste management data from ULs/other stakeholders

Template for collection of waste management data from ULBs/ other stakeholders				
No.	Waste Management Chain	Location ID & Photo	Unit	Result
1	Waste Composition (Plastic type if possible)		%	
2	Waste generation		t/d	
2-1	Household waste		t/d	
2-2	Commercial waste		t/d	
2-3	Market waste		t/d	
2-4	Public area cleansing		t/d	
2-5	Industrial waste		t/d	
3	Waste collection		%	
3-1	Formal Collection	x (Collection point)	t/d	
3-2	Informal Collection (Junkshop, waste picker)		t/d	
3-3	Open burning		t/d or %	
3-4	Burry (HH or Communal pit)		t/d or %	
3-5	Littering/dumping		t/d or %	
4	Intermediate treatment		t/d	
4-1	Transfer station (t/d)	x	t/d	
4-2	Recycling Facility	x	t/d	
4-3	Others (if any:- )	x	t/d	
5	Final Disposal		t/d	
5-1	Open dump site	x	t/d	
5-2	Sanitary disposal site	x	t/d	
6	Local Hotspot			
6-1	Indiscriminate disposal of waste	x (visual inspection, sheet 4)	number	
6-2	Waste condition in artificial barriers & drains	x (visual inspection, sheet 4)	number	

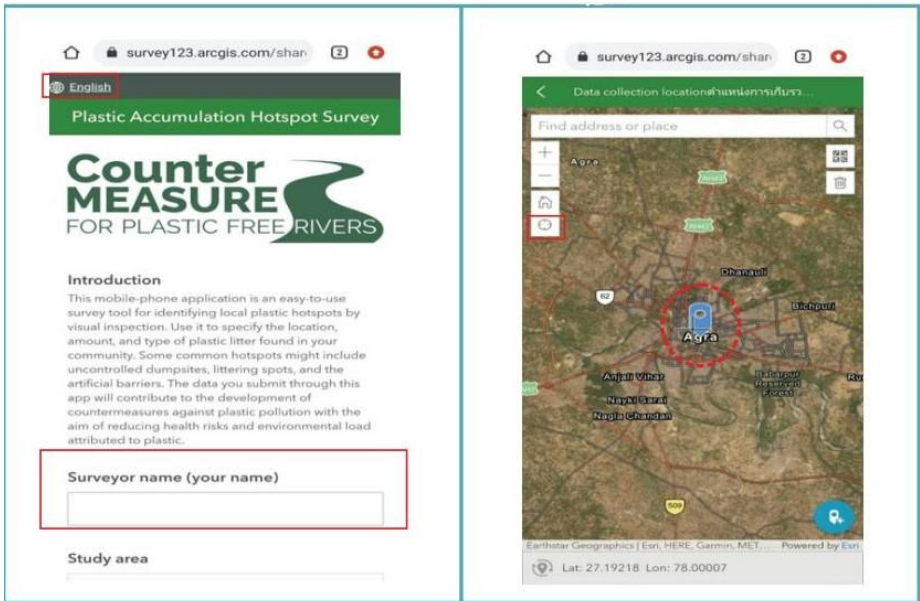
Adapted from IUCN-EA-Quantis, (2020)<sup>1</sup>

**3. Reconnaissance Survey (Field):** Data collection is to be carried out using GPS in the identified geographical area e.g., city/ watershed to identify the physical features/ benchmarks in the city's context. A photographic technique using 360 degrees camera, still photography can be used for reconnaissance survey. Based on the information gathered through the Perception Survey, a Reconnaissance Survey has to be undertaken in the city following which validation of data through visual devices such as 360 degrees camera or mobile phones with in-built GPS system. The main

<sup>1</sup>[https://www.iucn.org/sites/dev/files/content/documents/thailand\\_final-report\\_2020\\_compressed.pdf](https://www.iucn.org/sites/dev/files/content/documents/thailand_final-report_2020_compressed.pdf)

objective is to map plastic waste leakage density using multi-source geospatial data. Result will be used for monitoring and assessment of plastic waste and pollution reduction. For example, a mobile application developed by GIC, AIT is shown in figure 5 and similar applications may be developed in India which may be used to capture different kinds of hotspots under waste generation domains. The advantage of using this survey mobile application is its direct output in GIS friendly formats for further analysis. Conventional ground survey data collection needs to incorporate handheld GPS units for location information which will later be tagged with the collected information. Using the mobile survey application, the data will be directly geo tagged using the mobile phone location. One of the major key advantages of this application is that it allows to tract the real-time data. Another key advantage of this survey application is that the user does not have to pre-install the application. The survey form is accessible through a mobile phone browser using a direct link or by scanning a QR code.

Figure 4.2: Mobile Application developed by GIC, AIT Bangkok, Adapted from-ArcGIS<sup>2</sup>

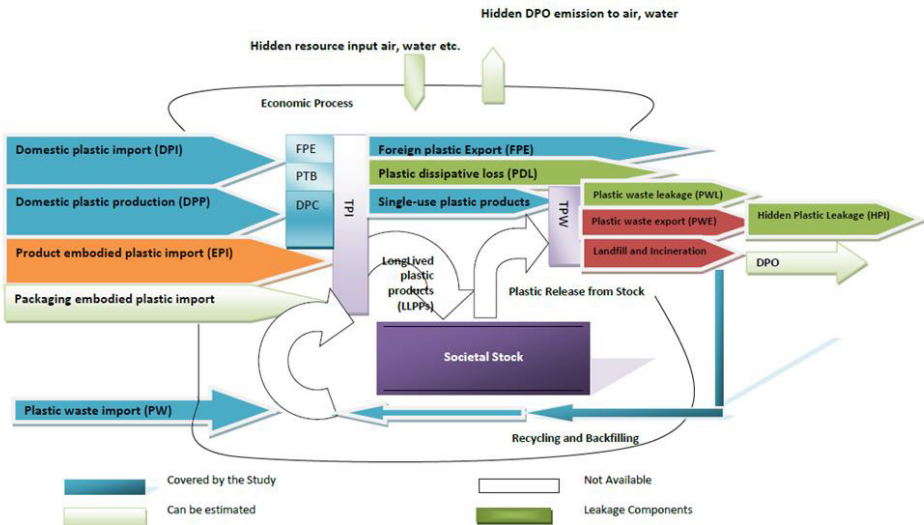


<sup>2</sup><https://survey123.arcgis.com/share/ebc26f67bf3347bd995c41a97631d2b3>

#### 4. Material Flow Analysis (MFA):

- i. A combination of hybrid MFA & LCA (Material Flow Analysis- Life cycle Assessment) shall be used in identifying and classifying of hotspots.
- ii. The study boundary includes different stages where input & output analysis shall be carried out within the boundary.
- iii. MFA is also adapted from Plastic Footprint methodology (Guidance Notes for stepwise description of the plastic footprint methodology are presented in **Additional Reading 4**).
- iv. Further, Guidance Notes for Plastic Value Chain and Plastic Waste Material Flow- Stage wise is presented in **Additional Reading 5**.
- v. Figure 4.3 indicates the schematic process of MFA-LCA Approach for Plastic Accounting.

Figure 4.3: MFA-LCA Approach for Plastic Accounting, Adapted from- Boucher J & Friot (2017)<sup>3</sup>



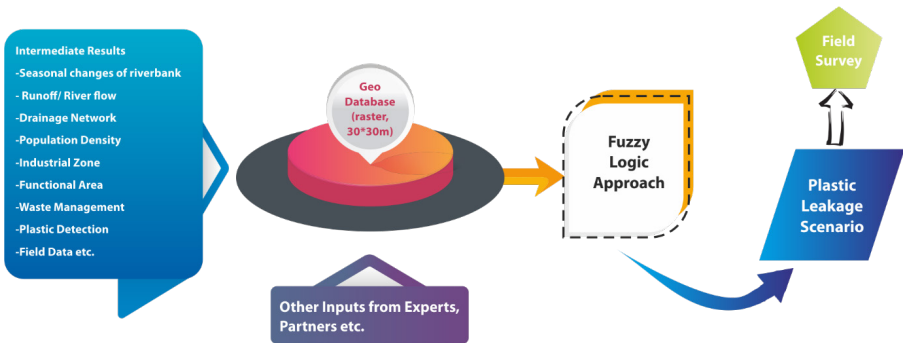
<sup>3</sup> <https://portals.iucn.org/library/sites/library/files/documents/2017-002-En.pdf>

Following templates and techniques are used in MFA: -

- **Economic Data Template:** Market/sales data can be helpful in establishing the quantities of goods and services that could be considered in defining a functional unit, and identifying subsequent data needs (e.g., Bill of Materials, purchasing data) to identify impacts from a life cycle perspective.
- **Waste Management Data Templates** will cater to the data related to waste generation, collection, transportation, treatment, and disposal.
- **Input?Output Tables:** At each stage or a combination of stages, material flow, money flow and their linkages to environment can be established using Economic Data templates versus Waste Management Data templates.
- **Ranking Technique:** Assessment of plastic usage, waste or recycling rates, with little focus on circularity can be used synergistically to identify the best scenarios in terms of reducing environmental impacts while aiming to maximize circularity.

5. **GIS Technique and Fuzzy Approach:** The fuzzy logic model is based on the concepts of Fuzzy sets. Unlike ordinary sets, fuzzy sets enable their elements to show a partial degree of membership in the range from 0 (no membership) to 1 (full membership). In this way, fuzzy models can represent graduations from one class to another class, which has been applied in many research fields for predicting something of interest or for decision-making. Figure 4.4 represents the flowchart for fuzzy logic methodology.

Figure 4.4: Flowchart of fuzzy logic methodology, Adapted from- NPC (2020a)<sup>4</sup>

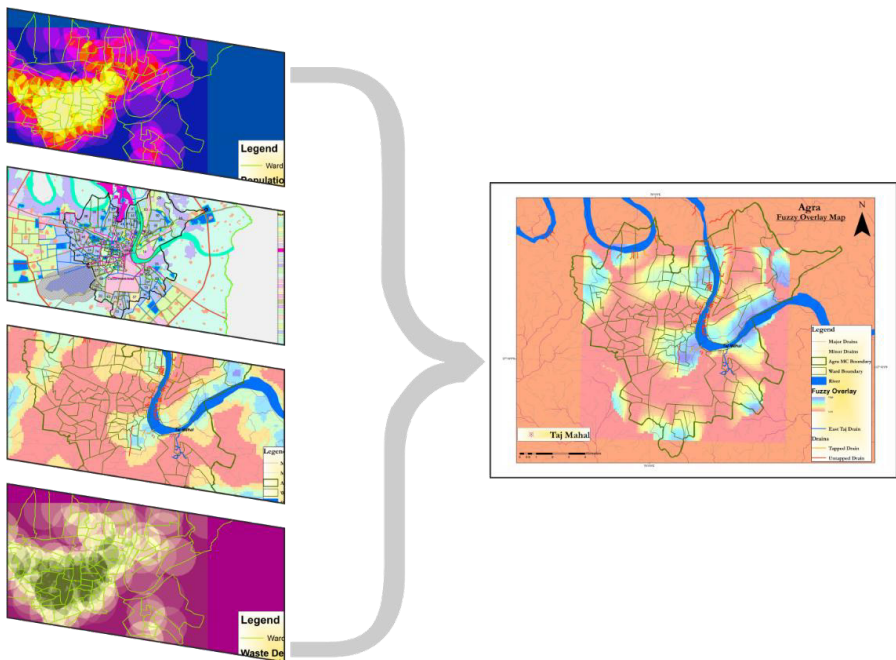


<sup>4</sup><https://www.npcindia.gov.in/NPC/Uploads/file%20upload/Plastic%20Leakage%20Assessment%20Toolkit%20-%2020240520.pdf>

Various steps are as given below:

- Geographical mapping of the waste plastic material flow chain is done by using geographical information system (GIS). This technique gives lots of information on plastic value chain hotspots, plastic leakage source hotspots and plastic accumulation spots as well as assists in development of risk maps of the geographical area.
- Guidance notes on categories of classification of hotspots is presented in **Additional Reading 6**.
- Various types of maps are generated with the help of GIS Technique and Fuzzy Approach- Topographic map, Slope map, Population density, Plastic dumping density map, Factory density map, River density map, Land use map, Potential plastic leakage map, Spatial distribution of sub-basin etc. (Detailed approach for Fuzzy Logic Model is presented in **Additional Reading 7**).
- The overlay of various layers as mentioned above and through use of fuzzy-logic model, plastic leakage vulnerable area map is generated as indicated in Figure 4.5:

Figure 4.5: Plastic Leakage Vulnerable Areas identified using Fuzzy Logic Approach, Adapted from NPC (2020a)<sup>5</sup>



<sup>5</sup><https://www.npcindia.gov.in/NPC/Uploads/file%20upload/Plastic%20Leakage%20Assessment%20Toolkit%20-%2020240520.pdf>

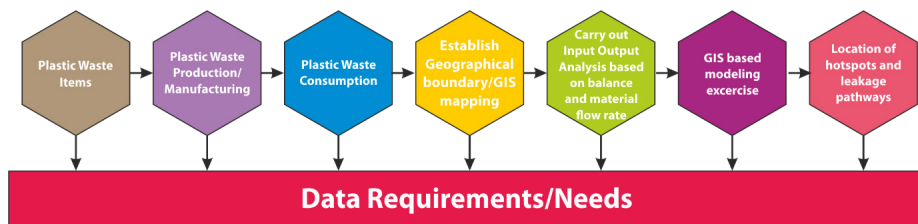
The major objective of guidance notes on to assist the target audience to map the plastic value chain in a geographical context, carry out material flow analysis and mass balance (Input and output) and its geographical mapping. This planning will include delimiting the area, establishment of plastic value chain, identification of stakeholders, hotspotting and their geographical location and mapping on a map. Guidance notes will assist the project designers and implementers to develop plastic risk map and carry out macro and micro plastic assessment, material flow analysis/ mass balance and their linkages. Guidance procedure includes completion of following steps.

1. Prepare conceptual plastic value chain and determine different blocks, which are applicable in the geographical area under study.
2. Prepare the tentative plastic value chain, which is applicable in the study area and determine the data points.
3. Procure data as per the data formats.
4. Prepare the matrix as per the data availability, reliability, range, completeness and relevance of the data.
5. Carry out input output analysis based on material flow and mass balance. Calculate the loss rate of the plastic waste from this mass balance.
6. Within the geographical boundary/ system boundary of study area (city/ region), procure maps of the area and prepare base map of the area with physical features marked on it. If the detailed map is not available easily then procure city map and fix up the municipal boundaries. Alternately, maps of the study area can be prepared based on standard map search engines available on the internet. The base map will be used for generation of different thematic layers. This mapping will give an insight into the possible hotspots and assist in carrying out the primary survey.

Following stepwise methodology towards developing Geographical Mapping of waste Plastic Material flow chain is:-

- a. Prepare the base map of the study area.
  - b. Develop layers of physical features (slope, contour, rivers, drainage etc.).
  - c. Develop layers of human interventions (land use, demography, socio-economic layers, points of interests, commercial, agriculture, industrial areas etc.).
  - d. Use GIS based analytical approach e.g., fuzzy approach by overlaying these layers to identify the vulnerable areas consisting of different hotspots, which may contribute to plastic leakage into river through carrier/medium like drains and air.
7. Prepare heat maps/ risk maps as per Steps 1 to 6.
  8. Compare the risk map/ heat map with the land use or waste density map to identify location of hotspots and tentative sampling locations for both macro-plastics and micro-plastics.

Figure 4.6: Data Requirements, Adapted from- NPC (2020a)<sup>6</sup>



6. **Verification/ Ground truthing:** Reconnaissance survey in the city is undertaken towards Ground Truthing the output of Fuzzy Logic Approach. It, thus, helps in validating the results generated from Fuzzy Logic Approach.
7. **Organization of Stakeholder's Consultation Workshop:** Stakeholder consultation workshop may be organized at local level to identify the plastic leakage areas in the city. Output of the preceding steps may be deliberated and consensus among the stakeholders regarding the plastic leakage sources and related quantities may be sought.

<sup>6</sup><https://www.npcindia.gov.in/NPC/Uploads/file%20upload/Plastic%20Leakage%20Assessment%20Toolkit%20-%2020240520.pdf>





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# 5

## Macroplastic Waste Assessment

### Plastic Leakage Characterisation

1. **Reconnaissance Survey (Preliminary):** This is conducted to identify representative hotspots for undertaking macro-plastic assessment (Cleanup study) and micro-plastic survey and a suitable criterion may be formulated in this regard as explained in subsequent section.
2. **Macro-plastic Assessment:** Macro-plastic clean up technique gives information about major polymers, plastic products as well as unmanaged waste (Qualitative and quantitative), which is getting leaked into the environment from the technosphere.

Macro plastics are large fragments of plastic, typically over 5 mm size which are found in the land as well as marine eco system mostly because of manmade menace. Macro-plastic degrades into micro-plastic due to different processes such as photo-degradation or mechanical/ physical degradation or chemical degradation. Land-based macro-plastic is considered one of the major sources of marine plastic debris. The conceptual understanding indicates the accomplishment of three step approach for carrying out macro-plastic assessment. These steps provide guidance and are used for on land plastic waste assessments but differ from the location.

3. **Identification of locations to carry out on land macro-plastic assessments:** This includes identification of locations, which serve as Plastic Leakage Source Hotspots. These hotspots are based on criteria including population density, waste generation rate, percentage of plastic in the waste-stream, waste collection rate, distance to shore, catchment runoff, slope and wind patterns. Figure 5.1 indicates a stepwise procedure for identification of hotspots. Examples also include Illegal dumpsites and littering spots as well as the area where waste collection service is not provided such as slum areas. A combination of area risk map/ heat map and survey locations eg.

Illegal dump sites and poorly serviced areas mapped through field survey provide the field survey team to identify such locations. **The fundamental approach requires the establishment of the places, where the plastic waste gets accumulated again and again, i.e., it becomes the source of plastic leakage.**

Figure 5.1: Hotspots Categorization and Identification, Adapted from- UNEP (2020)



Example of a criteria based on the location specification/ geographical context and considering the city-dwellers waste disposal practice/ habit may be as given below: -

- Output of Fuzzy Logic Model
- High abundance and occurrence of plastic waste litter existing waste management practice: Frequency of collection of waste from different litter points, frequency of cleaning of open-storm water/ wastewater drains, accessibility to the site, flood zone areas, geographical context- hilly/ plain/ coastal/ rural area; water logging areas/ wetlands, plastic accumulation zones; drainage pattern/ network to be considered, location of any river flowing through the city, if any; whether the city is zero-dustbin/ litter-free
- Land-use/ Land-cover (Whether agricultural/ industrial/ residential/ market etc)

*Note: This is not a complete criteria and suitable criteria may be developed based on the reconnaissance survey as well as the secondary data and Material balance undertaken above.*

**4. Carrying out on Land macro-plastic Sampling and Clean Up Surveys:** This step requires carrying out of the sampling and clean up surveys at the identified hotspots. This will include determination of the number of on land plastic samples as well as clean up surveys considering the seasonality and techniques used for sampling and clean up. The number of samples depends primarily on the cost versus utility. For higher statistical accuracy and confidence level (C.L), the number of samples will be more. There are a few common methods, adopted to analyze the samples at generation point and at the disposal point. The data may slightly vary from one method to another. For example, for higher confidence level, a greater number of samples may be collected at generation point and could be analyzed by hand sorting. These methods also differ in terms of cost and efforts. These methods can be divided into two categories – first is for measuring the amount of waste or quantification of waste and second, for characterization of waste. This could be further divided into characterization through visualization and characterization through hand sorting. **A step-wise schematic methodology is provided in Additional Reading 8.** In addition to this, **Additional Reading 9** includes Do's & Dont's and Identification of plastic/ Non-plastic waste.

Figure 5.2: Stills from Cleanup Study



Figure 5.3: Stills from Waste Segregation during Cleanup Study



Figure 5.4: Stills from Cleanup providing training to sanitation workers



Figure 5.5: Stills from Cleanup Study



5. **Carrying out macro-plastic survey in water body:** This step involves usage of barrier technique e.g., floating barriers to block macro-plastics floating in the flowing water and their assessment based on visual inspection i.e through high resolution 360 degrees camera or drones etc. Data from industry association can also assist in their identification. In case these macro-plastics are retrieved from the water body then they can be dried, segregated, quantified and characterized. Application of such barriers both upstream and downstream of the study area can give the leakage rate of plastics in the water body.

Figure 5.6: Macroplastic sampling in waterbody, Adapted from NPC (2020a)<sup>1</sup>



<sup>1</sup><https://www.npcindia.gov.in/NPC/Uploads/file%20upload/Plastic%20Leakage%20Assessment%20Toolkit%20-%2020240520.pdf>

# 6

## Microplastic Waste Assessment

### Micro-plastic assessment in Water body

- 1. Identification of Micro-plastic sampling sites:** In order to conduct sampling in the riverine, canal, waterways to understand the leakage of micro-plastic into the system, identification of micro-plastic site will be undertaken. Based on suitable criteria such as upstream/ downstream location (with respect to city), proximity to the affluent (domestic/ industrial/ storm water) discharge point location, application of water for drinking/ industrial/ irrigation/ agriculture, profile of city along riverine/ drain/ canal/ lake and contributing factors/ sources resulting from micro-plastic leakage.
- 2. Microplastic Survey & Assessment:** Micro-plastic survey and assessment technique gives information about major polymers, plastic products as well as unmanaged waste both qualitative and quantitative to some extent, which finds its way through leakage pathway into the environment (water) from the technosphere. Micro-plastics are tiny fragments of plastic smaller than a few millimeters, such as micro-beads used in exfoliators and injection moulding. It has been indicated that essentially there are two categories of micro-plastics, i.e. primary micro-plastics and secondary micro-plastics.

*Note: Primary micro-plastics are any plastic fragments or particles that are already 5.0 mm in size or less before entering the environment. These include micro-fibers from clothing, micro-beads, and plastic pellets. These are purposely manufactured to fulfill a function. These also include micro-plastics from cosmetics, detergents, paints, cleaning products, pharmaceuticals (nano-capsules), fertilizers etc. Secondary micro-plastics are micro-plastics that are generated from the degradation process and resulting from wear and tear or fragmentation of larger plastic products once they enter the environment through natural weathering processes. Sources of secondary micro-plastics include water and soda bottles, fishing nets, plastic bags and many others, including from wearing of tyres, synthetic textiles.*

*The basic aim of micro plastic assessment is to quantify different types of micro-plastic present in the riverine ecosystem. The approach and methodology is made to assess the amount and/or composition of plastic litter washing ashore over time from different carriers into the river/oceans. Figure 13 depicts some of the visuals from Micro-plastic Sampling.*

Figure 6.1: Visuals from Microplastic sampling in a water body, Adapted from NPC Fieldwork Study

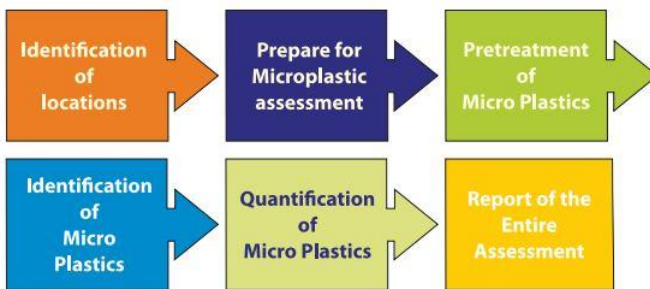


**The conceptual understanding gives steps to carry out micro plastic survey: -**

- **Step 1: Identification of locations to carry out micro plastic assessments in riverine or marine ecosystem.** Carry out activities to identify locations for micro plastic assessment in a river or sea. The activity wise procedure is described in **Figure 5.6**.
- **Step 2: Prepare for micro plastic assessment by carrying out activities** for preparation for micro plastic assessment which includes team formation, selection of location, timing of sampling and tools required for assessment
- **Step 3: Pretreatment of micro plastics using density separation, digestion** (separation of non-plastic material other than micro-plastics), picking out micro-plastics, counting and measurement, and material identification. Density separation may be performed to remove non-plastic material in the sample. Pre-treatment to digest organic substances with chemicals or enzymes is performed in many cases to remove the non-plastic material as well as bio-films that have formed on the surface of the sampled plastic particles.
- **Step 4: Identification of micro plastics** with larger particles identification with the naked eye, whereas small micro-plastics are identified by spectroscopic identification methods like Fourier transform infrared spectroscopy (FTIR), Raman Spectroscopy or Thermo-analytical methods.
- **Step 5: Quantification of Micro-plastics as per** classification of polymers, their count, size and the amount of MPs present in per liter of water and also by weight measurement.
- **Step 6: Reporting** of the entire assessment

Steps for Microplastic Waste Assessment is given below:

Figure 6.2: Microplastic Waste Assessment, Adapted from NPC (2020a)<sup>1</sup>



Guidance notes on selection of appropriate technique/procedure on microplastic sampling and analysis is given in **Additional Reading 10**.

<sup>1</sup><https://www.npcindia.gov.in/NPC/Uploads/file%20upload/Plastic%20Leakage%20Assessment%20Toolkit%20-%2020240520.pdf>





# 7

## Case Study

The cited case study is of a city selected under Smart City Mission launched by Ministry of Housing and Urban Affairs, Govt. of India

### Salient Features

- Location: A large urban city enclosed by the riverine system.
- Major urban agglomeration
- Slums population in the city are 4, 70,467 and households are 91,025
- Plastic composition is 3-4% of the total waste collected
- Macro Plastic cleanup activities were carried out at four hotspots points of plastic litter
- Hotspots point are also considered in the flood zones

Leakage Source identification & quantification: Tools and techniques used are as follows:-

### 1. Perception Survey

Through the Perception Survey, the type of waste generated in the city was found as follows:-

- i. industrial waste (plastic covers for covering sweetmeat boxes)
- ii. single-use plastic thrown in drain
- iii. synthetic leather
- iv. rubber trimming from footwear industry.

Further, with respect to the existing waste management process, it was found that the existing waste management process is inefficient leading to plastic leakage from different types of hotspots within the city into the river. Inefficiency in waste management process appears to be the major issue related to plastic leakage from the different types of hotspots within the city into the river. Therefore, a need to identify the cause-and-effect relationship needs to be identified so that necessary countermeasures could be designed.

## 2. Collection of Secondary Data

- i. **Demography:** A famous tourist place which encounters huge visitors annually and has a high population too. As per 2011 census and the projected population for 2021 is 2,261,561. Ward-wise population data was also obtained from ULB.
- ii. **Solid Waste Generation & Management:** As per the data obtained from Urban Local Body, total municipal solid waste generation in the city is about 700 metric tons per day. Ward-wise solid waste information/data was also obtained from ULB.
- iii. **GIS Data:** Visits were made to the governmental and GIS agencies to obtain GIS datasets, the hydrological network and statistical data were also obtained from relevant departments. The GIS datasets includes the Land Use Map and the Digital Elevation Map (DEM).
- iv. This waste is transferred to material recycling facility and finally dumped into landfill site at the outskirts of the city.
- v. **Land use pattern:** Land use pattern indicates that residential area as well as the western part of the city is a major area of consumption as well as generator of bulk of solid waste within the municipal limits.
- vi. Land use/ land cover was studied
- vii. Drainage network from Jal Board was studied
- viii. **Plastic Consumption:** Perception Survey from Plastic Manufacturing Associations Data on Domestic Plastic Import (DPI), Domestic Plastic Export (DPE), Domestic Plastic Production (DPP) was obtained from Department of Industries/ Ministry of Petroleum & Chemicals. Govt of India. Data on industries/ industrial areas were also obtained. Data on Plastic waste generation & collection was obtained from Urban Local Bodies (ULBs), Perception Survey & validated through Reconnaissance survey.
- ix. Procurement of topographic maps from the Survey of India, collection of city maps/ ward maps from Urban Development Authorities, procurement of satellite imageries of the city from NRSC.

### 3. Reconnaissance Survey (Field)

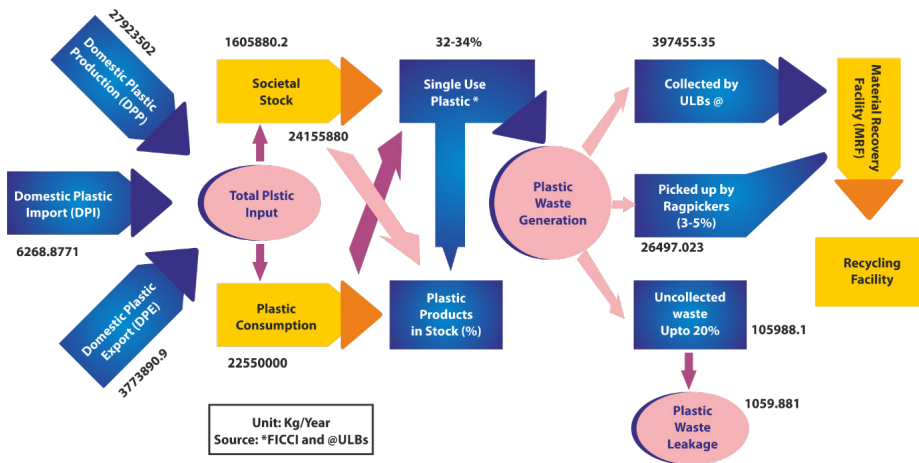
Under **Field Study** conducted as a part of **Reconnaissance Survey**, following techniques were used: -

- i. Photographic technique
- ii. Information gathered in Perception Survey was validated through fields visits to following: -
  - a. Sources of waste generation
    - Market place
    - Commercial place
    - Residential spots
  - b. Hotspot litter areas/ Plastic leakage points
  - c. Material Recovery Facility
  - d. Landfill Recovery Facility
    - Information on Hotspot leakages were captured through mobile applications.
    - Data captured was tracked on real-time basis on the dashboard.

### 4. Material Flow Analysis (MFA)

MFA was undertaken based on the information/ data gathered through Perception Survey, Secondary data collection & Reconnaissance Survey as indicated below in Figure 7.1 for the city.

Figure 7.1: Case Study- MFA-LCA Approach, Created by NPC



### 5. Fuzzy Logic Approach to identify plastic leakage areas

Land use map as obtained above served as the base map for modeling plastic leakage potential for the study region. The map for classified into five classes:- forest zone, water body, urban areas, low vegetative zones and bare soil. The slope was derived from DEM map.

The waste density of the study area was developed using population data and plastic consumption data. The drainage density map was created using the hydrological networks. Formula used for Plastic Waste Density Map is as given below: -

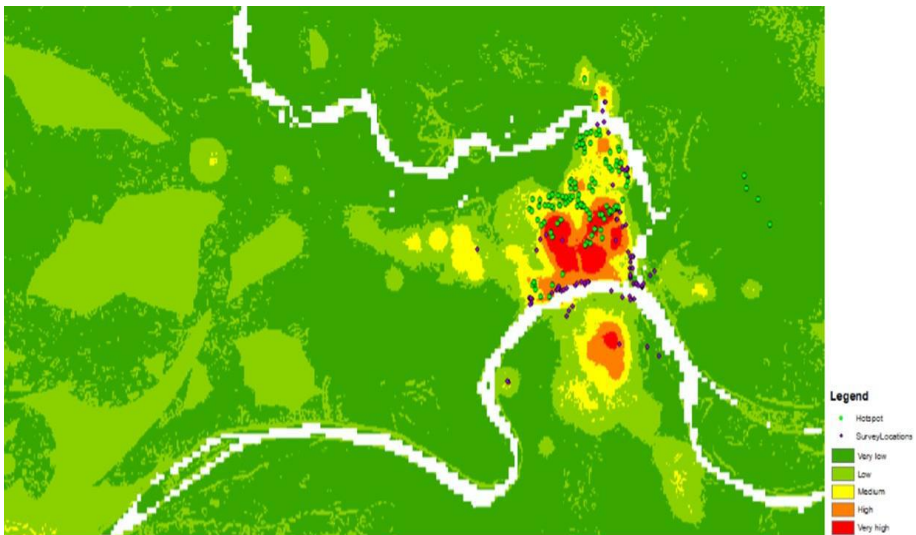
**Plastic Waste Density Map= Population X Plastic per capita consumption/ Area of the study**

Drainage Density which also has effect on leakage of waste to the riverine body was mapped using the following formula:-

**Drainage density= Total length of all streams in a basin (L)/ its Area (A)**

Drainage density was classified as High, Medium and Small Drainage density areas. The fuzzy membership tool was used to reclassify the various leakage models (drainage density, waste density Map), land-use map and slope of the study areas. After reclassification, they were overlaid with Fuzzy Overlay Operation. The resultant map is the Plastic Leakage Density Map (Figure 16). **Through Fuzzy Logic approach, plastic leakage vulnerable areas were identified and indicated as given in the figure 7.2 below:-**

Figure 7.2: Map of Plastic Leakage Vulnerable Areas identified using Fuzzy Logic Approach, Adapted from NPC (2020a)



6. **Ground Truthing** was conducted to validate the findings from Fuzzy Logic Model. Visuals of the locations of high plastic leakage areas (as indicated in Figure 7.2) are depicted in Figure 7.3.

Figure 7.3: Visuals from Ground Truthing of High Plastic Leakage areas, Adapted from NPC Fieldwork Study



7. **Macro-plastic Assessment at representative plastic leakage hotspots:** Clean-up activities were undertaken at 4 appropriate sites. These clean-up points are under observation for few months after clean-up and it was found that waste is again accumulated within a short period of time that validated the identification of the hotspots. Clean-up Activity was undertaken as per the methodology stated in Section B (Point IX) following which the results of clean-up studies are given below:

8. **Total Plastic by Count and Weight (in%) (Case Study) is given below:**

Figure 7.4: Total Plastics by Count (in%)

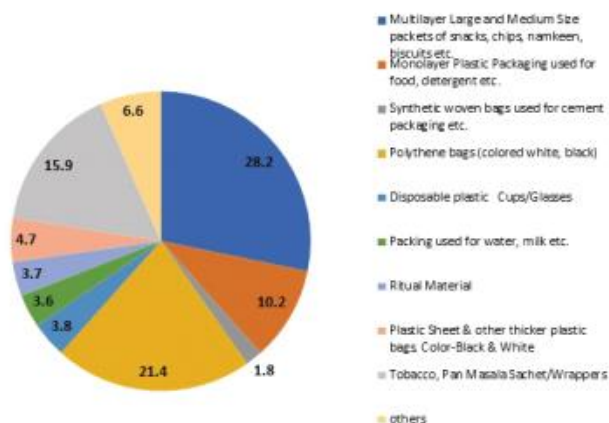


Figure 7.5: Total Plastics by Weight (in%)



### 9. Micro-plastic Survey:

Micro plastic sampling and analysis was undertaken in riverine body at different locations.

Total numbers of polymer types found were between the range 17- 40. Further, based on macro-plastic assessment studies, land based waste sources have been correlated with micro-plastic survey as depicted below:

Total no. of MPs – 1.23 MPs /m<sup>3</sup> to 5.69 MPs/m<sup>3</sup>  
 Color- Green> Red>Black> Grey> others  
 Type of Plastic particles- Fragment> Film>Fiber  
 Polymer types – EVOH> Polyacetylene > Polyisoprene > PVC> PVAL> Polyamide

# 8

## **Development of strategies/ interventions/action and the required instruments for reducing mismanaged plastic waste and its leakage into the environment**

This training manual has attempted in outlining the broad methodology towards identifying most relevant plastic polymers, applications, industrial sectors, regions, or waste management stages causing the leakage of plastics into the environment (including land, air, water, and marine environment), as well as associated impacts, through the life cycle of plastic products.

To reduce the leakage of plastic into environment, specific tangible actions that can be taken to mitigate the cause/source of plastic pollution needs to be formulated and are to be prioritised and designed to address the most influential hotspots in the plastic value chain.

These interventions may be practically implemented through specific regulatory, financial, or informative measures, considering context factors such as country dynamics and existing measures. As an illustrative example, an ULB may identify “mismanaged polyethylene bags and mismanaged MLP” as one of the reason/cause/sources of plastic pollution. A relevant intervention may be an increase in collection rate of these waste. A relevant instrument may be to implement a MLP deposit scheme.



Following methodology (IUCN-EA-Quantis, 2020) may be used to identify the interventions and appropriate instrument for implementation of the intervention as presented in Figure 8.1:

- **STEP 1:** choose up to 3 interventions for each actionable hotspot
- **STEP 2:** assess criteria levels for each chosen intervention
- **STEP 3:** visualize priority interventions in the top right corner of the chart

The list of interventions preliminary identified should be elaborated through a multi-stakeholder consultation process. Interventions may occur at any point along the value chain. According to IUCN-EA-Quantis, 2020, they may be categorized into six types of approaches along the value chain as given in Figure 8.2:

Based on the finalized interventions, appropriate instruments may be developed following the process of identification of interventions. In this process, technical and socio-economic assessment of each instrument should be performed. Qualitative assessment with three levels is suggested by IUCN-EA-QUANTIS, 2020.

Some instruments may be beneficial to multiple interventions, thus creating a positive synergetic effect. The proposed instrument may also require to be harmonised well with instruments already in place.

Figure 8.1: Methodology for identifying interventions, Created by NPC

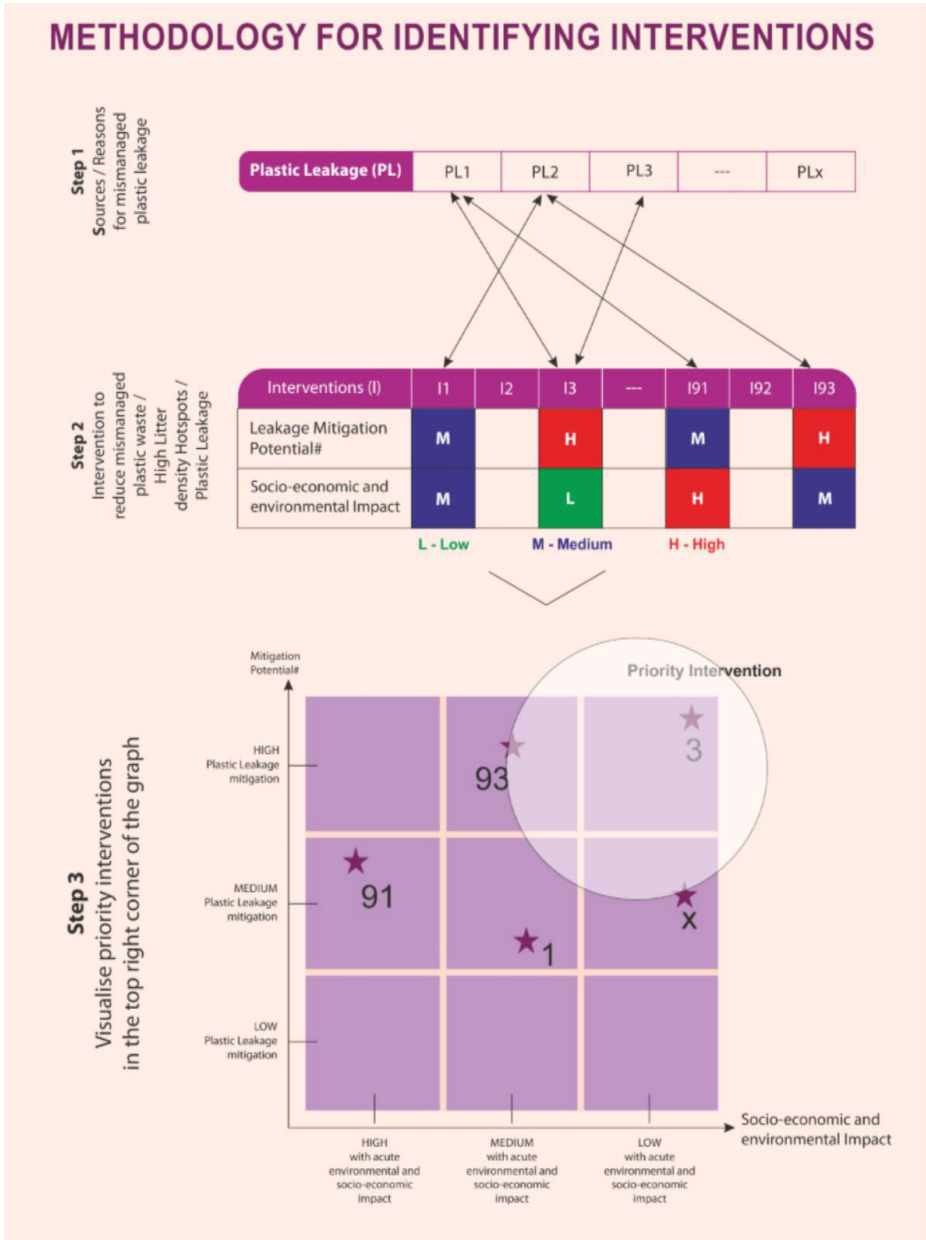
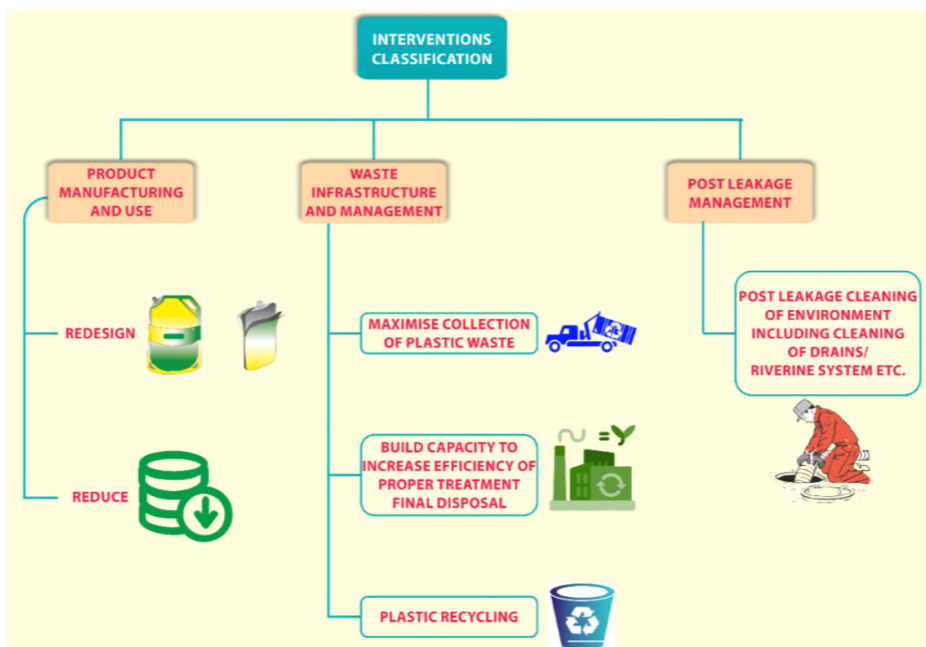


Figure 8.2: Classification of interventions, Adapted from IUCN



# 9

## Case Exercises

### MCQ Questions

1. Which are the correct steps in scientific disposal of waste?
  - a. Segregation of waste at source – collection of segregated waste – dry waste to MRF - wet waste to composting facility – inert waste to landfill
  - b. Collection of mixed waste at source – segregation of waste at secondary storage –dry waste to MRF - wet waste to composting facility – sent inert waste to landfill
  - c. Collection of mixed was
  - d. te at source – segregation of dry waste at secondary storage – dry waste to MRF - wet waste to dump yard.
  - e. Collection of mixed waste at source – segregation of dry waste at secondary storage – dry waste to MRF -wet waste to composting facility

Which are the correct steps in scientific disposal of waste?

Mentimeter

Segregation, collection, dry waste (MRF), wet waste compost, landfill

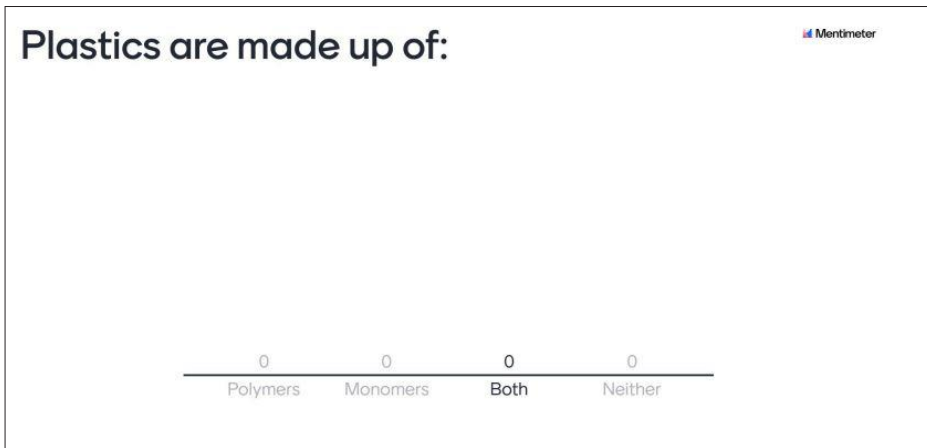
Collection, segregation, dry waste (MRF), wet waste compost, landfill

Collection, segregate dry waste, dry waste (MRF), wet waste – dumpyard

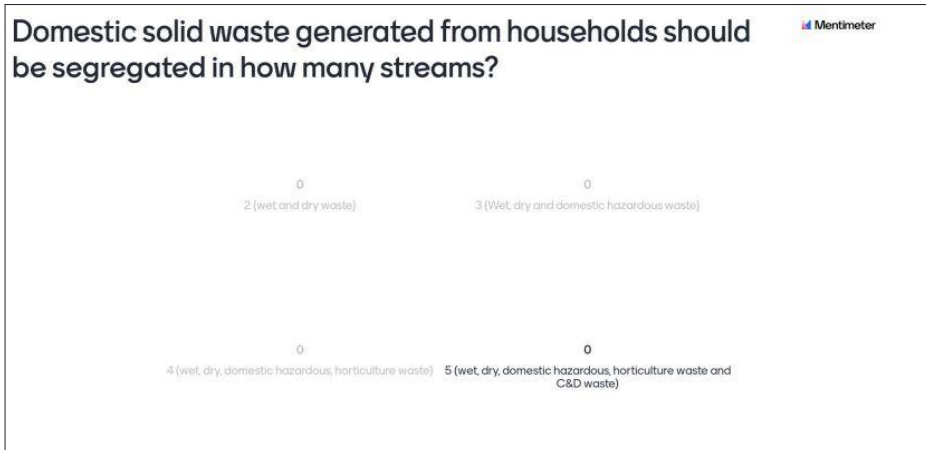
Collection, segregate dry waste, dry waste (MRF), wet waste compost.

2. **Plastics are made up of:**

- a. Polymers
- b. Monomers
- c. **Both (a) & (b)**
- d. None of the above



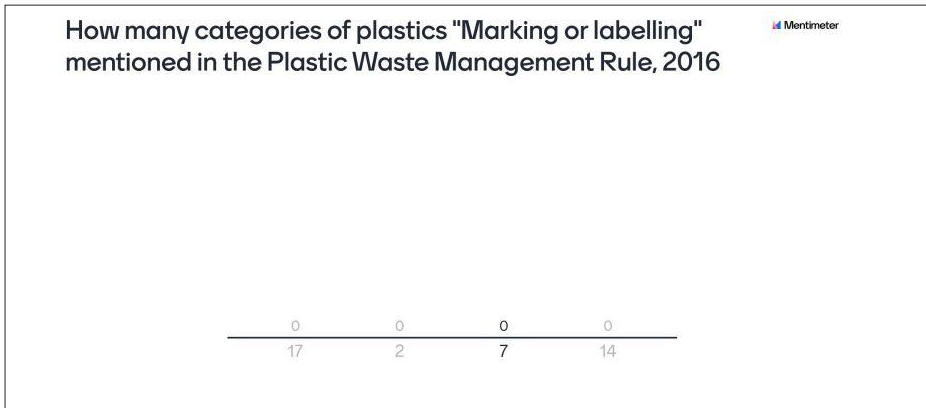
3. Domestic solid waste generated from households should be segregated in how many streams?
- 2 (wet and dry waste)
  - 3 (Wet, dry and domestic hazardous waste)
  - 4 (wet, dry, domestic hazardous, horticulture waste)
  - 5 (wet, dry, domestic hazardous, horticulture waste and C&D waste)



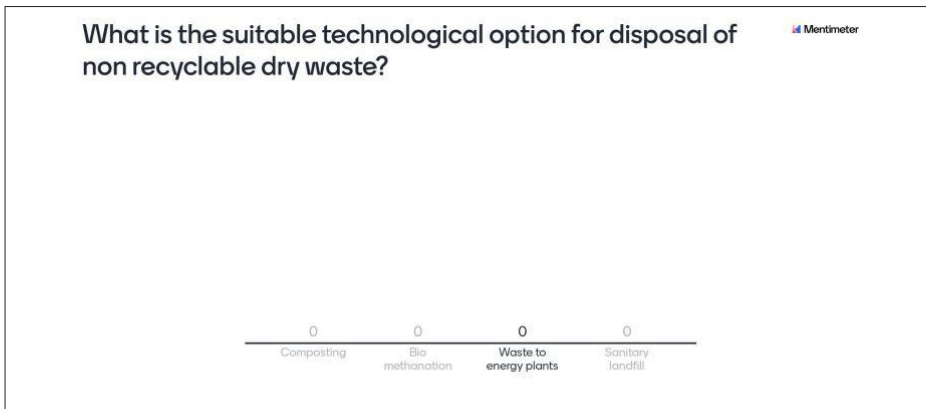
4. What is the suitable technological option for treatment and disposal of wet waste?
- Composting or bio methanation
  - Co-processing
  - Residue Derived Fuel (RDF)
  - Incineration



5. How many categories of plastics “Marking or labelling” mentioned in the Plastic Waste Management Rule, 2016
- 17
  - 2
  - 7
  - 14



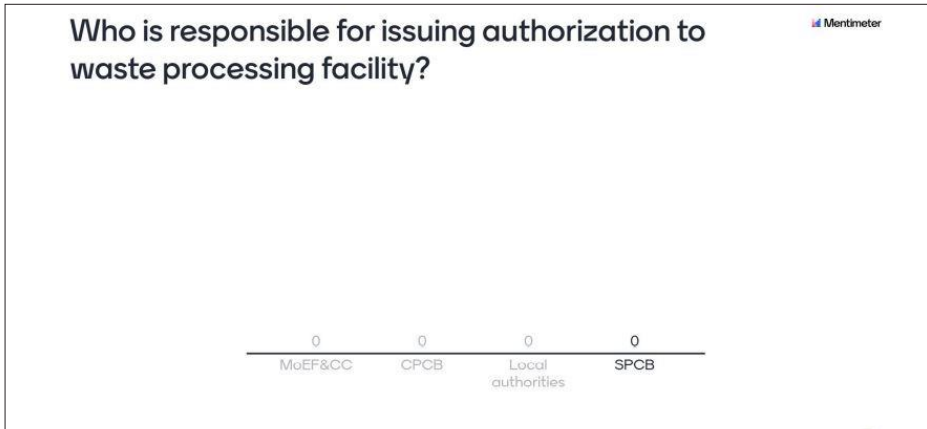
6. What is the suitable technological option for disposal of non recyclable dry waste?
- Composting
  - Bio methanation
  - Waste to energy plants**
  - Sanitary Landfill



7. Who is responsible for setting up waste processing facility in a city?
- a. MoEF&CC
  - b. CPCB
  - c. Local authorities
  - d. SPCB



8. Who is responsible for issuing authorization to waste processing facility?
- a. MoEF&CC
  - b. CPCB
  - c. Local authorities
  - d. SPCB





9. Which of the following outcomes are associated with the mismanaging of plastic waste?
- Choking of drains/water channels/bodies
  - Ingestion of waste by the cattle at littering point.
  - Burning of waste at local level
  - All of the above

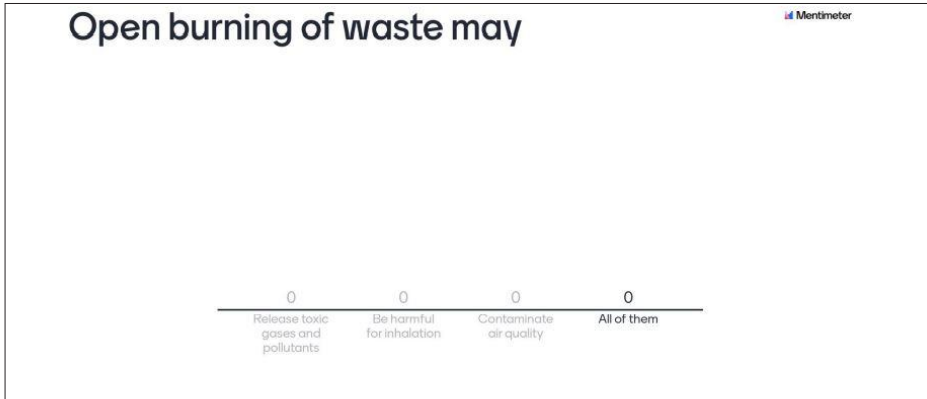


10. Storage of plastic waste shall be done in which of the following?
- Wet waste bin
  - Dry waste bin
  - Domestic hazardous waste bin
  - None of the above



**11. Open burning of waste may**

- a. Release toxic gases and pollutants
- b. Be harmful for inhalation
- c. Contaminate air quality
- d. **All of the above**



**12. Which are the highest consuming sectors for plastics in India?**

- a. Construction
- b. Textile
- c. Transport
- d. **Packaging**



**13. Compostable Plastics are made of**

- a. Biomass
- b. Petroleum products
- c. Wood
- d. None of the above



**14. Which of the following are essential in recycling & reusing of plastic waste**

- a. Segregation at source
- b. Collection
- c. Adequate Infrastructure
- d. All of the above



15. In which year has India banned import of solid plastic waste?

- a. 2016
- b. 2019
- c. 2014
- d. 2018

16. Strewn waste in open area

- a. Reaches the water body through runoff
- b. Causes mosquito breeding
- c. Contaminates soil quality
- d. All of the above

17. Ingestion of plastics by cattle, mammals, etc. causes?







- a. Harm to their health
- b. Plastic entering into the food chain
- c. Both (a) & (b)
- d. None of the above

18. Which of the following plastics are widely recyclable?

- a. PET, HDPE
- b. PP, HDPE
- c. LDPE, PS
- d. PS, O

### Identification of recyclable/non-recyclable plastics.

Please indicate widely recyclable plastics. You may choose only one answer.

Marking / labelling	Short Name	Scientific Name	properties	Mark here if recyclable
	PET	Polyethylene terephthalate	Clear, strong and light weight	
	HDPE	High-density polyethylene	Stiff and hardwearing: hard to breakdown in sunlight	
	PVC	Polyvinyl chloride	Can be rigid or soft via plasticizers: used in construction, healthcare, electronics	
	LDPE	Low-density polyethylene	Light weight, low cost, versatile, fails under mechanical and thermal stress	
	PP	Polypropylene	Tough and resistant, effective barrier against water and chemicals	
	PS	Polystyrene	Light weight, structurally weak, easily dispersed	
	O	Other, Poly carbonate, Poly urethane (PU), FRP	Diverse in nature with various properties	

## Secondary Data Collection

As per your perception, what are the approaches/ techniques for reducing plastic pollution.

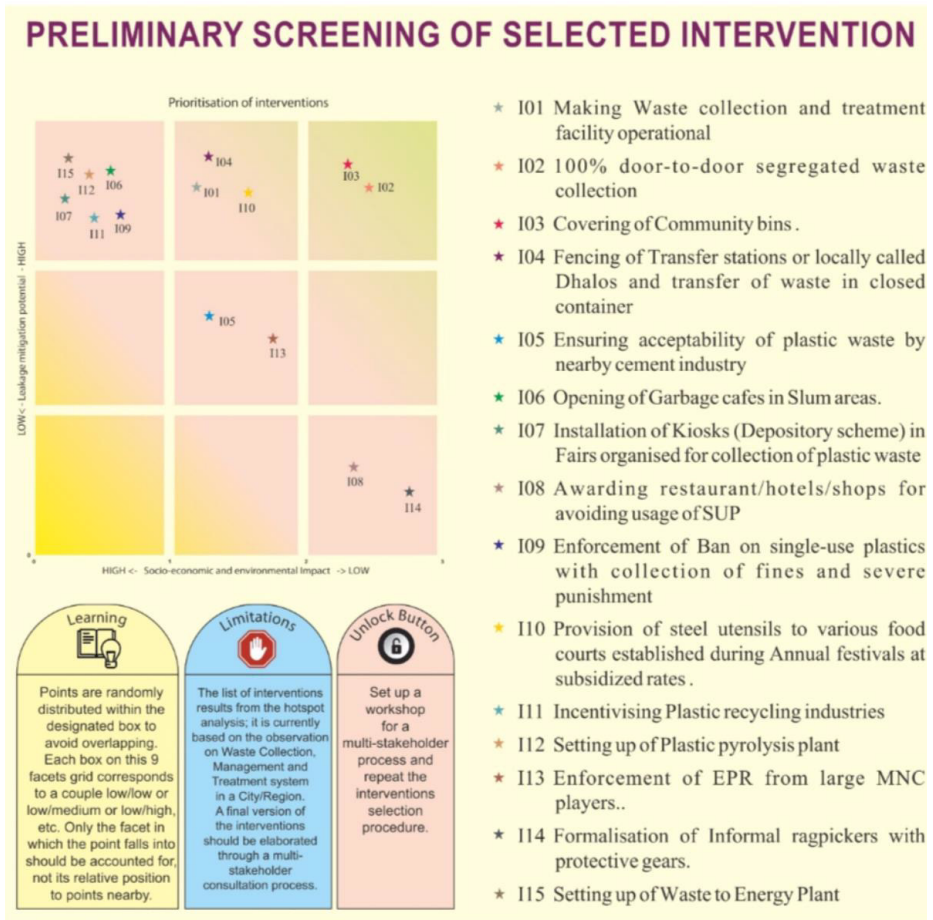
As per your perception what are the approaches/techniques for reducing plastics pollution

Mentimeter

## Prioritisation of interventions

1. Place the intervention in the right square as mentioned in the figure given below:

Figure 9.1: Screening of interventions for reducing mismanaged plastic waste, Created by NPC



Please place the position of intervention (square code) as depicted in Figure 9.1, below each intervention code:

Figure 9.2: Placing the right intervention in the right square based on its socio-economic and environment impact as well as its leakage mitigation potential, created by NPC

Intervention code	I01	I03	I11	I15	I37	I38	I71	I82	I85	I89	I91	I92	I93
Square	Sq. A, B, C, D, E, F, G, H or I?												





## List of Additional Readings

### 1. Guidance notes for hotspots, interventions and instruments.

#### STAGE 1: HOTSPOTS | WHERE TO ACT?

This stage consists of three steps: data collection, leakage and impact modelling, and hotspots prioritisation.

- i. **Data collection:** Obtaining data and information to better understand the plastic value chain at the production, consumption and disposal stages of plastic products, as well as the waste management system. This step prepares data inputs and information for the quantitative analysis at national, sub-national or local level for hotspot identification.
- ii. **Leakage and impact modelling:** Analysing the key sources of leakage and the associated potential impacts for both macro-plastics and micro-plastics.
- iii. **Prioritisation of hotspots:** Engaging stakeholders to prioritise and formulate hotspots in a strategic and explicit way considering stakeholders' knowledge of the local policy and socio-economic context.

#### STAGE 2: INTERVENTIONS | WHAT TO DO?

Prioritisation of interventions is based on a three-step process.

- i. **Match** the hotspots with interventions by selecting relevant interventions from a repository of generic interventions gathered from previous works and literature review.
- ii. **Specify** the interventions to the national context by refining the existing interventions and designing new ones when needed.
- iii. **Prioritise** the interventions based on a two dimension map picturing on one axis their plastic leakage mitigation potential, and on the other axis the presence/absence of any suspected unintended consequences.



### STAGE 3: INSTRUMENTS | HOW TO DO IT?

The last stage seeks to offers insight on key strategies for stakeholder engagement and identification of appropriate regulatory, financial or informative measures to successfully implement the planned interventions.

## 2. Guidance Notes for Key Features of the Systemiq/roadmap and UN Environment/ IUCN Methodologies

Key Features of the Systemiq / road map and UN Environment/ IUCN methodologies: -

- i. The action ability of the methodologies is high on regional basis, where plastic leakage is assessed in different geographies through regionalized factors such as mismanaged waste ratio, distance to shore or wastewater treatment efficiencies.
- ii. Methodologies with a regionalized actionable component account for regional specificities in the release rate of plastics that relate strongly to local infrastructure. This is relatively easy to measure.
- iii. Life cycle approach considers the range of impacts throughout the life of a product by taking the entire life cycle into account i.e. From the extraction of natural resources to material processing, manufacturing, distribution and use, and finally to the reuse, recycling, recovery and disposal of any remaining waste. Life Cycle Assessments (LCA) quantify these steps by assessing the emissions, resources consumed and pressures on environment, health and safety that can be attributed to a product or service.
- iv. Phase of life cycle assessment involves the compilation and quantification of inputs and outputs for a product throughout its life cycle the methodologies focus on the leakage pathway and allow the establishment of a plastic leakage inventory for different plastic types at different stages of life cycle.

- v. The methodologies focus more on developing calculation rules and modelling leakage pathways, enabling the creation of synthetic metrics to support decision-making and monitor progress. It provides guidance for calculating micro- and macroplastic leakage quantities at each life cycle stage. The first step to start a plastic leakage analysis is to collect data on the mass of plastic waste differentiated by different types of polymers (if possible) including regionalized information on macroplastics' end-of-life. The loss rate represents the mass of waste lost as a percentage of the mass of plastic waste generated.

$$LR = LR_{dirpath} + LR_{uncol} + LR_{poorman}$$

$LR_{dirpath}$  = Loss rate for the direct pathway

$LR_{uncol}$  = Loss rate for the uncollected waste pathway

$LR_{poorman}$  = Loss rate for the poorly managed waste pathway

- vi. These methodologies inform and guide decision-making towards reducing plastic leakages through counter measures to be implemented at policy, regulatory, planning, program and project level.
- vii. The methodologies intend to provide the user with a qualitative assessment of the environmental impacts of the plastic leakage resulting from different plastic applications, in order to define priorities for actions (hotspots).

### 3. Detailed template for secondary Data Collection

Table 11.1: Template for secondary data collection

Data Inventory			Unit / Format	Description	Purpose: Relation to the plastic leakage
<b>1. Demographic information</b>					
	1.1	Population	Number	Total population in the selected district, city, community, with disaggregation by sex (male and female)	There is a link between population density and plastic leakage to the sea (Jambeck, et al., 2015), also previous studies have model plastic losses of leakage within a water basin using the amount of plastic used per person. Since plastic waste generation and leakage is dependent on population density.

	1.2	Population Growth Rate	%	This is the rate at which the number of individuals in the population increases in a given time period. The population growth rate's unit is percentage per year.	The increasing urbanization along with the population growth rate are responsible for an unaccountable amount of plastic pollution (Hoornweg and Bhada-Tata, 2012). Due to rapid urbanization and rising consumer demands, more plastics (single-use plastics) have been made more than any other plastic manufactured in history.
	1.3	Floating Population	Location	Density of restaurants/hotels. Information will be extracted from booking.com/agoda.com and/or google earth	One of important indicator for the scenario. For example, plastic waste will be procured more at the weekend as well as holidays or festival at the area of interest, where has high density of hotels and restaurants.
	1.4	Household	Number	Number of household of the level x of subdivision	Need to identify the (plastic) waste generation per household in addition to the (plastic) waste generation per capita to verify the differences among pilot cities for the purpose of generalization of regional plastic leakage
	1.5	Slum Spot (if any)	Location (Zone)	This is a place has high density of population in urban area, decrepit housing units in a situation of deteriorated or incomplete infrastructure, inhabited primarily by impoverished persons.	The slum spot is considered as one of potential plastic leakage sources because collection service in a slum spot is not usually provided by the municipality. In addition, awareness activities is also not frequently conducted in a slum spot.

	1.6	Others (Income categorization)	If any	education level, career, income level, sanitation level, etc., (Please list up the necessary data after the consultation with local partners)	In general, when waste characterization survey is conducted, it is conducted in income levels such as high, middle and low income areas. In general, a lower income area is considered of more potential plastic leakage area.
<b>2. Topographic/Basin characteristics information</b>					
	2.1	River networks: Main stream and Tributary of rivers,	Shapefile	The network of main river, stream and the tributary in the watershed	This is very useful for hydrological correction of the digital elevation model (DEM) in the purpose of extraction of the river basin.
	2.2	Digital Elevation Model (DEM)	Tif file	The data shows Digital Elevation Model (DEM) that is a digital cartographic dataset in three (XYZ) coordinates and has been derived from contour lines or photogrammetric methods. The terrain elevations from ground positions are sampled at regularly spaced horizontal intervals. This data downloaded ALOS-PALSAR data acquired by the Japan Aerospace Exploration Agency (JAXA), distributed by the EARTHDATA, NASA. The pixel size of this data is 12.5 × 12.5 m and 16 bits per pixel, is obtained with a fixed incidence angle of 34.3° in the ascending orbit.	Plastic leakage must be affected by the topographic feature described by DEM according to the water flow direction in the watershed.

	2.3	Flow Observation	m3/s	The flow and water level at any station in the outlet, or at the river mouth. The availability should be extend for more than 3-5 years in order to capture the in seasonal variation	The flow and the runoff data is useful for identify the flow capacity in each sub-basin. MRC agree that we can get the raw data for our study area.
	2.4	Rainfall runoff data	m3/s	Rainfall runoff data in each sub-basin, generated from rainfall runoff model	The output from the rainfall runoff model is used for identify the flow capacity in each sub-basin.
	2.5	Temporal Change of River Banks		Temporal Change of River Banks will be captured by spatio-temporal analysis of satellite images along the main rivers of study sites	Along the Main rivers of study sites in Mekong, temporal land contributes as plastic accumulation, commercial and agriculture activites which have potential to produce plastics
	2.6	Flood Hazard Map	Shapefile	Could be annual report about the flash flood in the city or the shapefile of any research study for the flood inundation in the city.	Flood hazard map are necessary in the flat area as we are not able to produce such information with Digital Elevation model. With result of the flood extent yearly, we can use it as indicator in the proxy approach for identify the most prone area for flooding.
	2.7	Others		(Please list up the necessary data after the consultation with local partners)	N.A

3. Infrastructure					
			Shapefile	Industrial zone, development zone	As a potential plastic leakage source
	3.1	Industrial area/ Economic zone/ Factory location	Shapefile	Location of factory with their information: type of factory (ex: companies producing plastic raw materials, cosmetics, shampoo, hygiene products), size,....	As a potential plastic leakage source
	3.2	Tourism area	Shapefile	Urban, nature, culture and history, beach	As a potential plastic leakage source
	3.3	Other Point of Interests	Location, Type	Including: pagoda, temple, school, hospital, hotel, market,....	As a potential plastic leakage source
	3.4	Road network	Shapefile	Including alleyway	(Please let me know why we need this parameter)
	3.5	Building footprint	Shapefile	The outline of the total area of a lot or site that is surrounded by the exterior walls of a building or portion of a building.	Building footprint plays an important role for mapping fine-scale of population density.
	3.6	Others		(Please list up the necessary data after the consultation with local partners)	N.A.
4. Land use information					
	4.1	Administration		Boundary of study areas in difference level: province, district and sub-district	To make recommendation with countermeasures in each administration according to their own local context
	4.2	Land use land cover	Land use types/ units	Including different type of land use: built-up (city, commercial, village), paddy field, annual crops, livestock, irrigation	To make recommendation with countermeasures to an administration level

	4.3	Plastic manufacturer	Location, Type		As a potential plastic leakage source
	4.4	Agriculture	Location, Type		As a potential plastic leakage source
	4.5	Fishery and Aquaculture	Location, Type		As a potential plastic leakage source
	4.6	Waste collection points	Location	The collection of solid waste from point of production (residential, industrial commercial, institutional) to the point of treatment or disposal.	As a potential plastic leakage source
	4.7	Intermediate treatment facility (transfer station, recycling facility, junkshop)	Location, type		As a potential plastic leakage source
	4.8	Illegal dump	Location, Photo	The unlawful deposit of waste larger than litter onto land. This waste material is dumped, tipped or otherwise deposited onto private or public land where no license or approval exists to accept such waste.	As a potential plastic leakage source
	4.9	Disposal site (dumpsite)	Location, Photo	A site for the disposal of waste materials by burial or burning	As a potential plastic leakage source
	4.10	Wastewater facility	Location	A facility in which a combination of various processes (e.g., physical, chemical and biological) are used to treat industrial wastewater and remove pollutants	As a potential plastic leakage source

	4.11	Others		(Please list up the necessary data after the consultation with local partners)	N.A.
<b>5</b>	<b>Satellite imagery</b>				
	5.1	Optical imagery		Freely imagery: Sentinel-2, Landsat	(Please let me know why we need this parameter)
	5.2	Night time light imagery		Density of light at night	To identify settlement areas

#### 4. Guidance Notes for stepwise description of the plastic footprint methodology

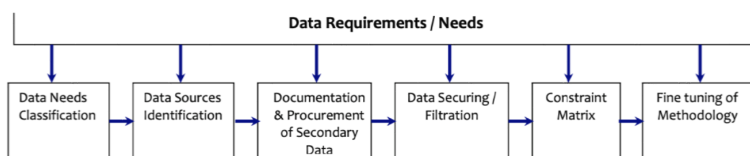
##### Plastic Footprint Methodology

The major objective of guidance notes is to assess the plastic footprint methodologies and their application in countries or regions to generate data to guide policymakers towards measures to address plastic leakage.

Guidance procedure includes completion of following steps as given below: -

- i. Identify the study area or the geography and fix the geographical boundaries where the assessment is being undertaken e.g. municipal/ rural area/ watershed/ basin/ state/ region boundary.
- ii. Identify data requirements by classifying data needs under the heads of households, production, consumption/calculated sales, stock data, waste generation, storage data, reuse, recycle and landfill for plastics.
- iii. Identify tentative sources of data and refer to information guide/ meta data sheet for preparing preliminary or detailed interview guide/ checklist/ questionnaires for data collection for each time.
- iv. Document secondary sources of data for each type of metadata and visit the respective agency to procure data i.e., published/ unpublished/ historical.
- v. Check the availability, reliability, amount and range and completeness of data against the decision criteria.
- vi. Prepare the constraint matrix as by mapping outputs from step V
- vii. Devise strategies to overcome data constraints by combining blocks of plastic value chain where data prior stage data and post stage data is available.

Figure 11.1: Guidance Procedure for Data Needs Assessment for Plastic Value Chain Assessment, Adapted from NPC (2020a)





## 5. Guidance Notes for Plastic Value Chain and Plastic Waste Material Flow- Stage Wise

### Plastic Value Chain: Stage-wise

The plastic value chain mapping can be described starting from manufacturing, production, import, consumption, waste generation, sources of generation, treatment (facilities of material recovery) and disposal. It starts from material engineering for plastic and leads to its production followed by its consumption, collection, recycling and repurposing and finally its conversion and disposal. When the entire chain is mapped in a geographical context (nation, region, city/ other), it gives a fair understanding of material flow and leakage pathways.

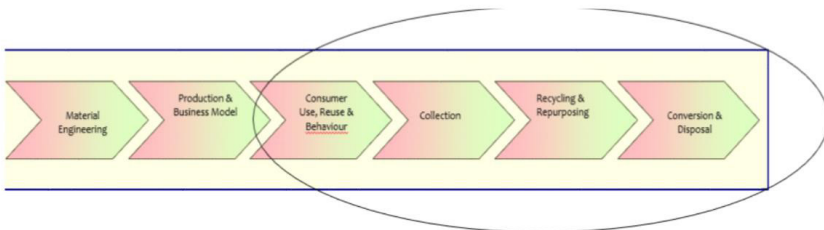
The establishment of material flow within a geographical boundary assists in identifying, networks / chain connecting different phases of life cycle of plastic value and associated stakeholders in a geographical context. Once the chain gets established, “material flow balance” ex. Input/ output (mass) balance in each phase forms the basis of quantification of plastic waste generation. The salient features of this approach are given below: -

- i. The model is based on the ‘unit process approach’, where a unit process represents processes or activities.
- ii. The material flow model considers all unit processes and flows within a defined boundary. Arrows indicating the flow of material link the unit processes.
- iii. There are two different kinds of unit process. Type 1 receives material without any alteration, where there are no conversions. Therefore, input is equal to output ex. use and collection of plastic waste. In Type 2, a conversion of materials takes place, thus creating new materials (products, waste, etc.) ex. treatment of plastic waste into raw material etc.

The boundary is the interface between the existing system and the external environment or other systems.

For example, if in a particular geography, only the blocks of the plastic value chain within the oval are present then material flow related data will be focused on consumption, reuse, collection, recycling & repurposing, conversion, and disposal. Further, only a part of the plastic value chain will be mapped in that geography.

Figure 11.2: Blocks of Plastic Value Chain, Adapted from NPC (2020b)



## Plastic Waste Material Flow: Stagewise

**Material cycle of plastic** has been described considering **life cycle approach**. It considers the range of impacts throughout the life of a product by taking the entire life cycle into account i.e., from the extraction of natural resources to material processing, manufacturing, distribution and use, and finally to the reuse, recycling, recovery and disposal of any remaining waste. Life cycle assessments (LCA) quantifies these steps by assessing the emissions, resources consumed and pressures on environment, health and safety that can be attributed to a product or service.

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

## 6. Guidance Notes on categories of classification of hotspots

### Methodology: Classification of Hotspots

Hotspots are defined as a country, product, polymer or value chain stage that contributes significantly, directly or indirectly, to the leakage. Hotspot is a life cycle stage, process and elementary flow which accounts for a significant proportion of the impact of functional unit, where the functional unit is a measure of the function of the studied system to which inputs and outputs can be related.

Table 11.2: Classification of hotspot

Hotspot	Definition	Note
1. Plastic value chain hotspot	Plastic value chain hotspot includes attributes of the plastic value chain in the region, including elements of plastic production, conversion, trade, use or disposal. Such attributes may be related to domestic, commercial or industrial activities. Plastic value chain hotspots are not related to any specific plastic application or product but can often be related to a plastic type (e.g., a polymer) or an industry.	Examples include rates of plastic production or trade, key industries that drive plastic production or use, or inadequate infrastructure for appropriate disposal.
2. Plastic leakage Source hotspot	It is the high-risk source of plastic waste to be leaked to waterways connecting to the ocean, which is identified through an optional analysis, relying on GIS tools, and allowing to identify the locations of highest leakage within country. The hotspot mainly consists of localities or watersheds.	These hotspots are based on the criteria including population density, waste generation rate, percentage of plastic in the waste stream, waste collection rate, MWI, distance to shore, catchment runoff, slope and wind patterns. Examples also include Illegal dumpsites and littering sports as well as the area where waste collection service is not provided and slum.
3. Plastic accumulation hotspot	Plastic accumulation hotspot is wastes accumulated at the artificial barriers and topographic barriers in waterways and rivers locally and regionally. This hotspot assists in identification of plastic items getting leaked into carrier (water) and identification of plastic leakage source hotspots while tracking it back to the source. It will assist the practitioner to correlate the plastic waste to loss rate and leakage rate into carrier medium.	The location of accumulation should be Artificial barriers, Dam Topographic barriers in waterways and rivers

Hotspot	Definition	Note
4. Plastic application hotspot	Plastic application hotspot is related to a plastic application, or an activity related to the plastic application. Plastic application refers to a product or packaging partially or completely made of plastic. For Example: A “hotspot” as defined in this category can be a product category with high environmental impact in multiple impact categories e.g., PET cans and PE bags. Generally, this hotspot assists the decision maker for prioritizing actions related to polymer	Common examples of applications include straws, grocery bags, plastic beverage containers, fishing nets, etc. Common examples of activities related to applications include driving a car (leading to tyre abrasion) or on the go eating (potentially leading to littering).

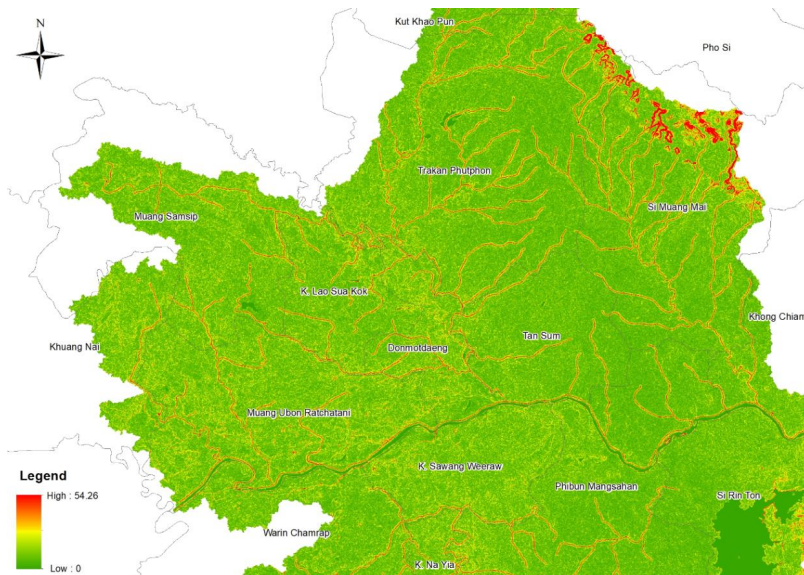
## 7. Detailed approach for Fuzzy Logic Model

### i. Data use

The main thematic layers (from intermediate results, other input from experts and/or local partners) are generated as an input for predicting potential plastic leakage for the project. Several processes were performed to prepare these layers for being used as an input in a fuzzy model. Some of maps are illustrated as follows:

- Topographic and slope maps are generated by using DEM (Digital Elevation Map) from SRTM data with spatial analyst tools (ArcGIS).

Figure 11.3: Slope map in UbonRatchathani.  
The map unit is in degree, Adapted from NPC (2020a)



- a. Density maps, including population density, dumping density, factory density, and river/stream density are produced using collected geospatial data with spatial analyst tools (ArcGIS), particularly is point density function. The result is a raster dataset.

Figure 11.4: Population density map in UbonRatchathani, Adapted from NPC (2020a)

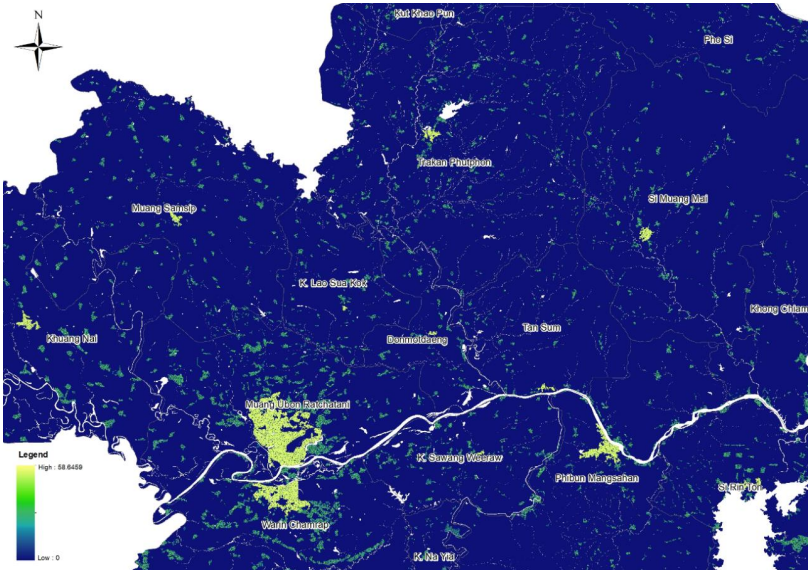


Figure 11.5: Waste/Plastic dumping density map in UbonRatchathani, Adapted from NPC (2020a)

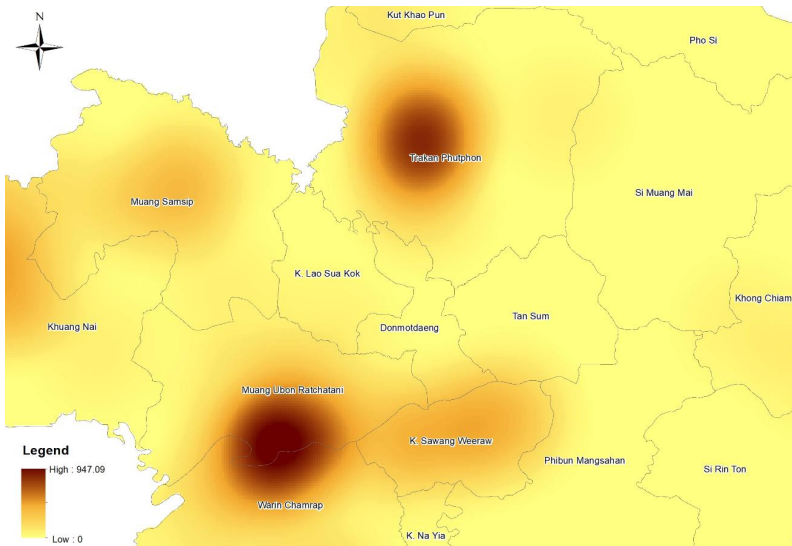


Figure 11.7: River density map in UbonRatchathani, Adapted from NPC (2020a)

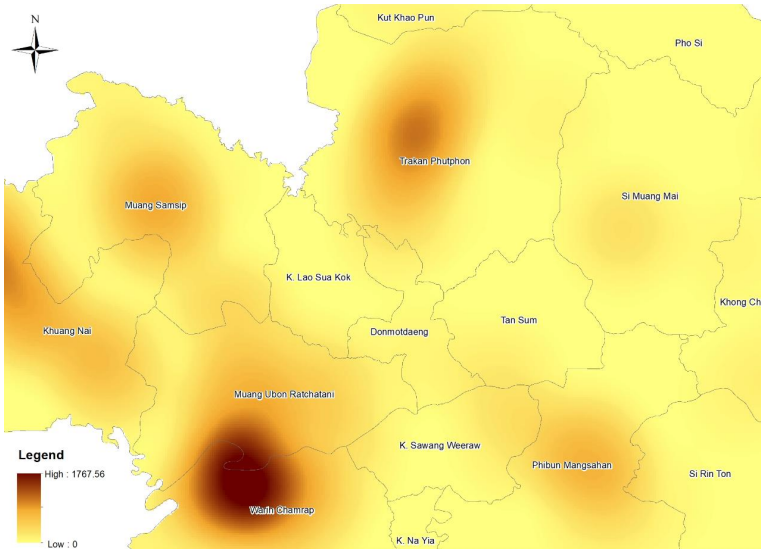
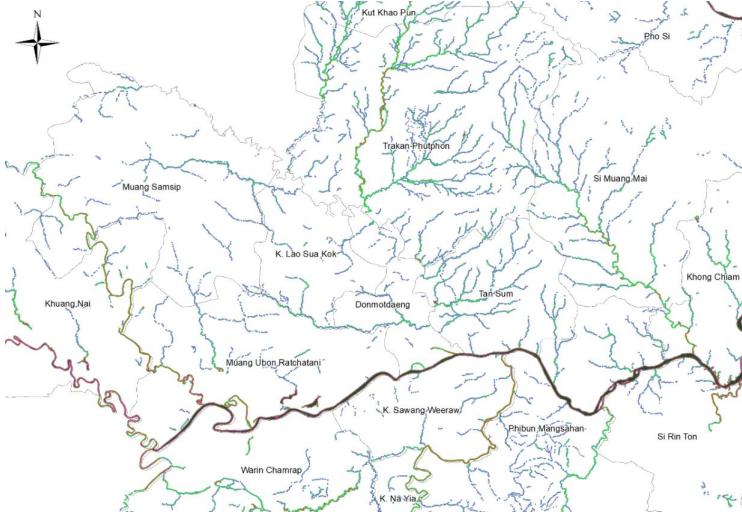


Figure 11.6: Factory density map in UbonRatchathani, Adapted from NPC (2020a)



- b. Distance maps, including nearest distance to river network, nearest distance to road network, and nearest distance to other POIs (hotel, school, etc.) are produced using collected geospatial data with spatial analyst straight line distance function in ArcGIS which creates such maps by calculating the straight line (Euclidean) distance from the main objective site (in this case: road, river, etc.). The result is a raster dataset in which every cell represents the distance to the main objective site in meters.

Figure 11.8: Distance to river network, Adapted from NPC (2020a)

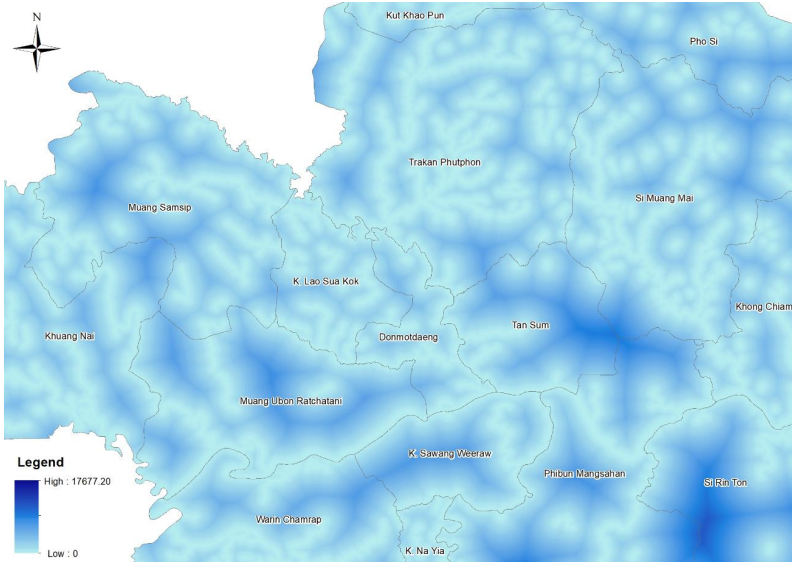
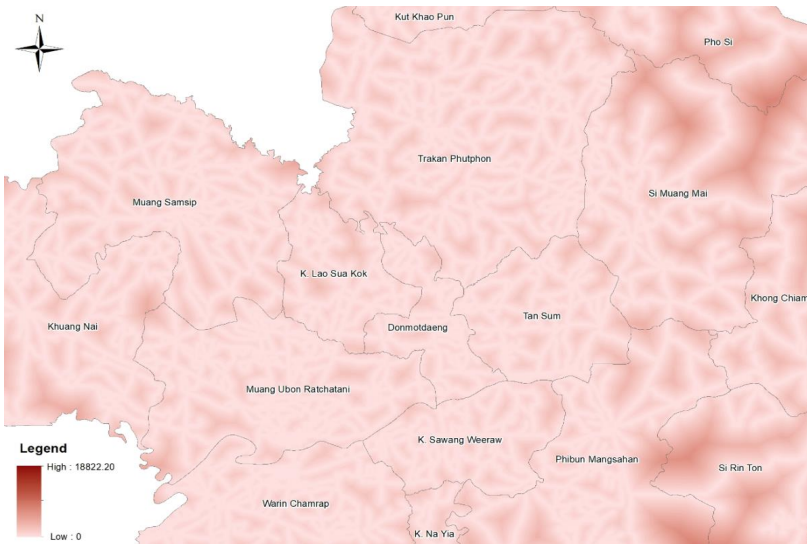


Figure 11.9: Distance to road network, Adapted from NPC (2020a)



- c. Land use map is reclassified and converted into raster data with 6 main classes, including built up, industrial and commercial, agriculture, complex agriculture, forest, and water body using spatial analyst tools (ArcGIS).

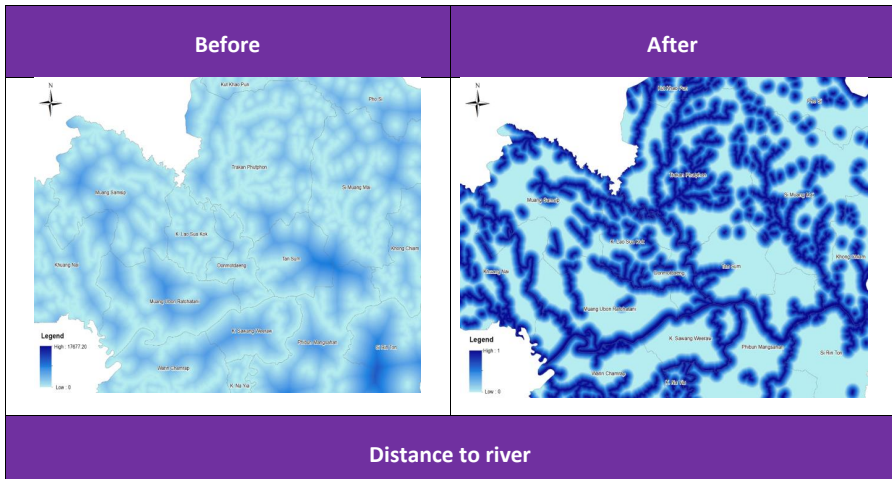


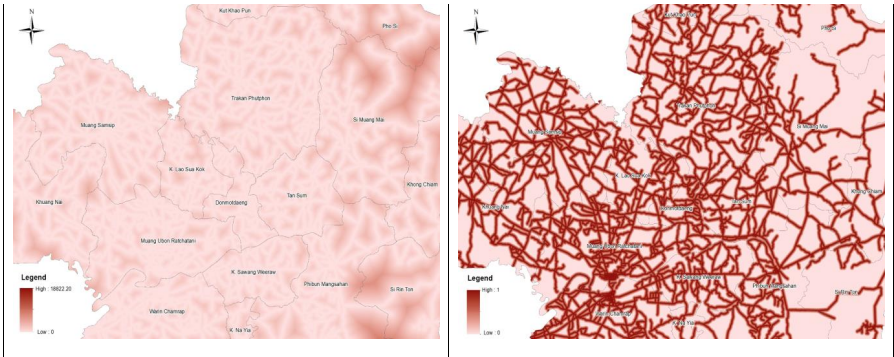


Table 11.3: Parameter used to reclassify input raster using fuzzy linear transformation function

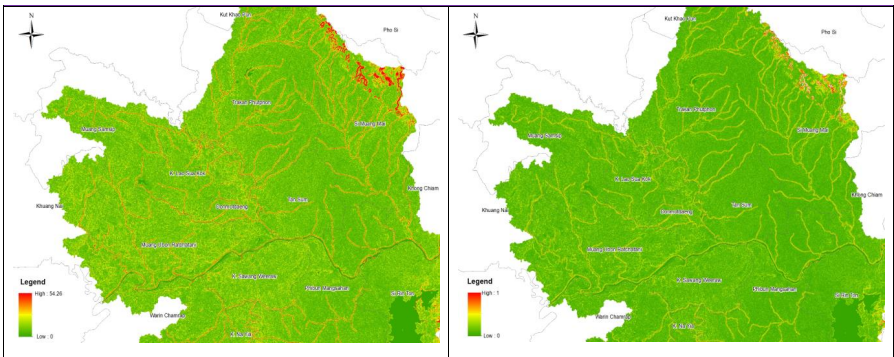
No	Indicator name	Input value		Output value	
		Min	Max	Min	Max
1	Slope	0	20	0	1
2	Population density	Min	Max	0	1
3	Plastic dumping density	Min	Max	0	1
4	Factory density	Min	Max	0	1
5	River density	Min	Max	0	1
6	Distance to river	0	2000	0	1
7	Distance to road	0	600	0	1
8	Distance to POIs	0	1000	0	1
9	Land use	Min	Max	0	1
...	...	...	...	0	1

Figure 11.11: Reclassified input raster data using fuzzy linear membership function, Adapted from NPC (2020a)





**Distance to road**



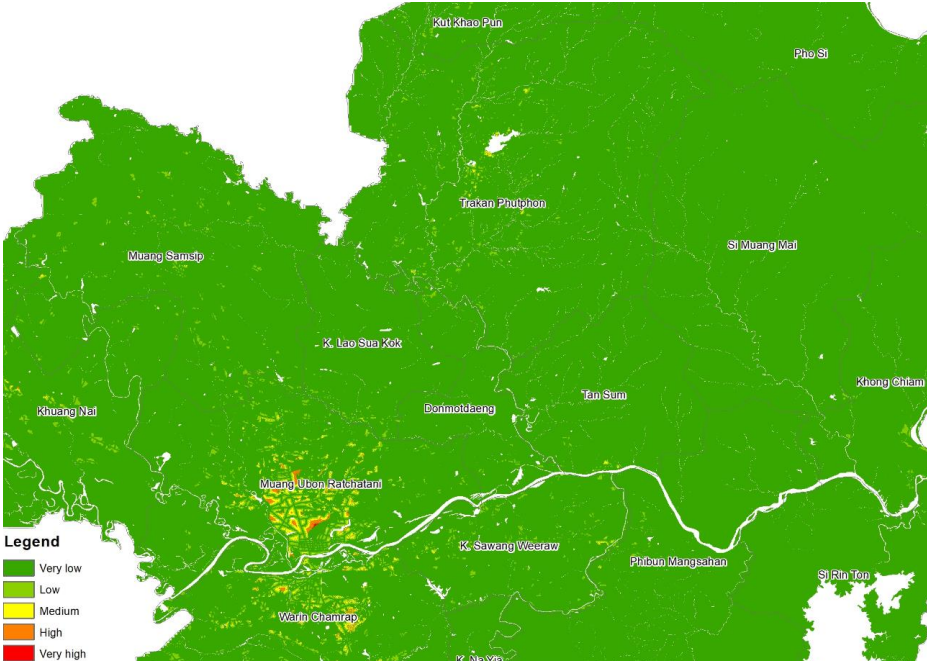
**Slope**

**iii. Fuzzy overlay**

Once the appropriate fuzzy membership value for data criteria is assigned several reclassified surfaces showing a value from 0 to 1 are generated. The next step in applying fuzzy logic is to overlay these input maps. This step is similar to weighted site selection (a site selection type that allows us to rank raster cells and assign a relative importance value to each layer) because the different reclassified surfaces are compared to each other. To complete this step, we tried to apply several fuzzy overlay types (for example: fuzzy OR, fuzzy Sum, etc.,). Finally, fuzzy AND overlay type is selected for the study, because it gives a better result than others overlay types.

Figure 11.12. shows the potential plastic leakage map, result of the fuzzy overlay. The fuzzy overlay was classified from 0 to 1, according to fuzzy scale, 0.0 to 0.2 (green) and 0.2 to 0.4 (light green) were classified as very low and low plastic leakage, respectively. While 0.4 to 0.6 was ranked as medium plastic leakage, while 0.6 to 0.8 (yellow) and 0.8 to 1 were classified as high and very high plastic leakage, respectively.

Figure 11.12. Potential plastic leakage map in UbonRatchathani, Adapted from NPC (2020a)

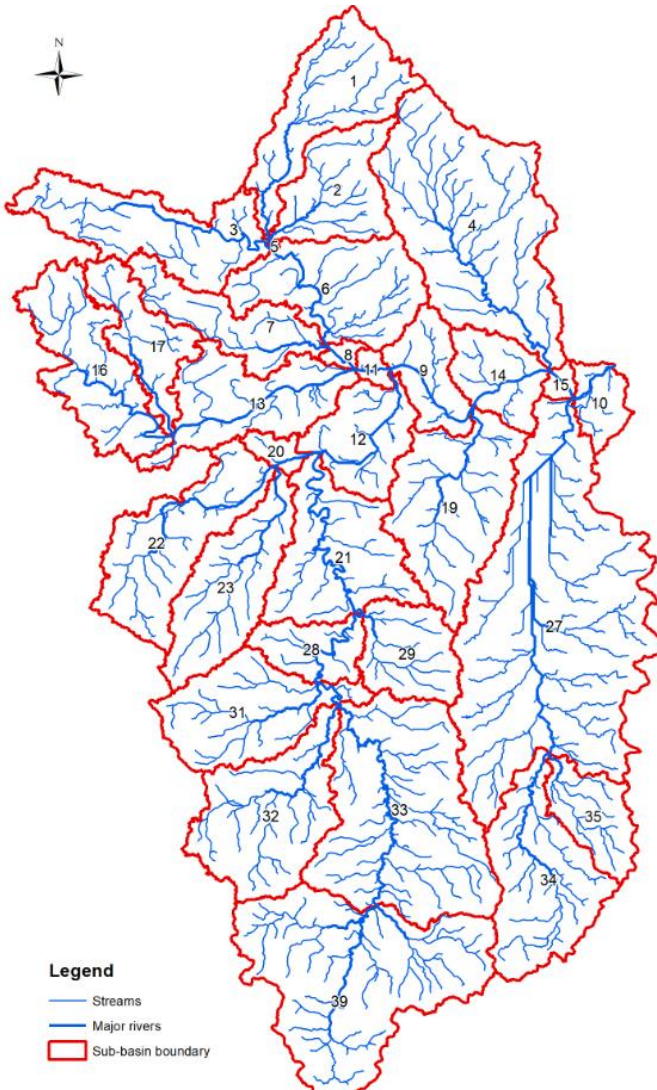


## 8. Identifying the causality between source and accumulation in sub-tributary level

### i. Sub-basin map

Sub-basin map is generated using DEM data and stream network (from HydroSHED) with Arc Hydro toolbox. Analysis result shows in **Figure 11.13**. In total, we extracted 31 sub-basins which are contributed into main river in the area.

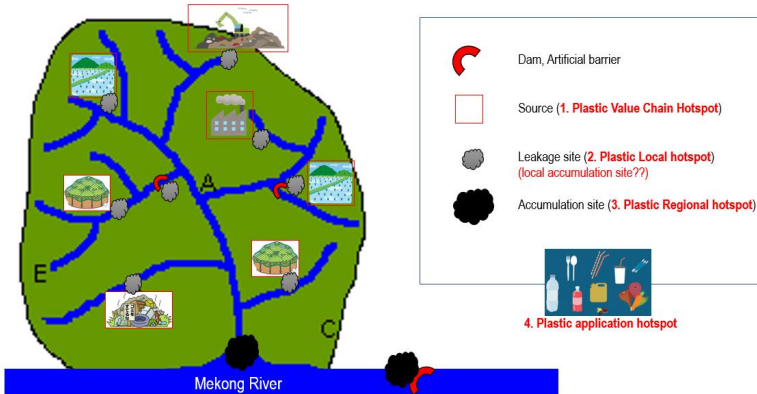
Figure 11.13: Spatial distribution of sub-basin in UbonRatchathani, Adapted from NPC (2020a)



## ii. Identifying sources and accumulation of plastic at sub-basin level

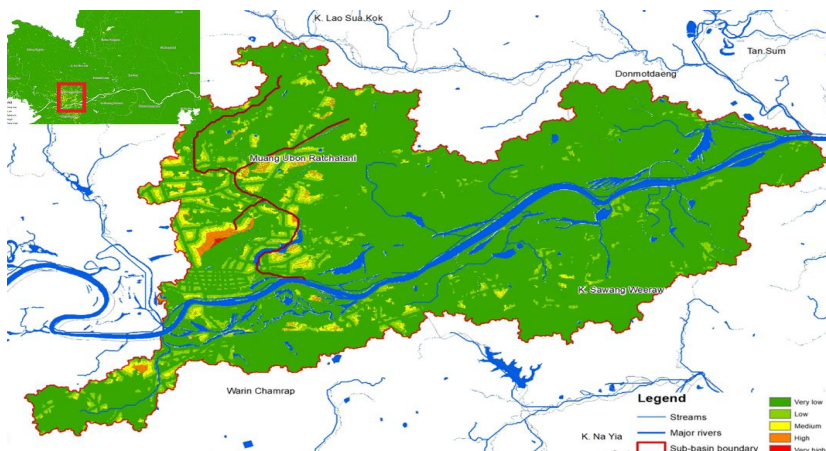
As shown in Figure 11.14, there are 4 types of hotspot including plastic value chain hotspot, plastic leakage hotspot, plastic accumulation hotspot and plastic application hotspot.

Figure 11.14: Conceptual of plastic hotspot (proposed by Mako-san), Adapted from NPC (2020a)



Based on Figure 14, this research tried to identify hotspots from potential plastic leakage map (Figure 11.12) with sub-basin map. Therefore, 13th sub-basin (see Figure 11.13) is selected to test our approach. We selected this sub-basin because it is contributed much plastic in the region and its location as well (central area, near the main river). Figure 11.15 shows boundary of in-situ area.

Figure 11.15: Selected site for identifying plastic leakage and accumulation zones, Adapted from NPC (2020a)



Potential plastic leakage map and source of plastic waste maps which extracted and/or collected from open source, and field data (for example: factory, hotel, school, etc.,) were overlay, to identify the main sources of plastic. Commercial activities and consumer

activities are the main source of plastic waste in this sub-basin (plastic value chain hotspot). Moreover, streams are highlighted in red color may have contribute plastic into major/main river. It means we can identify plastic leakage hotspot/local hotspot along those streams. And if there are any barriers and or dams on major/main river, accumulation hotspot will be identified (Figure 11.16). If the finer scale local data is not available, then the pixel level final results may have to generalize into sub-basin level.

Figure 11.16: Accumulation hotspots at barriers, collected at Chiang Rai province, Source- NPC Fieldwork Study



Once the appropriate fuzzy membership value for data criteria is assigned several reclassified surfaces showing a value from 0 to 1 are generated. The next step in applying fuzzy logic is to overlay these input maps. This step is similar to weighted site selection (a site selection type that allows us to rank raster cells and assign a relative importance value to each layer) because the different reclassified surfaces are compared to each other.

In order to achieve this objective, Geoinformatics Center (GIC), AIT developed a mobile survey application with ESRI Survey123 for the collection of data by local partners. The advantage of using this survey mobile application is its direct output in GIS friendly formats for further analysis. Conventional ground survey data collection needs to incorporate handheld GPS units for location information which will later be tagged with the collected information. Using the mobile survey application, the data will be directly geo tagged using the mobile phone location.

Another key advantage of this survey application is that the user does not have to pre-install the application. The survey form is accessible through a mobile phone browser using a direct link or by scanning a QR code which will be discussed further in this user guide.

## 9. Step-wise schematic methodology for waste characterization

Figure 11.17: Macro Plastic Sampling and Clean Up Surveys















  			
<b>PLASTIC WASTE</b>			
<b>Milk Pouch and Water Pouches</b>		<b>Multilayered packaging material</b>	
<b>Razor toys Plastics</b>		<b>Cloth type- polypropylene Bags</b>	
<b>Ritual Material e.g. Plastic Chains, Gods frame, Plastic moulds</b>		<b>Low density plastic packaging material e.g. Tea packs, Sanitary packs</b>	
<b>Food wrappers (Biscuits, namkin packet etc)</b>		<b>Bottle and Beverage Bottle (plastic)</b>	
<b>Lids (Plastic)</b>		<b>Straws</b>	
<b>Grocery Bags (Plastics)</b>		<b>Polybags</b>	
<b>Woven Bags (e.g. Cement bag)</b>		<b>Tubes (e.g. toothpaste)</b>	
<b>Disposable cups</b>		<b>Rubberised slipper</b>	
<b>Cups &amp; Plates (foams)</b>		<b>Cigarette Butts</b>	

Figure 11.18: Categorisation of plastic and non-plastic waste

  			
<b>NON-PLASTIC WASTE</b>			
<b>Papers waste</b>		<b>Metal parts</b>	
<b>Food waste</b>		<b>Wood</b>	
<b>Beverage Bottle (glass)</b>		<b>Beverage Cans (Non-Plastic)</b>	
<b>Disposal Plates (paper)</b>		<b>Biodegradable waste</b>	
<b>Cotton fabric</b>			



Figure 11.19: SOP for Microplastic Assessment/ Cleanup activity

<h2 style="text-align: center; color: #0070C0; margin: 0;">SOP For Macro-Plastic Assessment / Clean-up Activity</h2>		
Steps	Description	Sample Photos
1.	<b>Wear your protective gear (masks and gloves) when handling the waste</b>	
2.	<b>Beware of sharps present in the waste. Don't pick them directly with your bare hands</b>	
3.	<b>Segregate the plastics from the mixed waste</b>	
4.	<b>The plastic product should be crushed/mutilated to avoid reuse</b>	
5.	<b>Collect the waste till the bag is 3/4th full</b>	
6.	<b>Do not drag the bags and lift the bags carefully with support from 3-4 volunteers per bag</b>	
7.	<b>Use broom and dustpan to pick the waste and clean the area</b>	
8.	<b>Avoid needle (or from any other sharp) prick injuries</b>	
9.	<b>Be careful regarding staples on the labels from being torn or separated from the bag</b>	
10.	<b>Use permanent marker pens for coding/labeling bags</b>	
11.	<b>Prefer to use tare weight when weighing segregated and sorted plastics on the electronic balance</b>	
12.	<b>Be cautious while weighing with spring balance such as not to injure hand or so</b>	
13.	<b>Avoid overcrowding on the tarpaulin areas</b>	
14.	<b>Wash/rinse hands well after/post clean up exercise and use hand sanitiser before taking refreshments</b>	

## 10. Do's and Don'ts for Macroplastic assessment study

Figure 11.20: Do's and Don'ts during Cleanup activity

**UN environment programme**

**Counter MEASURE FOR PLASTIC FREE RIVERS**

### Dos and Don'ts

#### Do's ✓

1. Wear your protective gear (masks and gloves) when handling the waste
2. Beware of sharps present in the waste. Don't pick them directly with your bare hands
3. Segregate the plastics from the mixed waste
4. The plastic product should be crushed/mutilated to avoid reuse
5. Collect the waste till the bag is 3/4th full
6. Do not drag the bags and lift the bags carefully with support from 3-4 volunteers per bag
7. Use broom and dustpan to pick the waste and clean the area
8. Avoid needle (or from any other sharp) prick injuries
9. Be careful regarding staples on the labels from being torn or separated from the bag
10. Use permanent marker pens for coding/labeling bags
11. Prefer to use tare weight when weighing segregated and sorted plastics on the electronic balance
12. Be cautious while weighing with spring balance such as not to injure hand or so
13. Avoid overcrowding on the tarpaulin areas
14. Wash/rinse hands well after/post clean up exercise and use hand sanitiser before taking refreshments

#### Don'ts ✗

1. Do not Reuse plastic products
2. Do not Mix plastic with other wastes
3. Do not burn plastic waste
4. Do not Spill waste
5. Do not walk into slush or on wet soil and wear proper shoes that can grip the soil or the ground surface
6. Do not vigorously dust the plastics or cloth or such waste being collected to control dust from becoming air borne during the process of clean up

## 11. Guidance notes on selection of appropriate techniques/procedures on microplastic sampling and analysis

### Selection of Sampling and Analysis Methodologies for Microplastics in River Bodies

Micro-plastics is defined as a mixture of heterogeneous particles ranging in sizes from a few microns to several millimetres produced as a result of anthropogenic activities. [Bergmann et al. 2015]. Studies have shown that like their parent member; plastics, MPs are harmful to the healthy wellbeing of the ecosystem and owing to their small size, they are more easily absorbed by microorganisms and are then transmitted to humans as well through food chains. Researchers have found microplastics in the gastro intestines of humans. Hence, it is necessary to address the rising concerns arising from increasing concentration of microplastics in the environment. Likewise, in the following section how sampling and analysis is done in water bodies is briefly discussed along with the advantages and disadvantages of the methods, techniques and instrumentations used.

### Microplastics assessment– Focus on Sampling

Sample collection is the initial stage of the microplastics analysis. It is known that MPs are difficult to detect because of their small size and heterogeneous physicochemical features, as well as different particle sizes and shapes [Syberg K et al.]. In addition, no

standard protocols exist for sampling plastic particles, making data comparison unreliable [Bergmann et al, Hermsen et al]. Considering this while determining concentration of microplastics, the selection of an appropriate technique (from existing ones) is essential as it will determine the types of microplastics that are collected, separated, identified and subsequently reported. The method of sample collection is influenced by many factors. However, primarily the matrix to be sampled (water, sediment, soil, air or biota) will determine the abundance, size and shape of the microplastics obtained.

There are three main methods of sampling:

- **Selective Sampling**

In selective sampling, items visible to the naked eye are directly extracted from the environment, for example, on the surface of the water or sediment.

Advantages	Disadvantages
This collection method is adequate in situations where different microplastics of similar morphology and of a size greater than 1mm are present, such as primary microplastics pellets and similarly shaped secondary microplastics.	The less obvious, more heterogeneous items are often overlooked, particularly when they are mixed with other contaminants.

- **Volume reduced sampling**

In case of Volume Reduced Sampling, the volume of the bulk sample is reduced until only the specific items of interest for further analysis remains. Thus, the majority of the sample is discarded.

Advantages	Disadvantages
This method is typically utilized to collect samples from surface water because it has the advantage that large areas or quantities of water can be sampled.	Since entire volume is not taken, there are chances of over/under estimation of microplastic concentration.

- **Bulk sampling**

As the name indicates, Bulk Sampling takes the entire sample without its volume being reduced.

Advantages	Disadvantages
Although there are practical limitations to the amount of sample that can be collected, stored and processed, the advantage of this method is that in theory, all the microplastics in the sample can be collected, regardless of their size or visibility.	A large amount of water is taken up, and thus it makes the analysis quite time consuming.

## Microplastics assessment– Focus on Sampling Techniques

For determination of microplastic concentration, sampling of different sections of water bodies is required. Broadly, the water bodies are classified into 3 sections for carrying out sampling, which includes: water surface, water column and sediment. Sampling of Water surface and water column in different water bodies such as lakes, rivers etc. is generally carried out in two ways:

### 1. Using Nets:

Usage of nets to determine concentration of microplastics indicates that most studies apply nets with mesh sizes of around 300 µm. Samples are typically large, so that with a 30 cm manta trawl, 20-50 m<sup>3</sup> of water can be sampled in 10-30 minutes. However, it has been found that using finer nets will detect more particles, especially fibres, although sample volumes will necessarily be lower with such an approach. Different types of nets that are used includes:

- Manta Trawl
- Neuston Net
- Plankton Net

### 2. Pumping:

Larger sampling volumes can be achieved by pump and filtration sampling, where water is pumped through a series of filters of decreasing mesh size (Bannick et al. 2019). Sampling of sediment in different water bodies such as lakes, rivers etc. is generally carried out (in riverbed samples) by using metal spoons (as for shore samples) or different grab samplers, usually covering the top 10-15 cm of sediment. These samples are large enough (in the kilogram range) to obtain meaningful microplastic concentrations.

## Sampling of Lakes and Reservoirs

In case of large lakes, samples representing large parts of the near-surface water can be obtained using manta trawls or neuston nets. However, their mesh size (typically 300-390 µm; Hidalgo-Ruz et al. 2012) limits the detection of microplastic particles. Plankton nets have finer mesh sizes (down to 100 µm for oceanographic nets) and can be used for horizontal or vertical sampling. The selection of mesh size always poses a trade-off between the lower cut-off of particle sizes and the risk of clogging due the presence of suspended sediment and organic material such as plankton and leaves.

## In Lake Sediment

Similar to water sampling, the mode of sampling is determined by Lake Morphometry and hydrology. Sampling frequency can be guided by the sedimentation rate (the higher this is, the more sampling dates and the greater the sediment depth to be considered) or by certain events (e.g., storms, floods, major land use changes in the catchment). The number of necessary sampling sites is determined by Lake Morphometry and Hydrology. A bathymetric map is helpful. If this is not available, transects of depth measurements can provide necessary information about lake bottom structure.

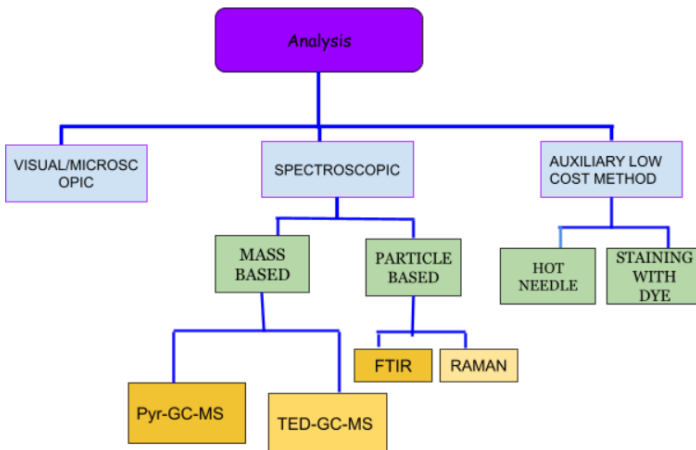
Using rod-operated or cable-operated Ekman grabs, samples from soft sediments without large debris or vegetation can be obtained. These grabs typically extract the top 15 cm and provide a large amount of sample in a single step. A drawback of this is that the sediment surface is disturbed, and the exact depth of the grab cannot be determined. An alternative to this is gravity coring which can be used for sediment sampling. Gravity corers come in various diameters, with cores typically 6 cm or 9 cm wide. Depending on sediment structure and compaction, cores up to 40 cm long can be obtained with an almost undisturbed sediment surface. It is recommended to take three cores per site in order to determine possible variation. Sediments can be divided into defined layers with simple mechanical devices available from the corer manufacturer. Drawbacks associated with gravity coring is that the relatively smaller volume of samples in the top 15 cm, and the fact that liners used for coring are typically made of clear plastic polymers such as polyvinyl chloride (PVC). Therefore, scraping with spoons, etc. has to be avoided when retrieving the sediment from the liner, and scratched old liners should not be used for sediment microplastic sampling.

To summarise, the lakes and reservoirs have both vertical and horizontal zoning, which must be addressed during sampling efforts. Density stratification and, consequently, mixing of inflows may vary with the annual cycle. For horizontal plastic concentrations in surface water, it is important to ascertain the main and prevailing wind direction. From ocean studies, it is known that a large fraction of plastics floats on the surface and that concentrations decrease with depth (Choy et al. 2019). This pattern is apparently less uniform in freshwater.

### Microplastics Assessment– Focus on Analysis

The presumptive analysis of microplastic samples consists of physical characterization, chemical characterization and, in some cases, biological characterization. The diagram given below illustrates the various analysis techniques used for identification.

Figure 11.21: Flowchart for Microplastic Analysis study, Adapted from UNEP (2020a)



The most commonly used techniques for the qualitative identification of plastic particles are spectroscopic methods, in particular FT-IR and Raman spectroscopy. FT-IR and Raman spectroscopy generally involve a laser light source and return a spectra which can be compared to references or commercially available databases. Both these techniques have the advantages of being non-destructive for the samples, permitting further analyses after spectroscopy. They can also be coupled with optical microscopies, permitting 2D imaging of the samples which can highlight the morphological features of particles. For the analysis of MPs, FT-IR can be conducted in attenuated total reflection (ATR) mode or in transmission mode. After the observation of MPs in the sample, both FT-IR and Raman spectroscopy allow the matching of the spectra obtained in the sample with libraries and standards in order to recognize the different polymers and possibly quantify them. With the help of chemometric tools this process could be automatized.

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