PROMOTION OF COUNTERMEASURES AGAINST MARINEPLASTIC LITTER IN SOUTH EAST ASIA AND INDIA

Plastic Leakage Assessment Toolkit

UN environment programme

Counter MEASURE FOR PLASTIC FREE RIVERS

राष्ट्रीय उत्पादकता परिषद

National Productivity Council

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Authors

Amit Jain, Technical Advisor, NPC & Managing Director, IRG Systems South Asia Pvt. Ltd.
Saloni Goel, United Nations Environment Programme

Contributors

K.D. Bhardwaj, Regional Director, National Productivity Council, New Delhi
Dr. Shukla Pal Maitra, Director, National Productivity Council, New Delhi
Dr. Harsh Thukral, Deputy Director, National Productivity Council, New Delhi
Sanjeev Satyanarayan, GIS & Geomatics Specialist, IRG Systems South Asia Pvt. Ltd.
Apoorva Agrawal, Assistant Consultant, IRG Systems South Asia Pvt. Ltd.
Shaila Sam Joseph, United Nations Environment Program

Cover Illustration & Infographics

Mr. Ashish Kumar Kharwar, IRG Systems South Asia Pvt. Ltd.

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Abbreviations

ATR	Attenuated Total Reflection
CL	Confidence Level
FTIR	Fourier Transform Infrared Spectroscopy
GIS	Geographical Information Systems
GPS	Global Positioning System
CIRAIG	International Reference Center for Life Cycle of Products, Services and Systems
ISWA	International Solid Waste Association
IUCN	International Union for Conservation of Nature and Natural Resources
LCA	Life Cycle Assessment
MFA	Material Flow Analysis
MOFA	Ministry of Foreign Affairs
MMR	Mumbai Municipal Region
NPC	National Productivity Council
NGOs	Non Government Organizations
NTNU	Norwegian University of Science and Technology
PPE	Personal Protective Equipment
PDP	Plastic Disclosure Project
PUCP	Pontifical Catholic University of Peru
EA	Shaping Environmental Action & University of Applied Sciences and Arts
UNEP	United Nations Environment Programme
ULBs	Urban Local Bodies
WPO	Wet peroxide oxidation

Executive Summary

The project on Promotion of Countermeasures Against Marine Plastic Litter in Southeast Asia and India (hereafter referred to as "CounterMEASURE") was officially launched in May 2019 aiming to identify a region-based model for monitoring and assessment of plastic leakage and pollution reduction. The target is land-based plastic leakage entering waterways such as rivers and canals or drainages to the sea. Recognizing this rapidly emerging and serious issue of plastic pollution and marine litter, this toolbox has been prepared as a 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. This document has been prepared based primary and secondary sources including publications from scientific journals, reports and web sites.

The toolbox describes different tools and techniques for data acquisition, review and stakeholder engagement. The toolbox has been prepared in seven chapters. Chapter 1 gives introduction and background. Chapter 2 describes the methodology adopted for overall assessment of plastic footprint in a riparian city, region, basin and country followed by guidance notes to assist policymakers/ project designers and other stakeholders in the plastic value chain to design the project for plastic leakage/ plastic footprint assessment in a city, region and country. Guidance notes at the end of this chapter will provide assistance to identify the scope of work and methodology and data requirements to design the relevant project relevant in their local context. Chapter 3 describes the perception survey and reconnaissance survey as a tool for carrying out the preliminary exercise to identify different items involved in plastic value chain. Guidance notes at the end of chapter will assist in understanding issues regarding the production, consumption, (starting from manufacture, production, import, consumption, plastic waste generation, treatment and disposal), sources of generation, market controls like availability and implementation of regulations and facilities of material recovery, socioeconomics and environmental impacts and level of consumer awareness, major hotspots, plastic leakage pathways, inefficiencies in plastic value chain and possible counter measures in a particular geography. Chapter 4 describes plastic value chain mapping and predictive pathways based on secondary data in a geographical setting. Guidance notes will provide assistance 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. Chapter 5 describes methodology for carrying out macro plastic waste assessment, where an understanding of plastic value chain in a geographical setting after consumption is addressed. Guidance notes will assist in describing material flow analysis based on mass balance after consumption including collection, transportation, treatment and disposal. Chapter 6 describes methodologies for

micro plastic assessment in the river/ water body. Guidance notes suggest the procedure to carry out micro plastic assessment.

Finally Chapter 7 presents one case study from Agra city in India, which encapsulates the experience about application of assessment methodology in a real developing country context. This will assist practitioners to design any plastic leakage assessment and countermeasure project in a geographical setting with better understanding of on-the-ground situation.

Chapter 1: Introduction

1.0 Introduction

The project on Promotion of Countermeasures Against Marine Plastic Litter in Southeast Asia and India (hereafter referred to as "CounterMEASURE") was officially launched in May 2019 aiming to identify a region-based model for monitoring and assessment of plastic leakage and pollution reduction. The target is land-based plastic leakage entering waterways such as rivers and canals or drainages to the sea. This project, funded by the Ministry of Foreign Affairs (MOFA), the Government of Japan, is implemented by the United Nations Environment Programme (UNEP) Regional Office for Asia and the Pacific in collaboration with local partners in the region such as line ministries, academia and civil society. During its 10-month implementation period, the project organized several technical consultations and expert group meetings which discussed the methodology in identifying plastic leakage pathways in Mekong region and India. Data collection and surveys in study areas in Mekong basin, Ganga basin and Mumbai was conducted based on the developed data inventory. Moreover, the project conducted several outreach activities that linked science with policies and raised awareness of the general public. After synthesizing the overall outputs, the project developed countermeasures to reduce plastic pollution. Therefore, and effort has been made to develop a toolkit to summarize the experience gained during its implementation in India.

1.1 Objectives

The major objective to develop the tool kit is 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

1.2 Scope

The preparation of this manual has involved collection of data from secondary as well as primary sources including publications from scientific journals, reports and web sites. A case study based approach has been adopted to provide the practitioner examples of live situations so that it can be adopted in a country/ geographical region or city. The manual should be usable in all the countries, where plastic waste assessment projects have been initiated.

1.3 Format

The manual has seven chapters. Chapter 1 gives introduction and background. Chapters 2 to 5 provide background information supported by examples from different cities and followed by guidance notes. Chapter 2 describes the methodology adopted for overall assessment of plastic footprint in a riparian city, region, basin and country followed by guidance notes to assist policymakers/ project designers and other stakeholders in the plastic value chain to design the project for plastic leakage/ plastic footprint assessment in a city, region and country. Guidance notes at the end of this chapter will provide assistance to identify the scope of work and methodology and data requirements to design the relevant project relevant in their local context. Chapter 3 describes the perception survey and reconnaissance survey as a tool for carrying out the preliminary exercise to identify different items involved in plastic value chain. Guidance notes at the end of chapter will assist in understanding issues regarding the production, consumption, (starting from manufacture, production, import, consumption, plastic waste generation, treatment and disposal), sources of generation, market controls like availability and implementation of regulations and facilities of material recovery, socioeconomics and environmental impacts and level of consumer awareness, major hotspots, plastic leakage pathways, inefficiencies in plastic value chain and possible counter measures in a particular geography. Chapter 4 describes plastic value chain mapping and predictive pathways based on secondary data in a geographical setting. Guidance notes will provide assistance 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. Chapter 5 describes methodology for carrying out macro plastic waste assessment, where an understanding of plastic value chain in a geographical setting after consumption is addressed. Guidance notes will assist in describing material flow analysis based on mass balance after consumption including collection, transportation, treatment and disposal. Chapter 6 describes methodologies for micro plastic assessment in the river/ water body. Guidance notes suggest the procedure to carry out microplastic assessment. Chapter 7 presents one case study from developing countries, which encapsulates the experience about application of assessment methodology in a real developing country context. This will assist practitioners to design any plastic leakage assessment and countermeasure project in a geographical setting.

Chapter 2: Tool Box for Selection of Methodology for Plastic Waste

2.0 Introduction

Plastic waste leakage assessment in a riverine system within a particular country/ region/ city forms the basis of any countermeasure/ disposal/ treatment strategy within the geographical setting. The basic objective is to identify the plastic leakage quantity, its sources, pathway of leakage and the carrier medium into the river. Globally, there is no standardized methodology to assess it. An effort has been made to develop this methodology within a riparian geography (rural/ urban) and pilot testing it within a river basin. This chapter describes a brief review of the methodologies involved globally, its design, constraints and advantages and different steps to implement it. Further, constraints in their application in developing countries have been enumerated followed by guidance notes.

2.1 Review of Methodologies

Literature survey cites nineteen methodologies for plastic footprint as summarised in Table 2.1. These methodologies can be classified in three main categories:

1. Business- or product-level footprint methodologies, intended to be used by the private sector;
2. National- or regional-level footprint methodologies, intended to be used by the public sector; and
3. Individual-level footprint methodologies, intended to be used by citizens and consumers.

Table 2.1 indicates the scope and coverage of each methodology based on:

- The full and short name.
- The name of the organization that developed it.
- Its web link (if available)
- A short description
- An overview of what is and is not included.

Despite the very high and increasing public awareness of plastic pollution and its related environmental, economic and social impacts, the number of methodologies available to calculate the plastic footprint of individuals is relatively limited. Currently no methodology allows measuring the trade-off between different impact categories along the plastic value chain.

Table 2.1: Inventory of existing and under-development plastic footprint methodologies

	Name of Methodology	Organisation	Link	Short name	Include Microplastics	Date of release
CORPORATE / PRODUCT	Plastic Scan	Searious Business	http://oceanimpactquickscan.azurewebsites.net	Plastic Scan	NO	2017
	Plastic Disclosure Project (PDP)	Ocean Recovery Alliance	http://plasticdisclosure.org	PDP	NO	2016
	Plastic Footprint for Companies	Plastic Soup Foundation	https://www.plasticsoupfoundation.org/en/psf-in-action/plastic-footprint-3/	PSF Footprint	YES	2017
	Plastic Scorecard	BizNGO	https://www.bizngo.org/sustainablematerials/plastics-scorecard	Plastic Scorecard	NO	2014
	Marine Plastic Footprint	IUCN / EA	n.a.	Marine Plastic Footprint	YES	n.a. 2019
	Plastic Leak Project	Quantis / EA	https://quantis-intl.com/metrics/initiatives/plastic-leak-project/	Plastic Leak Project	YES	n.a. 2019
	Circularity Indicators Methodology	EMF	https://www.ellenmacarthurfoundation.org/programmes/insight/circularity-indicators	Circularity Index	NO	2015
	Plastic Drawdown	Common Seas	https://www.commonseas.com/projects/plastic-drawdown	Plastic Drawdown	YES	2019
	Marine Impacts in LCA	CIRAIG / PUCP / NTNU	n.a.	MariLCA	YES	n.a.
	PlastikBudget	Fraunhofer Institute	n.a.	Plastik budget	YES	n.a. 2020
	Plastic Pollution Calculator	ISWA	http://marinelitter.iswa.org/	Plastic Pollution Calculator	NO	n.a. 2019
	PET Collection, Landfill and Environmental Leakage Rates in South East Asia	GA Circular/companies	https://www.gacircular.com/publications/	PET GA PET Collection	NO	n.a. 2019
	Plastic Life Cycle Assessment (LCA)	JRC	https://eplca.jrc.ec.europa.eu/permalink/plastic lci/plastic lca report/2018.11.20.pdf	LCA	YES	n.a. 2020
COUNTRIES / REGIONS	PiPro SEA	EMF / Companies	n.a.	Project SEA	NO	2019
	National guidance for plastic pollution hotspotting and shaping action	UN Environment / IUCN	n.a.	Hotspot + Action	YES	n.a. 2019
	A Global Roadmap to Achieve Near-zero Ocean Plastic Leakage	SYSTEMIQ / PEW	n.a.	SYSTEMIQ Roadmap	YES	n.a. 2019
INDIVIDUALS	Plastic Footprinter	R4W	http://www.plasticfootprint.ch	R4W	NO	2014
	My Little Plastic Footprint	Plastic Soup Foundation	http://mylittleplasticfootprint.org	My Little Plastic Footprint	YES	2017
	Plastics Calculator	Greenpeace	http://secure.greenpeace.org.uk/page/conte	Greenpeace	NO	2016

[dashed box] Include the microplastic component

Source: International Union for Conservation of Nature and Natural Resources (IUCN) 2019; Review of plastic footprint methodologies - Laying the foundation for the development of a standardised plastic footprint measurement tool

Table 2.1 indicates that **Systemiq/road map** and **UN Environment/ IUCN methodologies** are regionalized (national context) and are rated high on actionability and accountability. The **accountability** includes **use or waste of plastics**, **loss and release and impacts**.

Use or Waste of Plastic: the output metric is a measure of a quantity of plastics used or wasted (mass unit) or a measurement of the circularity of the system (index or recycling rate);

Loss and release: the output metric is a measure of the plastics leaking from the technosphere1 into the environment (mass unit), i.e. the plastic footprint consists of an inventory methodology in the sense of LCA; and

Impacts: the output metric is a measure of the environmental impacts generated by the plastic leakage (e.g. unit of biodiversity loss or harm to human health

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

- 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 waste water treatment efficiencies.
- 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.
- The methodologies are based on life cycle approach (LCA)
- The methodologies focus on the leakage pathway and allow the establishment of a plastic leakage inventory for different plastic types and life cycle stages.
- 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.
- 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.
- 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).

2.3 Approach & Methodology

A conceptual approach has been adopted based on a combination of Systemiq / road map and UN Environment/ IUCN methodologies covering all the salient features given in section 2.2. This will help to design countermeasures i.e. actionable items required to be implemented. These measures are also derived and integrate countries/regions efforts to implement 3Rs policy principles, resource efficiency, extended producer's responsibility and circularity. The conceptual paradigm of this approach is shown in **Figure 2.1**. **Plastic Hotspotting**

and identification of **leakage pathways** form the backbone of this approach within a geographical context. This methodology has been pilot tested in riparian centers in Ganga and Yamuna basin and Mumbai. The basic approach adopted includes understanding of the concept of hotspotting and defining the leakage pathways. This approach is supported by usage of a number of techniques and the tools in achieving the desired outcome. Each of these items are described below.

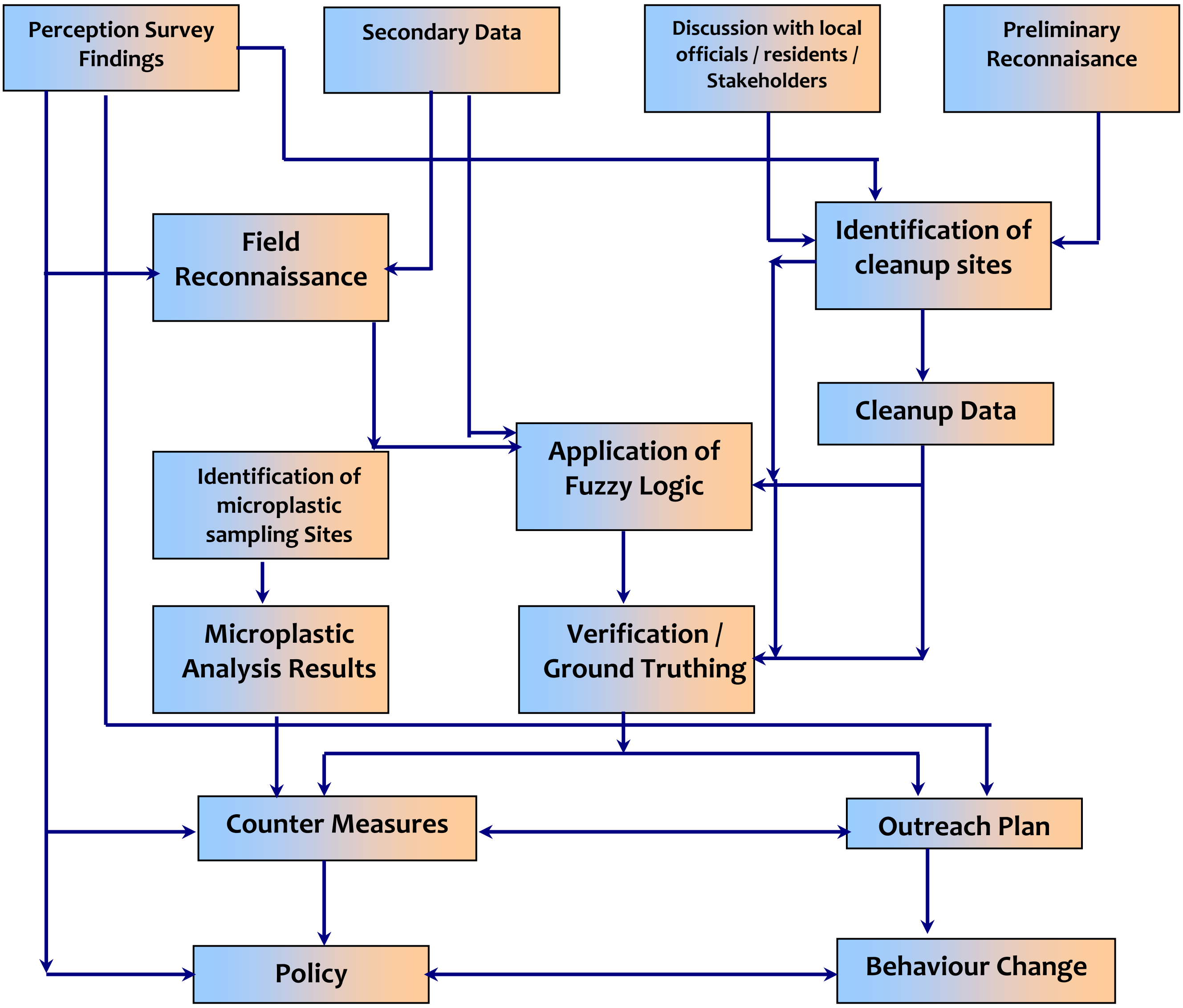


Figure 2.1: Process Flow Diagram for Approach & Methodology

Source: Prepared by Saloni Goel (2020); UN Environment & Amit Jain - IRGSSA

2.3.1 Conceptual Understanding of Hotspotting

Hotspot is a life cycle stage, process or elementary flow which accounts for a significant proportion of the impact of the functional unit, where the functional unit is a measure of the function of the studied system to which inputs and outputs can be related.

Life Cycle Assessment (LCA) provides information on the relationship between a specified functional unit and specified environmental impacts. In case of plastics, the conceptual LCA when applied to the material flow as shown in **Figure 2.2** can be used to define this relationship, where inputs and outputs at each stage can be related to environmental impacts. However, the study boundary will vary in a geographical context. For example, in a city's context it can include all the stages or some of the stages prior to distribution, but will include distribution and post distribution stage as highlighted by the dotted line.

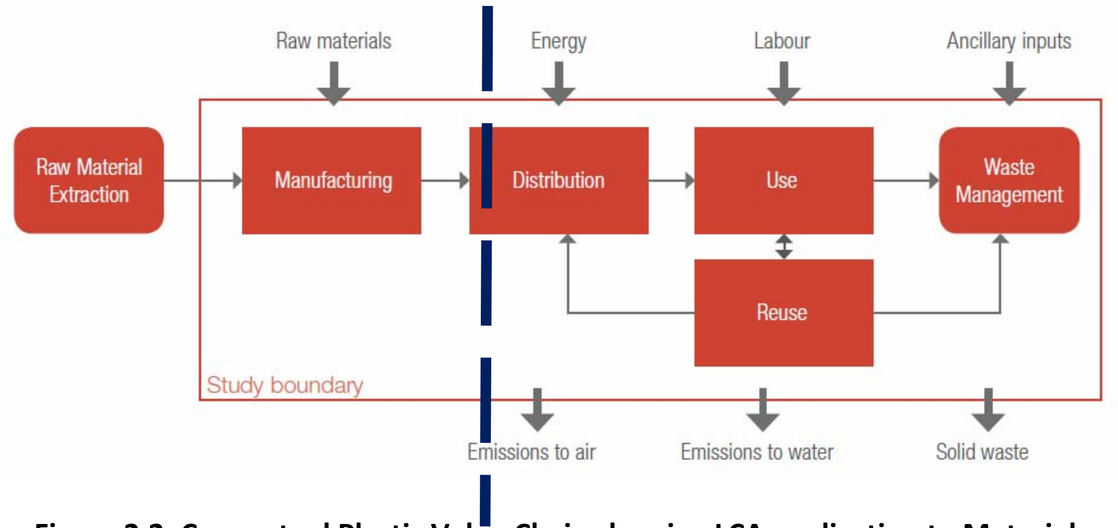


Figure 2.2: Conceptual Plastic Value Chain showing LCA application to Material Flow Analysis (MFA)

Source: UN Environment ROAP (2017); Hotspots Analysis – An Overarching Methodological Framework and Guidance for Product and Sector Level Application

Since there is no specific methodology defined so far to assess the environmental impacts, therefore, the ultimate goal is to get an approximate understanding of where significant impacts occur. So hotspots analysis shall consider all the geographies in which impacts occur. A comprehensive assessment of the relevant geographies will also help to establish the broader socio-political context in which the hotspots analysis is being conducted. **Therefore, a combination of hybrid MFA-LCA when applied in sub-national geographical areas (region/city/any other geography) will assist in identification and classification of hotspots. The study boundary may include different stages where input-output analysis can be carried out within the boundary. The classification and definition of the hotspots based on this understanding is given in Table 2.2. It covers all the stages i.e. production, consumption (Use & Reuse) and waste management as shown in Figure 2.2.**

Table 2.2: Classification of Hotspots

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. **This will include all the stages shown within the study area given in Figure 1.**	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	Plastic leakage source hotspot is the	These hotspots are based on

Hotspot	Definition	Note
source hotspot	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 consist of localities or watersheds.	criteria including population density, waste generation rate, percentage of plastic in the waste-stream, waste collection rate, MWI, distance to shore, catchment run-off, 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
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).

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); National Productivity Council (NPC)

2.3.2 Approach for Hotspot & Plastic Leakage Pathway Analysis

To date there is no common methodology to either measure (through field studies) or assess (through modelling) plastic flow for a country. However, an effort has been made to develop this methodology in a city's context. Literature cites that a hotspot is defined when its threshold contributes 10% of the total impact. But there is no precise agreement upon level. **Therefore, two approaches may be used to identify the hotspots.**

1st Approach: A hotspot shall always be a percentage greater than if the impacts were evenly distributed across life cycle stages. For example, if there are 5 life cycle stages, a hotspot should not be defined lower than 20% of the impact category, and if there are 7 stages, it should not be lower than 14%.

2nd Approach: Where the hotspot has been identified based on qualitative information, it will not be possible to identify a hotspot with quantitative precision. Therefore, the analysis should be confident that the majority of impacts (i.e., over 50%) are covered. Clear boundaries are essential to ensure that appropriate information is obtained and used within the analysis.

In majority of countries, where input output data related to each of the stages shown in Figure 2.2 are not available, use of second approach is the most preferred option.

A number of **tools/ techniques both quantitative and qualitative** can be used to determine the geographical locations, vulnerable areas and input output analysis covering each stage or a combination of stages or complete plastic value chain shown in **Figure 2.2**. **Some of these tools/ techniques include:**

Reconnaissance Survey: The first step to carry out data collection is to carry out field reconnaissance survey using GPS in the identified geographical area e.g. city/ watershed and 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.

Perception Survey: Different stakeholders e.g. Policy & Regulatory bodies, Institutions, businesses and communities mapped as per **Figure 2.2.** They can be surveyed using a number of tools like questionnaire, 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 identified in Table 2.2. This technique has been extensive used in Indian component of the project.**

GIS Technique and Fuzzy Approach: Develop layers of physical features (slope, contour, rivers, drainage etc.) as well as human interventions (land use, demography, socio-economic layers, points of interests, commercial, agriculture, industrial areas etc.) using Geographical Information Systems (GIS). Use the fuzzy approach, an analytical tool 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. **'Heat Maps' will provide an overview of the hotspots identified in the study, the issues or impact categories associated with them and their location in the economy, sector, product lifecycle or value chain. 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.**

Macroplastic Clean up Technique: Macroplastic 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.

Microplastic Survey & Assessment: Microplastic 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.

Economic Data Templates: 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. Sector economic data may be available at the level of an organisation, trade association, region or nation through information collected by businesses, associations and national statistics bodies. **This will assist in establishing production and consumption material flow trends as well as analysis across the plastic value chain.**

Waste Management Data Templates: This will cater to the data related to waste generation, collection, transportation, treatment and disposal. This will also give information related to money flow related to waste management.

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. Environmentally extended input output information can be used to identify hotspots and causal links through a supply chain.

Ranking Technique: Some form of ranking or points system can be used to convert the qualitative information into a quantitative metric to arrive at environmental impact. 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 maximise circularity.

Hotspot analysis is an iterative approach. Steps naturally form a sequence, there will be a need to revisit steps in the process to refine the analysis as it develops. All the techniques or a combination of techniques can be used to identify hotspots and leakage scenarios. Depending upon the number of impact categories selected, the number of hotspots may vary. Consideration should be given to how these can be most effectively used to develop counter measures and communicated with stakeholders identified at the same time. Various steps involved in identification of hotspots, leakage pathways and counter measures are given below.

Step 1: Carry out the reconnaissance survey and perception survey to identify all types of tentative hotspots (Value Chain, Leakage Source, Accumulation and Application Hotspots).
Step 2: Develop GIS layers and use Fuzzy approach to identify the leakage vulnerability of the study area
Step 3: Identify the "**Plastic leakage source hotspot**"
Step 4: Identify the "**Plastic accumulation hotspot**" with "**Plastic application hotspot**"
Step 5: Merge other layers and data (e.g. river network, littering spot) and including "**Plastic Value Chain, Plastic leakage source** & **Accumulation Hotspots** and physically verify the pathway visually as predicted by GIS & Fuzzy Logic approach.

Step 6: Estimate amount of plastic loss to the environment and leakage to the waterway (in municipal level) by using input/ output analysis.

1. Target the identified and verified hotspots and develop countermeasure.

2.4 Data Requirements and Data Sources

Data requirements for the application of above mentioned methods are given in **Table 2.3**. The extent of data required depends on the extent of geographical boundary, which could be national, regional or city boundary.

Table 2.3: Data Requirements for Plastic Value Chain Assessment

Methodologies / Data Requirements	Population		Number of household				Stock Data		Plastic Waste Generation	Storage Data	Reuse	Recycle	Landfill
	Household	Industry		Export Data	Import Data	Manufacturing / Production	Private	Industry					

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Data source is an important aspect of plastic value chain assessment. These sources can be divided into secondary data and primary data. The major factors, which should be considered while selecting sources of secondary data, are given below.

- Availability of data
- Reliability of data
- Quantum and range of data
- Completeness of data
- Relevance of data in terms of chosen method of calculation
- Source of data

Reliability, availability, amount and completeness of data are very important factors and differ with products, country, region and city. These factors decide the selection of the method for determining plastic Value chain assessment parameters. The major sources of data are given below.

1. National/ local Government Agency
2. Industry/ Trade/ Recyclers/ Waste Disposal Operator's Association
3. Market Research Agencies
4. Open source data like websites, Satellite Imageries etc.

An example of data source is given below in **Table 2.4.**

Table 2.4: Tentative Sources of Data

Data Sources / Item	National / Local Government Agencies (ULB/Local Government)	Industry / Trade Recyclers / Waste Disposal Operator's Association (Reports / Published Data)	Market Research Agencies (Reports / Published Data)
Saturation level household	√ (ex. Census data)	√	
Saturation level industry		√	√
Number of household	√ (ex. Census data)	√	
Export data	√ (ex. Census data)	√	
Import data	√ (ex. Census data)	√	
Manufacturing / Production		√	√
Stock data private		√	√
Stock data industry		√	√
Storage data		√	√
Waste Generation Data	√	√	√
Reuse		√	√
Recycled	√	√	
Landfilled	√	√	

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Decision criteria for selection of data with respect to availability, reliability, amount and range of data and completeness of data are given below.

Availability of data

1. Number of sources of data, which can provide data for study area. Generally, more than one source of data is preferred for item of interest.
2. In what format, data is available i.e. yearly, half yearly, cumulative or distributed
3. Whether the data is published/ unpublished, confidential/ public.
4. Mode of procurement of data.

Reliability of data

1. Data of at least two sources should match.
2. If there is any variation in sources of data, check the method of calculating and compiling the data from each source. If there is a difference in the calculation and compilation of data, then check the factor responsible for the difference.
3. Check the trends from the data obtained from different sources and correlations with other data.

Amount and Range of data

1. Check the availability of historical data for each block in the plastic value chain

Completeness of data

1. Historical data should be complete without any gap

2. If gap exists then source, which provide data with minimum gap should be selected so that the gaps can be supplemented
3. Incomplete data can be supplemented by trend analysis or by national/ regional/ city level assumptions.

The primary data sources are used to confirm the findings of secondary data and to further supplement it. The sources of primary data are major stakeholders of plastic value chain e.g. manufacturers and retailers, importers, exporters, individual households, business/ government sector, traders / scrap dealers / dissemblers/ dismantlers, recyclers, which are geographically distributed.

2.5 Constraints/ limitations for Plastic Waste in Developing Countries

Figure 2.2 describes the plastic value chain in a developing country. The chain shows that the material flows from an organised/ formal sector starting from export/ import/ production/ manufacture till consumption phase, where major part enters into unorganised/ informal sector and a small part enters into formal sector. The major constraints are related to availability, reliability, amount and range and completeness of the data, which makes the application of available methodology a difficult proposition. Therefore,

2.6 Guidance Notes

Objective: 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: Guidance procedure includes completion of following six steps as given below. The schematic representation of these steps is given in **Figure 2.3**.

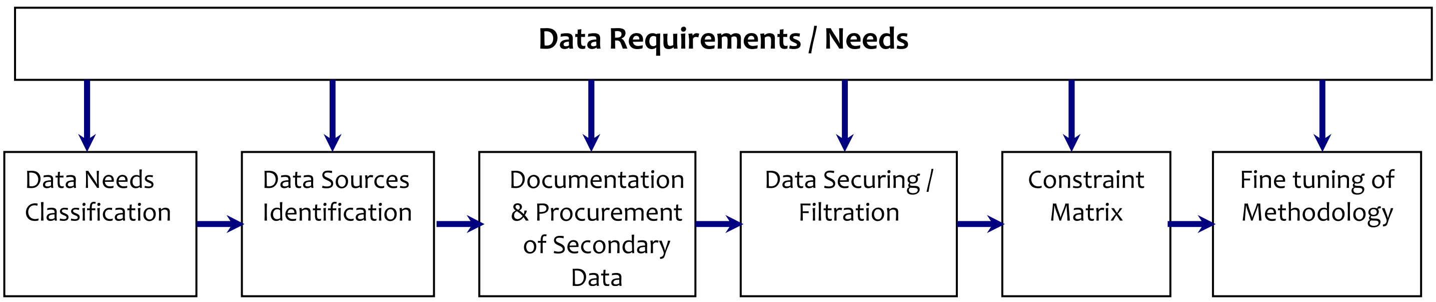


Figure 2.3: Guidance Procedure for Data Needs Assessment for Plastic Value Chain Assessment

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Step 1: 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.

Step2: 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 as given in Table 2.3.

Step 3: Identify tentative sources of data as described in Table 2.4. Refer information guide/ meta data sheet in Appendix 2.1 for preparing preliminary or detailed interview guide/ checklist/ questionnaires for data collection for each time.

Step 4: Document secondary sources of data for each type of metadata and visit the respective agency to procure data i.e. published/ unpublished/ historical.

Step 5: Check the availability, reliability, amount and range and completeness of data against following decision criteria.

Availability of data

1. Number of sources of data, which can provide data for study area. Generally, more than one source of data is preferred for item of interest.
2. In what format, data is available i.e. yearly, half yearly, cumulative or distributed.
3. Whether the data is published/ unpublished, confidential/ public.
4. Mode of procurement of data.

Reliability of data

1. Data of at least two sources should match.
2. If there is any variation in sources of data, check the methodology of calculating and compiling the data from each source. If there is a difference in the calculation and compilation of data, then check the factor responsible for the difference.
3. Check the trends from the data obtained from different sources and correlations with other data.

Amount and Range of data

1. Check the availability of historical data for plastic waste item. It can be in terms of item or polymer.

Completeness of data

1. Historical data should be complete without any gap.
2. If gap exists then source, which provide data with minimum gap should be selected so that the gaps can be supplemented.
3. Incomplete data can be supplemented by trend analysis or by national/ regional/ city level assumptions.

Step 6: Prepare the constraint matrix as given in table 2.5 by mapping outputs of step 5 and as shown below. Write **Yes** or **No** against each item for data.

Table 2.5: Constraint Matrix

Methodologies / Data Requirements	Household	Industry	Number of household	Calculated Sales			Stock Data		Waste Generation	Storage Data	Reuse	Recycle	Landfill
				Export Data	Import Data	Manufacturing / Production	Private	Industry					

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Step 7: Devise strategies to overcome data constraints by combining blocks of plastic value chain where data prior stage data and post stage data is available.

Chapter 3: Reconnaissance & Perception Survey

3.0 Introduction

The reconnaissance survey and perception survey are used for carrying out the preliminary exercise to identify different items involved in plastic value chain within geography. The first step to carry out data collection is field reconnaissance survey using different techniques in the identified geographical area e.g. city/ watershed. This is used to identify the physical features/ benchmarks in the geographical context. It is followed by perception survey to map different stakeholders e.g. Policy & Regulatory bodies, Institutions, businesses and communities. The major objective is to understand and draw preliminary inferences considering various issues regarding the plastic value chain starting from manufacture, production, import, consumption, plastic waste generation, treatment and disposal. This will also include issues related to sources of plastic waste generation, major hotspots, plastic leakage pathways, inefficiencies in plastic value chain, market controls like availability and implementation of regulations and facilities of material recovery, socioeconomics, environmental impacts, level of consumer awareness, and possible counter measures in a particular geography. Guidance notes at the end of chapter will assist in design and implementation of both types of surveys and their respective outcome.

3.1 Reconnaissance Survey

The reconnaissance survey aims to study the elements of conceptual plastic value chain showing material flow within a geographical boundary as shown in **Figure 3.1**. The study boundary may become the geographical boundary depending on the scope.

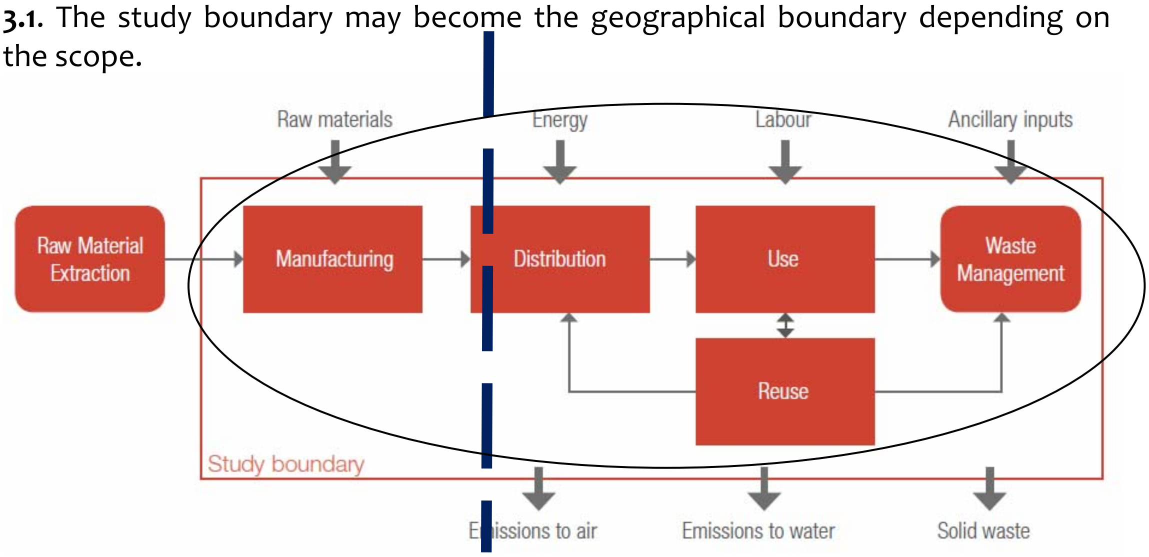


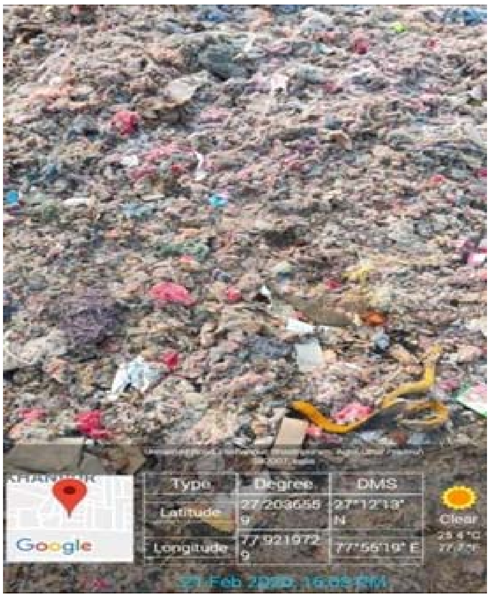
Figure 3.1: Conceptual Plastic Value Chain showing Material Flow within the Geographical Boundary

Source: UN Environment (2017); Hotspots Analysis – An Overarching Methodological Framework and Guidance for Product and Sector Level Application

The dotted line indicates the manufacturing and retail distribution of plastic products while the blocks beyond dotted lines represent part distribution, consumption, reuse and waste management. Therefore, reconnaissance survey has been designed upstream of the line of demarcation and downstream of line of demarcation.

3.1.1 Approach and Methodology Upstream of Demarcation

Industrial directory from the local department of industries as well as other statutory agencies gives data of installed capacity, production and waste/ emissions from the plastic product manufacturing units if any. Further, usage of transect walk in industrial areas gives information about the industrial unit's location as well as area surrounding it. For example, **Figure 3.2** shows that the transect walk in industrial areas of Haridwar and Agra gave an idea about the type of plastic waste being generated by the units. **It also indicates about plastic application hotspot as well as type of plastic waste generation.**



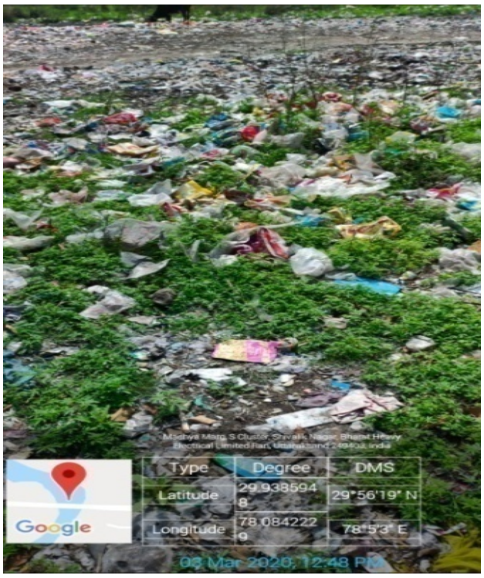


Figure 3.2: Waste found near Plastic Product/ Plastic Usage Industrial Units in Agra and Haridwar

Source: National Productivity Council (NPC) 2020

3.1.2 Approach and methodology downstream of demarcation

In this approach extensive reconnaissance survey is carried out starting from the stage of plastic collection, transportation, recycling and disposal as mentioned in the steps below below.

Step 1: Divide the municipal area into zones as per municipal master plan.

Step 2: Identify the waste collection routes and follow it from the start of collection process till its final disposal. This will include coverage of primary (door to door), secondary (till waste collection bin) and tertiary (waste collection bin to treatment/ recycling and landfill facility) waste collection and transportation system.

Step 3: Describe and document each process used in collection, transportation, recycling and disposal system.

Step 4: Identify the places where each step in this process takes place.

Step 5: Carry out photo documentation and geographical setting of each step

Step 6: Prepare the material flow diagram along with geographical and photo documentation.

Steps 1 to 6 give information about plastic source and plastic application hotspots.

3.1.3 Tools for Data Acquisition

A number of tools can be used for data acquisition for downstream of demarcation are given below.

- Secondary data review
- Communications
- Tools for exporting space (spatial dimension).
- Tools for exploring socio-economic issues (social dimensions).

Secondary data review
Relevant maps, master plans, waste statistics and report available are used in the preparation phase.

Communication
The tools, which can be used under this head include

Interviews: Structured/ semi structured interviews with individuals, key-persons, and establishment owner in case of Informal sector and structured for organized sector.

Discussion: with focus groups/ communities like rag pickers/ workers/collectors/ recyclers/dismantlers/ experts/ officials.

Workshops and meetings: To share and verify data and information collected.

Models/Charts/Photographs: They are used for visualizing results and activities and for linking "cause and effect" and "quantity flows". Extensive use of still photography as well as 360 degrees camera can be used for photo documentation.

Categorize of key stakeholders
The key stakeholders described in Chapter 3 as per tentative plastic value chain are classified into two categories formal and informal/ unorganized as described below.

Formal/ Organised & Informal/ unorganized Sector

The formal/ organized sector (retailers/ service providers/ commercial etc.) can be covered using a questionnaire as per the format given in **Appendix 3.1.** The informal sector can be covered using semi-structured interviews, focused and community/ recycler's/ stake holder's discussions. This can be carried out through preparation of interview guide, one "to" one direct contact and telephone. The purpose, principle and application of these tools are given below.

Semi-structured interviews

Purpose	Learn from the interviewed people about their situation
Principle	A semi-structured interview does not involve a formal questionnaire, but instead makes use of a flexible interview guide to help ensure that the interviews stay focused on the relevant issues, while remaining conversational enough to allow participants to introduce and discuss issues that they deem relevant.
Application	Interviewed people comprised of rag pickers, scrap-dealer, dissembler, recycler etc.

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Tools for exploring space and social issues

Spatial and social issues were explored using transect, tracer and hazardous process walk. The purpose, principle and application of these three walks are described below.

Transect walk

Purpose	Get an idea about applied practices, geographical patterns, system understanding, etc.
Principle	During a transect walk, a kind of exploratory walk is undertaken by the team along a pre-defined path with the stakeholders to observe and record in minute detail the differences of a particular area.
Application	Different transect walks through recycling areas can be defined by the investigation team. During the transect walk, the team observes, interviews people and describe in detail what happened along the path. This type of walk can be useful for data collection as described in step 1 and step 5 given above.

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Hazardous processes walk

Purpose	Get an idea about the hazards caused by the investigated object on the environment and on human beings
Principle	Places, where potentially hazardous processes take place are identified and visited. Stakeholders are interviewed using semi-structured interviews
Application	Socio-economic mapping

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

The outputs of reconnaissance survey gives inputs for conducting perception survey described below.

3.2 Perception Survey

A Perception Survey is designed and used to get response from a wide spectrum of stakeholders across the value chain about their understanding on plastics consumption, sources of waste generation, and their disposal. The designed mechanism and the tool used provided unique, contextualized, on-ground insights, information and data about all stages of plastic waste value chain. This survey is the first step to get both qualitative and quantitative information and data for identification and classification of hotspots, mapping leakage pathways, and recommending countermeasures predicated on ground realities and perceptions.

3.2.1 Target Group

The target audiences of the perception survey are the important stakeholders in the city context. The target audience can be identified after conducting reconnaissance survey, preliminary discussions with city residents, local government and non-government organisations, and other agencies. Broadly, the target audiences fall in the four broad categories given in **Figure 3.3**, though the specifics vary between the two geographies.

Figure 3.3: Identified stakeholders and target audiences

Source: Prepared by Saloni Goel (2020); UN Environment

3.2.1 Survey Tools

The perception survey can be conducted with the help of questionnaires. A sample standardized questionnaire is included as reference in Appendix 3.1. The questionnaire can be customized depending upon target audience, coverage, and extent of information sought within a geography. The survey can be conducted using either or both physical as well as virtual tools. All three mechanisms, face-to-face individual interactions, face-to-face group interactions, and mobile apps can be used in the project to obtain response from target audiences.

3.2.2 Standardised Perception Survey Methodology

The Perception Survey can be conducted in the following four stages as shown in **Figure 3.4** and described below.

1. Drafting- design questionnaire and survey tool, and identification of respondents
2. Piloting- questionnaire and survey tool
3. Conducting the survey, and
4. Drawing inferences

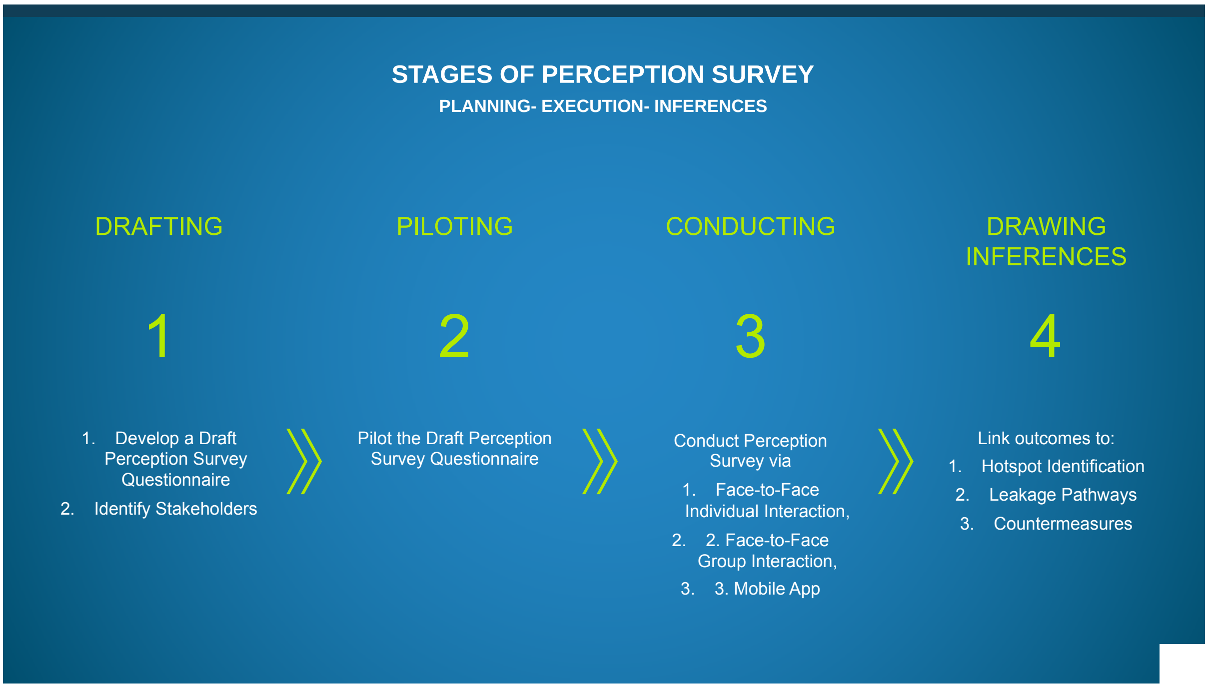


Figure 3.4: Stages of Perception Survey

Source: Saloni Goel 2020

Stage 1- Drafting: This stage involves development of a draft perception survey questionnaire (tools), and stakeholders that are to be targeted as survey respondents. The questionnaire may be developed around the following twelve categories of investigation:

1. Demographics
2. Knowledge about polymers
3. Knowledge of products and packaging made in part or whole with plastics
4. Reasons for preferring products and packaging with plastics
5. Knowledge about plastic waste management
6. Knowledge about effects of plastic on environment and health
7. Perception about what needs to be done to reduce plastic pollution
8. Steps taken to manage plastic waste at individual, community or government level
9. Awareness about alternatives to products and packaging using plastics
10. Willingness to forego plastic products and packaging
11. Perception about impediments to effective action on reducing plastic production consumption and management
12. Sources of information about plastics

Stage 2- Piloting: The draft questionnaire should be piloted and revised based on learnings from the pilot. It is crucial during the pilot to ensure that the questions are unambiguous and easily comprehensible to respondents. It is suggested that the perception survey planners consider developing the questionnaire in vernacular language also. The pilot results should also help planners in identifying if additional information needs to be obtained through the perception survey, which may be added at the time of finalizing the questionnaire.

Stage 3- Conducting: The questionnaire is conducted at this stage. A sample size needs to be finalized covering the four stakeholders before conducting the survey. This sample size will vary depending on the number of target audience. For example, government bodies and institutions covering the value chain may not exceed four or five in number under each category. Therefore, all the agencies under these stakeholders can be covered. However, production and consumption pattern under businesses and communities should be covered based on representative sampling covering all types of plastic products catering to all types of consumers across socio-economic strata including slums. The survey can be conducted in the form of Face-to-Face Individual Interaction, Face-to-Face Group Interaction, or using a Mobile App.

Stage 4- Inferences: This stage involves drawing inference form the results of the survey. For example, in the CounterMEASURE project, results have been drawn under the three broad heads of identification and classification of hotspots, mapping leakage pathways, and recommending countermeasures. The following **Table 3.1** identifies inference that may be drawn from each category of questions.

Table 3.1: Types of Inferences

Sr. No.	Category	Hotspot mapping	Leakage Pathway mapping	Counter Measure
1	Demographics			
2	Knowledge about polymers			
3	Knowledge of products and packaging made in part or whole with plastics			
4	Reasons for preferring products and packaging with plastics			
5	Knowledge about plastic waste management			
6	Knowledge about effects of plastic on environment and health			
7	Perception about what needs to be done to reduce plastic pollution			
8	Steps taken to manage plastic waste at individual, community or government level			
9	Awareness about alternatives to products and packaging using plastics			
10	Willingness to forego plastic products and packaging			
11	Perception about impediments to effective action on reducing plastic production consumption and management			
12	Sources of information about plastics			

Source: Dr. Shukla Pal Maitra National Productivity Council (NPC) 2020

Example 1: Inferences drawn from the perception survey in Haridwar, Agra, Prayagraj and Mumbai are given below.

- Stakeholders have limited knowledge of plastics and polymers. Only the ragpickers, scrap dealers and others involved in waste management have knowledge about products and packaging related to plastics.

- Low cost of plastic products and packaging material and their wide availability make them as attractive items for usage. Stakeholders are aware about the alternative items available to replace plastic items. But the affordability and availability deter them from their usage.

- Awareness about plastic waste collection and its management exist but segregation of plastics from the mixed waste is poor. Individual actions and efforts are the most effective way to address plastic waste and so stakeholders believe that plastic waste management should be taught through awareness campaign and strict enforcement.

- Efforts have been made by faith based organizations as well as educational institutions to reduce plastic usage as well as correct mechanism for disposal of waste. These institutions get the commitment from their subscribers to dispose plastic in a responsible manner.

- Lack of consensus among major consumers, habits of users and non availability of credible replacement are considered to be the major constraints and impediments for replacement of plastic items.

- Social media like TV and radio are biggest medium for raising awareness. Others include print media and campaigns by NGOs.

- Lack of knowledge about Solid Waste Management Rules, 2016 and 3R's have increased dumping in the areas further more

<u>Major findings related to hotspots and leakage pathways</u>

- Littered areas which are in close proximity of the river serve as hotspots and become part of the leakage pathways.
- Lacking of active Source Segregation and Plastic Recycling Units leading to the increase of dumping of plastics as a result of which new areas become hotspots for plastic leakage
- Open sewerage or drains as plastic tend to end up clogging it due to the utter negligence and carelessness of the people around the city. They also become carrier of plastics till their outfall points.
- Active Doorstep Waste Collection is found in high profile areas leaving the economically neglected areas unchartered and viable to creation of plastic waste. Therefore, slum areas become hotspots and a source of plastic leakage.

<u>Recommended countermeasures to tackle plastic pollution in the city</u>

- Action oriented campaigns by NGOs
- Imposing heavy fines on plastic use
- Educating people in various localities and societies and thus motivating everyone to contribute in managing plastic pollution and encouraging public participation in initiatives against plastic.
- Collective efforts by the government, NGOs and citizens.

- Policies and campaigns based on bringing about behavioural change is the key step to manage plastic pollution.
- Ample Research & Development for alternatives in order to ensure long term sustainability and minimal environmental impact.

Case Study 1 and Case Study 2 describes the application of Reconnaissance and Perception Survey.

Case Study 1: Story of the plastic cans used for collecting holy water of River Ganges in Haridwar

Plastic cans are manufactured in SIDCUL industrial area located near Haridwar city. These are made up of virgin HDPE and PET polymer, and cost INR 10-15. They are sold near the banks, and at bathing *ghats,* of the Ganges river in Haridwar. A *ghat*is a river bank location which has been developed to provide visitors safe access to the river. Visitors purchase these cans to collect and carry the holy river water to their homes. Around 7000 visitors visit the city every day during the non-festive season. During festive season this number can multiply manifold.

Perception survey, which included Focus Group Discussions with stakeholders, was undertaken in Haridwar to understand the plastic pollution problem. One of them was with the Shri Ganga Sabha. This 100 year old working Committee (Shri Ganga Sabha) comprising 49 workers takes care of the religious, infrastructure maintenance, cleanliness and other activities of the more auspicious and most visited *ghat* at the Ganges river in Hardwar.

As perceived by them, these plastic cans, used by the visitors to carry *Gangajal*(water from holy river Ganga) to their homes, are considered as auspicious as its contents. Thus visitors often choose to dispose the cans by immersing them in the river directly.

Inferences drawn: HDPE and PET cans are the major source of plastic pollution in the river.

Hotspot Identification: The two types of hotspots have been identified viz.(i) Plastic Leakage Source Hotspots (Ghats); and (ii) Plastic Application Hotspots (HDPE and PET). It also gives an insight that there could be Plastic Accumulation Hotspot if there is a major barrier like barrage on the main stem of the river or any river water diversion structure on its bank downstream of the river.

Leakge Pathways: Since water is the carrier of HDPE/ PET cans its leakage pathway gets identified i.e from the point of its purchase to its point of disposal. The flow of the river at the ghat determines the leakage rate.

Countermeasures: Simple counter measure could include (i) provisioning of dustbins in the vicinity of ghats and (ii) extensive awareness campaign to change the consumer's behaviour to dispose the cans in the dustbins.
Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

CASE STUDY 2: Plastic Pollution at Gharapuri Island (Elephanta Island), Mumbai

Gharapuri is home to the historical Elephanta Caves and is also known as the Elephanta Island, It features two hillocks separated by a narrow valley. The small island is dotted with numerous ancient archaeological remains that are the sole testimonies to its rich cultural past.

Gharapuri is a part of the Mumbai Municipal Region (MMR) and is located in the Mumbai Harbour off the coast of Uran in the Raigad district covering an area of 2.16 sq.km. With a population of about 1,200 from three villages namely ShethBundar, Raj Bundar and Mora Bundar, the highest economic activity is observed around the Shet Bundar village where the Elephanta caves are located. The trail upto the caves is lined by a number of stalls and restaurants which are major sources of plastic waste.

Figure 3.5: Volunteers conducting perception survey at Gharapuri

A perception survey was conducted by the TERI Western Regional Center, Mumbai with the help of NSS student volunteers in the ShethBundar village along the trail to the caves.

The survey indicated that the coastal areas near the Sheth Bundar village witness the highest plastic pollution as tonnes of plastic gets collected on the sea shores from the tourist activities. Respondents shared that marine plastic debris carried by the incoming tides in the Mumbai Harbour gets deposited in the wetlands and mangroves surrounding the island. The island needs frequent cleaning. This can be achieved by volunteer clean-up activities on beaches and in mangroves, followed by segregation and transportation of waste to the mainland, where waste can be disposed at the alloted solid waste disposal sites.

The perception survey highlighted the awareness of the people on the island with regard to the plastic waste menace. The residents showed concern on the increasing levels of pollution and agreed that a well established waste management system on the island was the need of the hour to help save the environment of the island from plastic pollution. The people were also willing to forego the use of plastic products and packaging if provided with an equally sufficient alternative.

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

3.3 Guidance Notes

Objective: The objective of guidance notes is to assist the project field / investigation team to apply the customized approach and methodology using the above tools and techniques to assess tentative hotspots and plastic leakage pathways, stakeholder's perception towards plastic waste management and countermeasures.

Guidance Procedure: A number of steps are involved in carrying out reconnaissance and perception survey. The schematic representation of these steps is given in **Figure 3.6**.

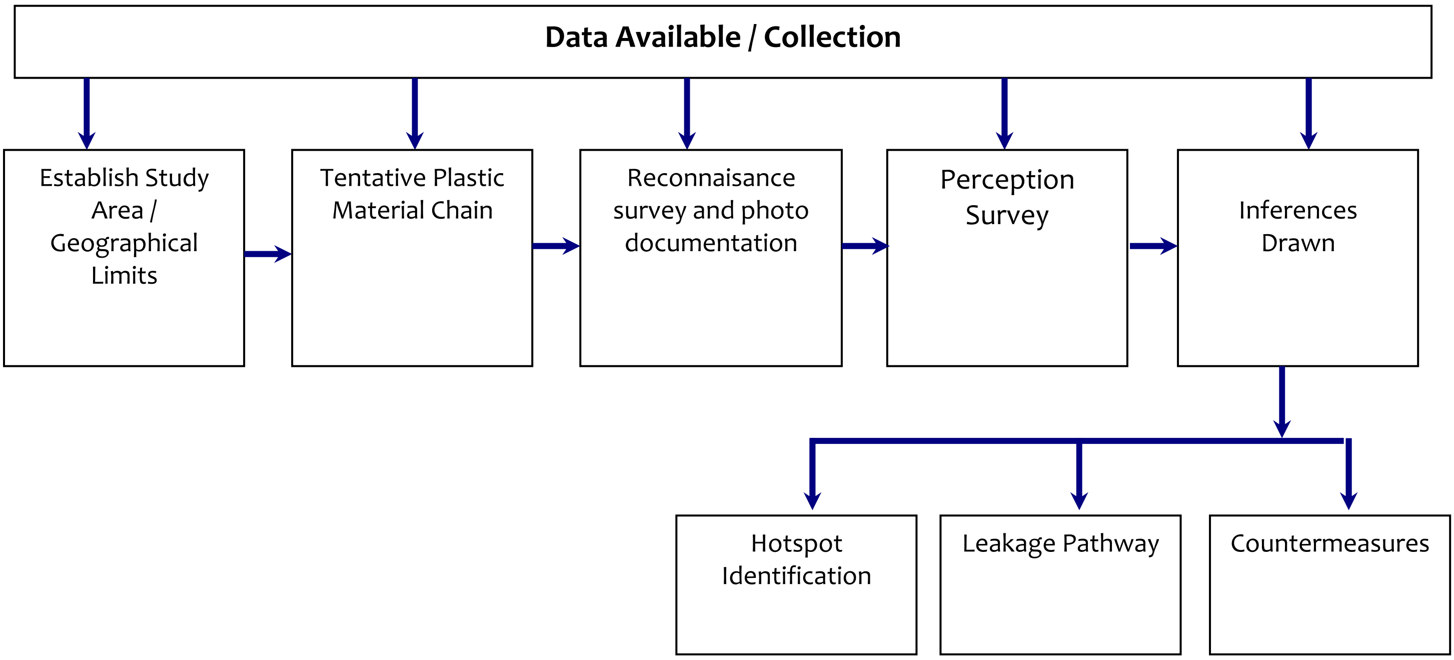


Figure 3.6: Guidance Procedure for Reconnaissance and Perception Survey
Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Step 1: Divide the municipal area into zones as per municipal master plan.

Step 2: Identify the waste collection routes and follow it from the start of collection process till its final disposal. This will include coverage of primary (door to door), secondary (till waste collection bin) and tertiary (waste collection bin to treatment/ recycling and landfill facility) waste collection and transportation system.

Step 3: Describe and document each process used in collection, transportation, recycling and disposal system.

Step 4: Identify the places where each step in this process takes place.

Step 5: Carry out photo documentation and geographical setting of each step

Step 6: Prepare the material flow diagram along with geographical and photo documentation.

Step 7: Conceptualize perception survey by identifying the stakeholders identified during reconnaissance survey.

Step 8: This step involves development of a draft perception survey questionnaire (tools), and stakeholders that are to be targeted as survey respondents. The questionnaire may be developed around the following twelve categories of investigation:

1. Demographics
2. Knowledge about polymers

3. Knowledge of products and packaging made in part or whole with plastics
4. Reasons for preferring products and packaging with plastics
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9. Awareness about alternatives to products and packaging using plastics
10. Willingness to forego plastic products and packaging
11. Perception about impediments to effective action on reducing plastic production consumption and management
12. Sources of information about plastics

Step 9: The draft questionnaire should be piloted and revised based on learnings from the pilot. The pilot results should also help planners in identifying if additional information needs to be obtained through the perception survey, which may be added at the time of finalizing the questionnaire.

Step 10: The questionnaire is conducted at this stage. A sample size needs to be finalized covering the four stakeholders before conducting the survey. This sample size will vary depending on the number of target audience.

Step 11: This stage involves drawing inference form the results of the survey as per **Table 3.1** from each category of questions.

Chapter 4: Mapping of Plastic Value Chain, Material Flow & Leakage Pathways

4.0 Introduction

A conceptual understanding of plastic value chain mapping, hotspotting and predictive leakage pathways based on secondary data in a geographical setting is an essential precursor before undertaking field work for macroplastic and microplastic surveys. 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. 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 following sections describe each of these items to facilitate an understanding of material flow chain in a country/ geographical region/ city followed by guidance notes. 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.

4.1 Conceptual Understanding of Plastic Waste Material Flow

Material cycle of plastic has been described considering life cycle approach. Conceptually, life cycle approach considers the range of impacts throughout the life of a product by taking the entire life cycle into account i.e. from the extraction of natural resources to material processing, manufacturing, distribution and use, and finally to the reuse, recycling, recovery and disposal of any remaining waste. Life cycle assessments (LCA) quantify these steps by assessing the emissions, resources consumed and pressures on environment, health and safety that can be attributed to a product or service. A conceptual plastic value chain has been described in **Figure 4.1**. It starts from material engineering for plastic and leads to its production followed by its consumption, collection, recycling and repurposing and finally its conversion and disposal. **Figure 4.2** describes activities at each stage of plastic value chain. The material / product input versus output at each stage determine the sources of plastic waste along the plastic value chain. Stage wise description of plastic value chain is given below.

Material Engineering (Stage 1): Different raw materials e.g. petroleum, non petroleum and other resources are identified to develop plastic product for a particular use. This may consist of virgin raw materials or their combination. At this stage, the formulation of plastic product determines extraction of raw materials from finite natural resource e.g. petroleum or secondary materials such as plastic waste.

Production and Business Model (Stage 2): At this stage, raw materials are converted into products using physical or chemical processes based on technology, economics and business model (export or domestic consumption). The efficiency of conversion determine plastic waste generation at this stage. Further, the formulation at stage 1 determines reuse or recycling of plastic waste generated at this stage or stage 5.

Consumer Use, Reuse and Behavior (Stage 3): Consumer behavior determines consumption of plastic products. 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.

Collection (Stage 4): Waste plastic is collected using formal and informal collection system. At this stage efficiency of collection system determines plastic leakage into the environment. Uncollected plastic waste leaks into drainage and sewer system or directly into waterways or seas.

Recycling and Repurposing (Stage 5): Collected plastic waste is segregated for reuse, recycling, energy recovery (non recyclable) and disposal. The efficiency of segregation in both formal and informal plastic waste management system determines leakage into the environment.

Conversion and Disposal (Stage 6): Plastic waste after recycling and repurposing is meant for disposal. The disposal mechanism includes disposal on land or water such as organized dumping into sanitary landfill site, unorganized burying / dumping, wild dumping close to waterways and directly into waterways.

Last Chance Capture (Stage 7): Plastic waste dumped on land can be captured at landfill or dump sites through manual or mechanical mechanism used for waste segregation. Plastic waste dumped into waterways can be captured through retention mechanism.

Figure 4.2 also describes cause, problem and effect of plastic waste generation. Further, it depicts stage wise sources of plastic waste generation and its leakage into the environment.

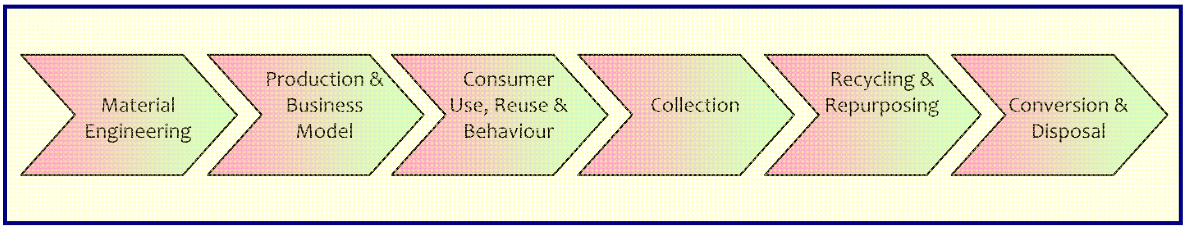


Figure 4.1: Conceptual Plastic Value Chain

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

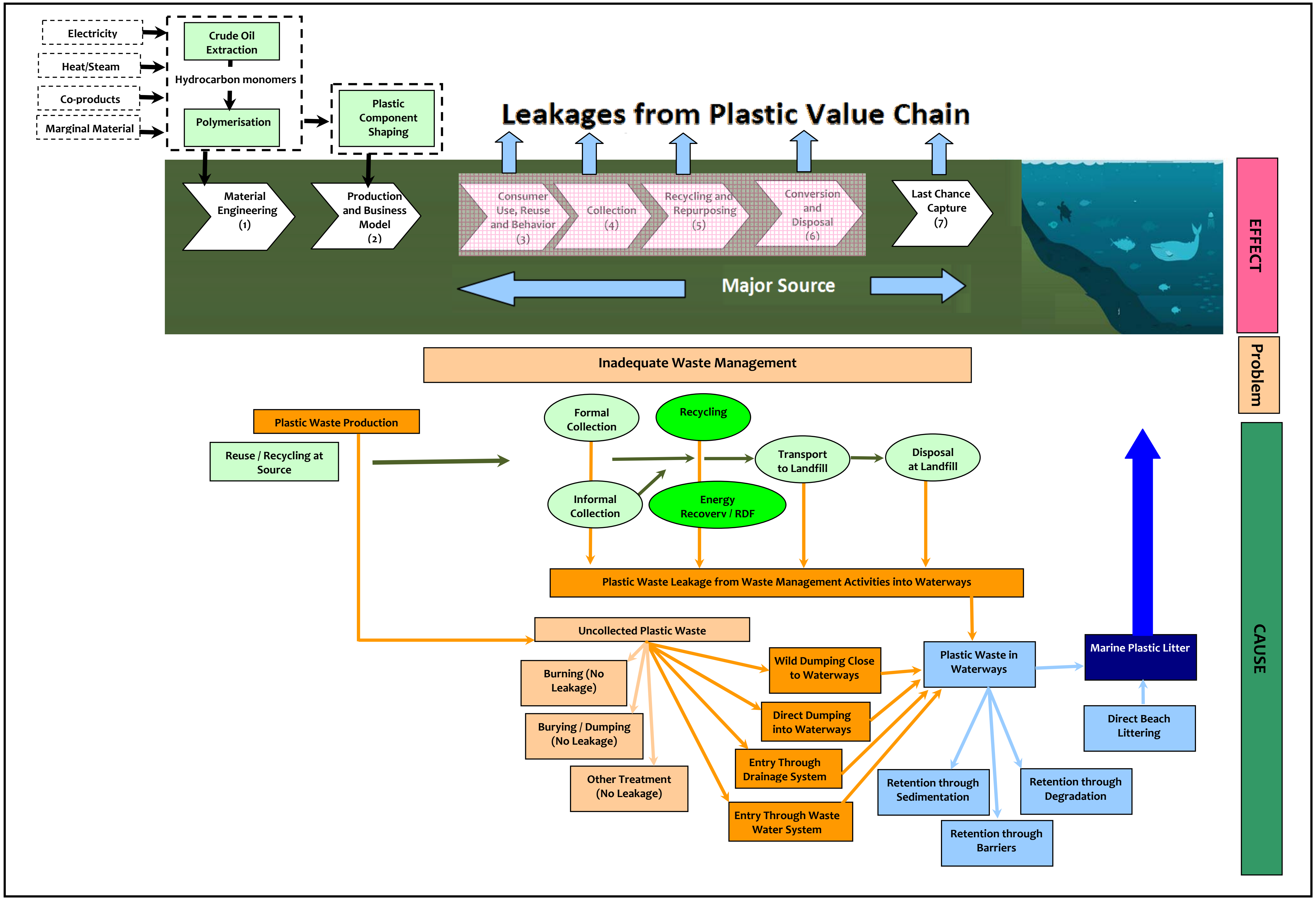


Figure 4.2: Sources of Plastic Waste Leakage into Environment [2][3][4]

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

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.

1. The model is based on the ‘unit process approach’, where a unit process represents processes or activities.
2. The material flow model considers all unit processes and flows within a defined boundary. Arrows indicating the flow of material link the unit processes.
3. 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.
4. 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 as shown in Figure 4.3, 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.

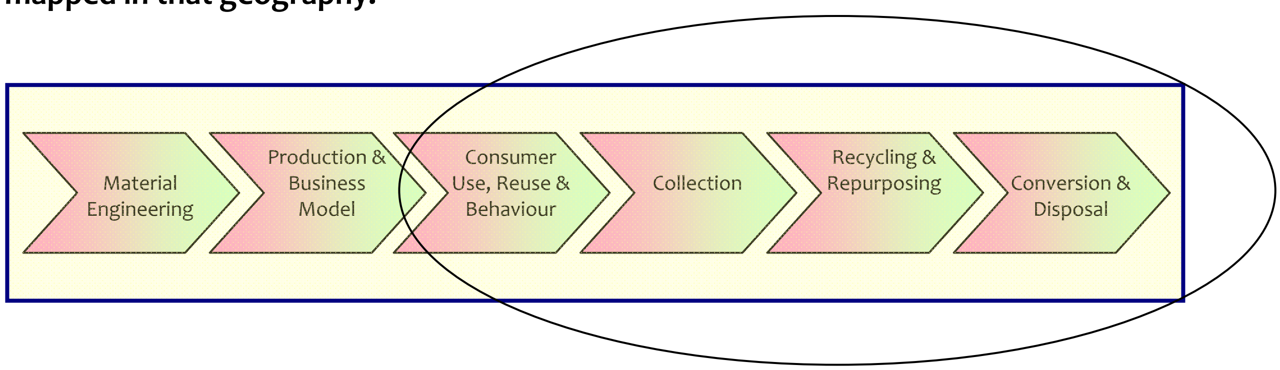


Figure 4.3: Plastic Value Chain Boundary Conditions within a Geography
Source: UN Environment (2017) - Reducing Marine Litter by Addressing the Management of the Plastic Value Chain in Southeast Asia

The data points for carrying out input output analysis considering scenario in **Figure 4.3 are given in Figure 4.4.**

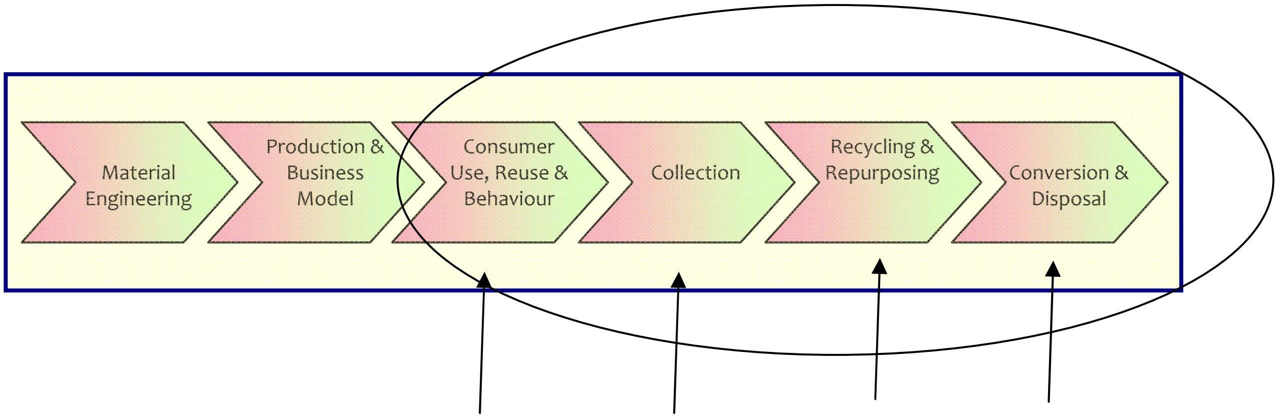


Figure 4.4: Data Points for Data Collection, Interpretation and Analysis

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

The situation in **Figure 4.3** and **Figure 4.4** will vary from geography to geography and is subject to change. Accordingly the data points for input output analysis will change.

Box 1: Waste Management and Material Flow Analysis in Agra

An example of material flow data analysis data in Agra indicated that only 2 to 3 % waste is collected from the slum. The high value recyclables solids are extracted by the rag pickers from the transfer stations. Out of this 4-5% of high value plastic is taken away by the rag pickers and 80-90 tonnes of flow plastic in dry waste reaches to MRF facility. Thus 80-100 TPD of plastic is attempted to bring back into the value chain. The remaining 10-3- tons per day plastic is directly disposed, open burned or littered into streets, drains etc. finally its way into the land and river ecosystem by various means. About 700 to 750 tons mixed MSW is being dumped at the site on daily basis. From the field study it was inferred that presently around 22 % of plastic waste was found in mixed waste in Kuberpur dumpsite. These include single use plastics and polythene carry bags. Based on the material flow analysis, waste material flow chain and the leakage pathway of plastics in the city has been depicted in **Figure 4.5**

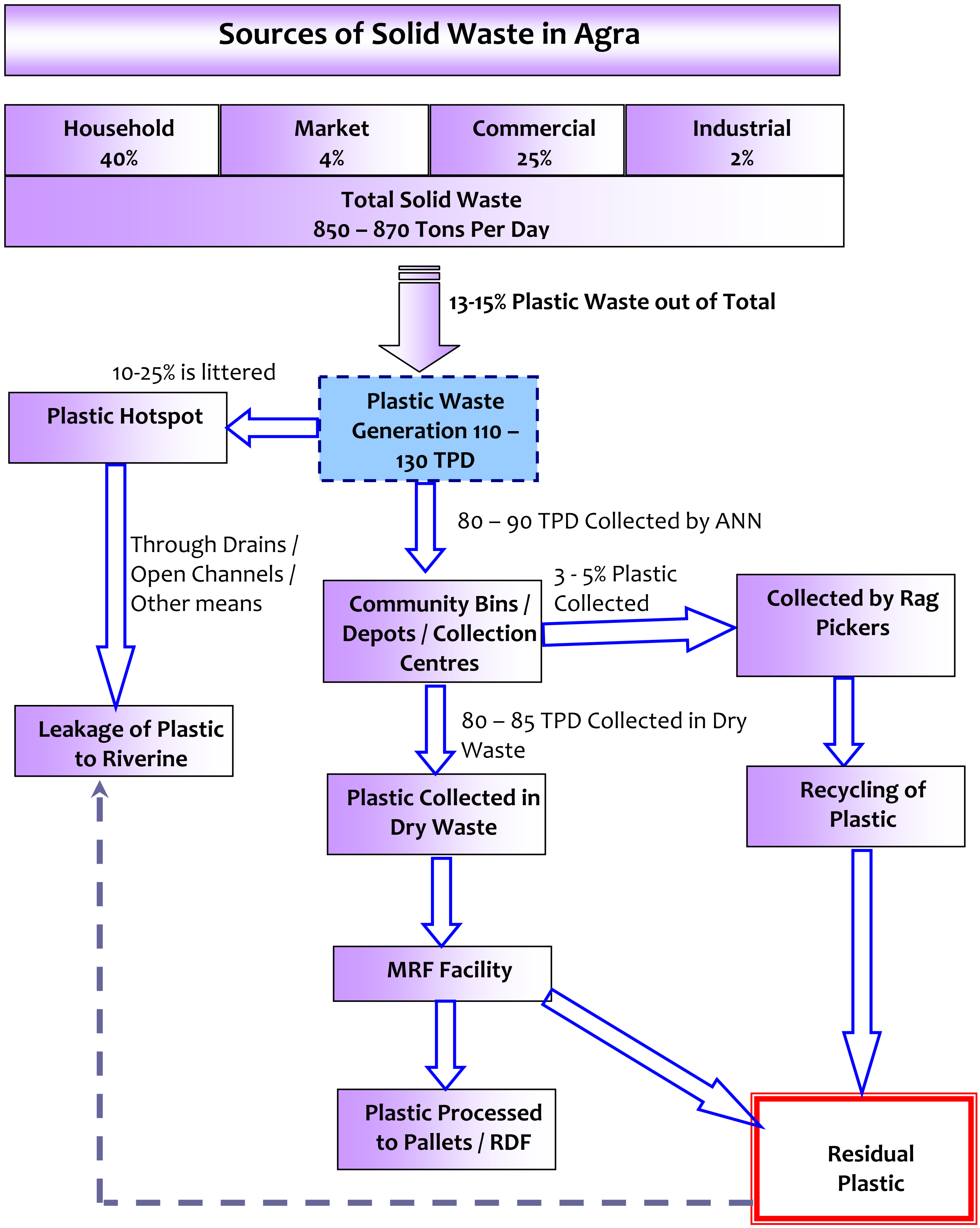


Figure 4.5: Waste Plastic Flow Chain in Agra

Source: Dr. Shukla Pal Maitra & Dr. Harsh Thukral; National Productivity Council (NPC) 2020

4.3 Geographical Mapping of Waste Plastic Material Flow Chain

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. It includes the following following steps.

Step 1: first prepare the base map of the study area.
Step 2: Develop layers of physical features (slope, contour, rivers, drainage etc.)
Step 3: Develop layers of human interventions (land use, demography, socio-economic layers, points of interests, commercial, agriculture, industrial areas etc.)
Step 4: 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. The basic logic to use fuzzy approach is described in **Appendix 4.1**
Step 5: Develop risk maps or 'Heat Maps' to provide an overview of the hotspots identified in the study area. The output of this step is shown in **Figure 4.6.**
Step 6: Compare risk map with the waste map, population density and land use map and identify the locations of tentative hotspots and plastic leakage pathways as shown in **Figure 4.7.**

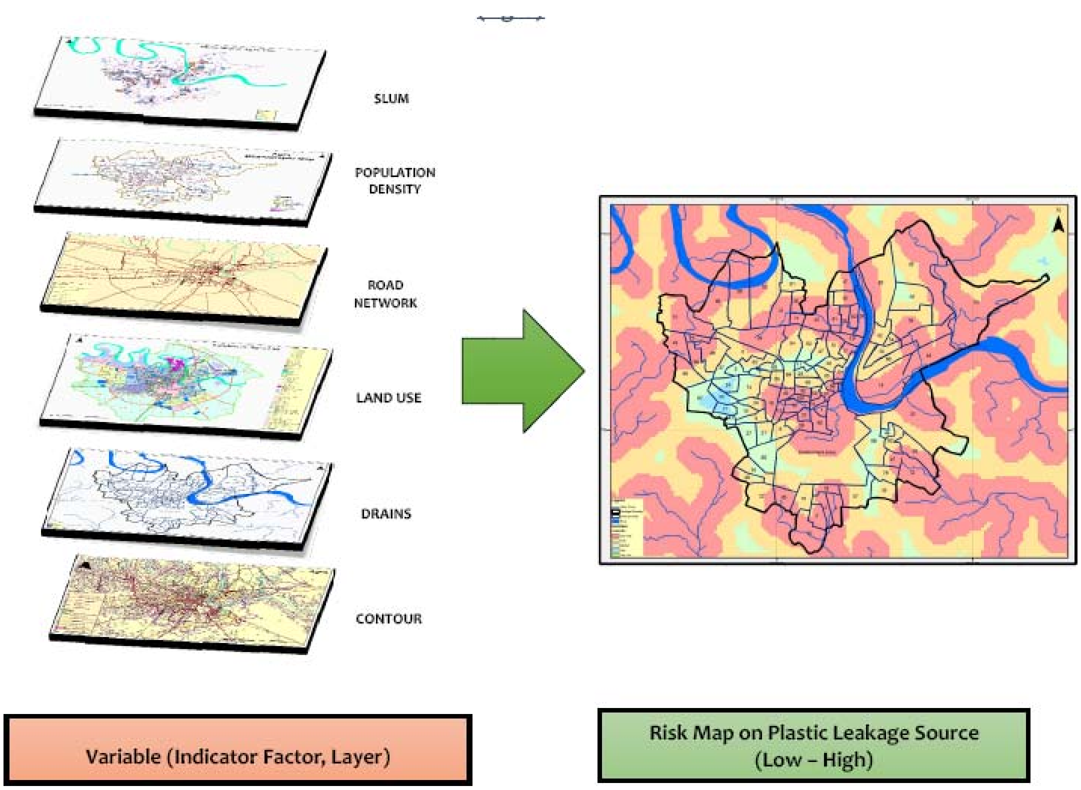


Figure 4.6: Plastic Leakage Risk Map of Agra
Source: Prepared by Amit Jain, Sanjeev Satyanarayan & Apoorva Agrawal (2020); IRGSSA

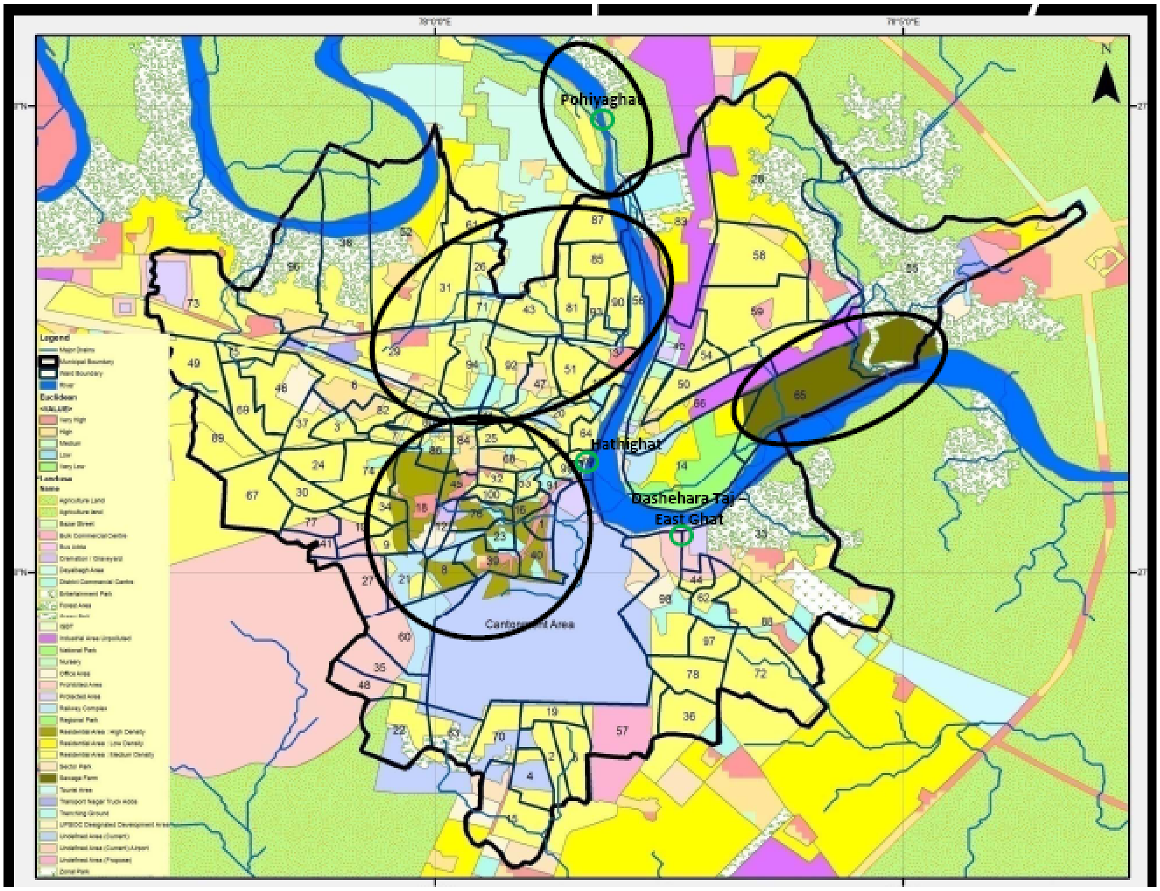


Figure 4.7: Locations for survey of Hotspots and Plastic Leakage
Source: Prepared by Amit Jain, Sanjeev Satyanarayan & Apoorva Agrawal (2020); IRGSSA

4.4 Guidance Notes

Objective: 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 Procedure: Guidance procedure includes completion of following nine steps.

The schematic representation of these steps is given in figure 4.8.

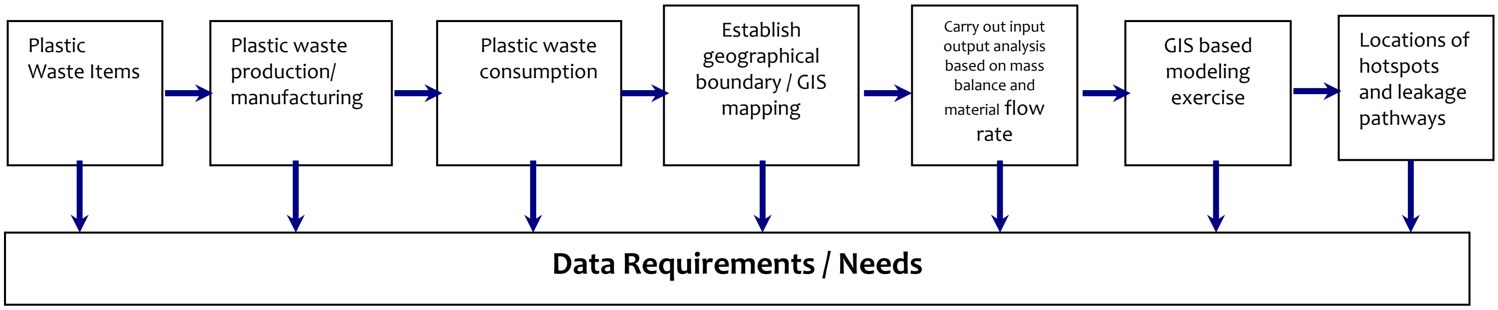


Figure 4.8: Guidance Procedure for Defining Plastic Waste Assessment

Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Step 1: Prepare conceptual plastic value chain as per **Figure 4.1** and determine different blocks, which are applicable in the geographical area under study.

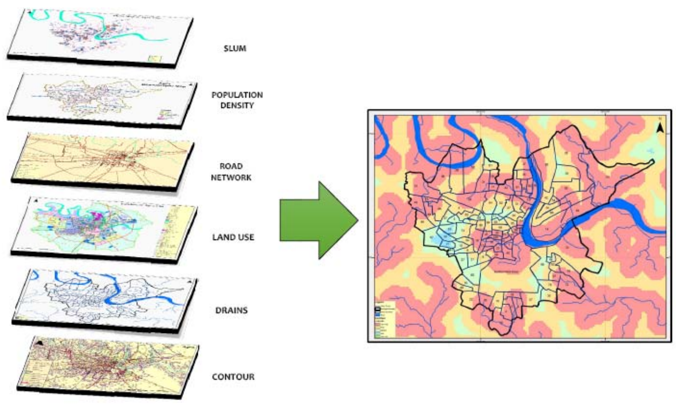
Step 2: Prepare the tentative plastic value chain, which is applicable in the study area and determine the data points as per **Figure 4.3** and **Figure 4.4.**

Step 3: Procure data as per the data formats given in Appendices of Chapter 2.

Step 5: Prepare the matrix as per the data availability, reliability, range, completeness and relevance of the data.

Step 6: Carry out input output analysis based on material flow and mass balance as per the example given in **Figure 4.5.** Calculate the loss rate of the plastic waste from this mass balance.

Step 7: 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 as shown in **Figure 4.9** . This mapping will give an insight into the possible hotspots and assist in carrying out the primary survey.



Layer 4: Hazards

Layer 3: Plastic Waste Routes

Layer 2: Stakeholders

Layer 1: Physical Features

Base Layer

Figure 4.9: Geographical Mapping of Different Attributes

Source: Prepared by Amit Jain, Sanjeev Satyanarayan & Apoorva Agrawal (2020); IRGSSA

Step 8: Prepare heat maps/ risk maps as per Steps 1 to 6 given in section 4.3.

Step 9: Compare the risk map/ heat map with the landuse or waste density map to identify location of hotspots and tentative sampling locations for both macroplastics and microplastics.

Chapter 5: Macro Plastic Waste Assessment

5.0 Introduction

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. Macroplastic is clearly visible plastic and generally will not (with a few exceptions) have a direct impact on the food chain. However, macroplastic degrades into microplastic due to different processes such as hydrolysis, photo-degradation or mechanical/ physical degradation. Land-based macroplastic is considered one of the major sources of marine plastic debris. However, estimations of plastic emission from rivers into the oceans remain scarce and uncertain, mainly due to a severe lack of standardized observations. This chapters describes the methodology for carrying out macro plastic waste assessment, where an understanding of plastic value chain in a geographical setting after consumption is addressed. This includes assessment of macroplastics, which are likely to leak into the rivers based on material flow described in Chapter 4. The outcome of this assessment will assist the decision makers to identify and focus their attention to develop countermeasures on the type and quantity of plastic waste that is likely to leak into riverine ecosystem. Guidance notes will assist in describing how to carry out macroplastic assessment.

5.1 Conceptual Understanding

The conceptual understanding indicates the accomplishment of three step approach for carrying out macroplastic assessment. These steps provide guidance and are used for on land plastic waste assessment but differ from the location.

Step 1: Identification of locations to carry out on land macroplastic 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 run-off, 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. A combination of area risk map/ heat map and survey locations eg. Illegal dump sites and poorly serviced areas mapped through field survey provides 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.** An example of this step is given in **Figure 5.1** and **Figure 5.2.**

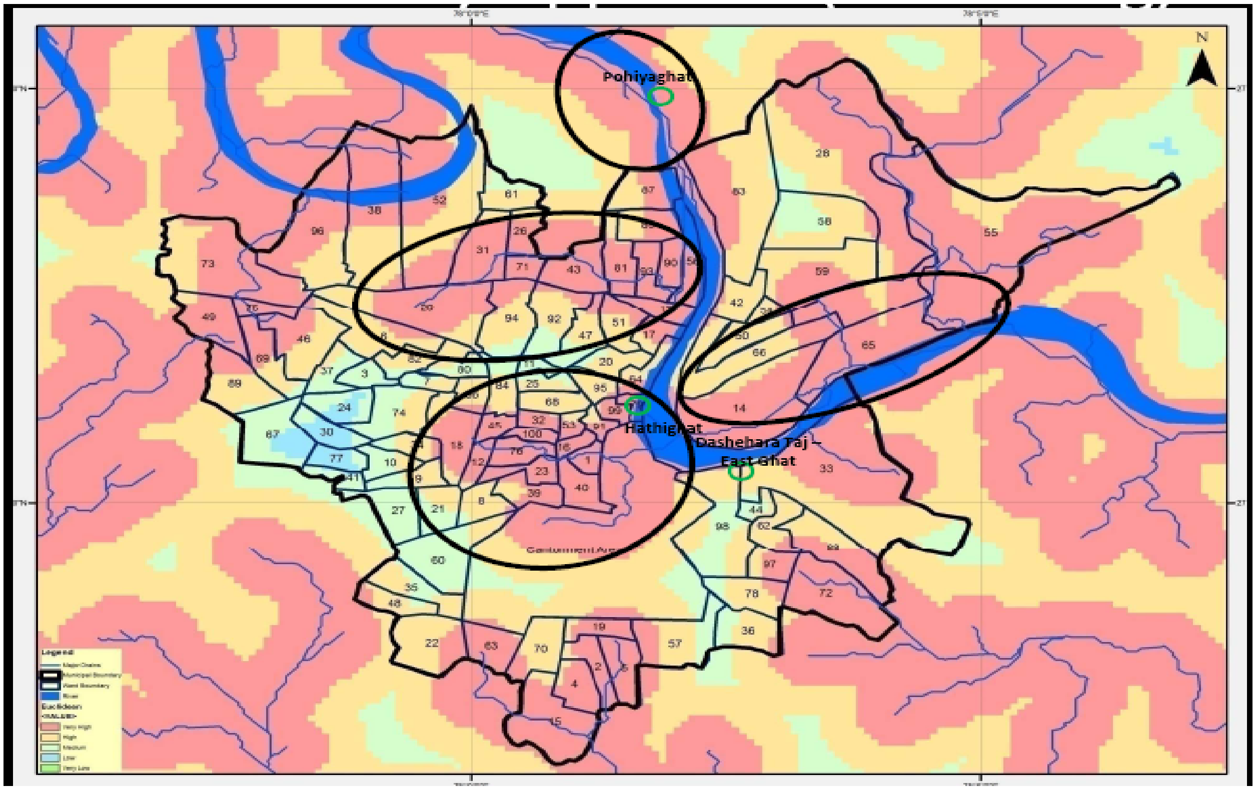


Figure 5.1: Location of Probable Hotspots in Agra

Source: Prepared by Amit Jain, Sanjeev Satyanarayan & Apoorva Agrawal (2020); IRGSSA

Figure 5.2: Field Reconnaissance& Verification of Hotspots

Source: Prepared by Dr. Shukla Pal Maitra, Dr Harsh Thukral & Apoorva Agrawal; IRGSSA (2020)

Step2: Carrying out the 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. Table 5.1 describes the idea of variation in the number of samples to achieve the desired confidence levels.

Table 5.1: Number of Samples for Waste Composition

Materials	C.L 95%		C.L 90%		C.L 80%		C.L 70%	
	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial
Newsprint	224-2397	698-3563	58-600	170-991	16-150	48-223	9-58	21-101
Cardboard	899-1955	533-997	225-499	134-250	58-123	35-64	27-66	17-30
Aluminium	275-1437	754-4399	70-350	191-1100	19-92	60-275	10-42	23-123
Ferrous	194-554	552-3411	50-139	138-953	14-37	36-214	8-18	17-97
Glass	145-619	596-2002	39-155	149-501	19-61	39-126	6-19	19-58
Plastic	261-1100	422-783	67-275	107-195	18-70	28-61	10-32	14-24
Organic	12-47	26-92	5-14	8-25	3-5	4-8	3-4	3-5

Source: UNEP (2009); Developing Integrated Solid Waste Management Plan Training Manual; Volume 1 – Waste Characterization and Quantification with Projections for Future

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, extensive 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 the second, for characterization of waste. This could be further divided into characterization through visualization and characterization through hand sorting. Example of guidance for guidance is presented in **Appendix 5.1** and **Appendix 5.2**. Data from industry association can also assist in their identification. Further, input and output analysis in the material flow chain in geography can be carried out using mass balance from the material flow after consumption, waste collection, treatment and disposal. The historical data with the regulator, local body, and private operator for collection, treatment and disposal can also assist to apply mass balance along the plastic value chain after consumption. The major data points are shown in **Figure 5.3.** This mass balance can give loss rate of plastics.

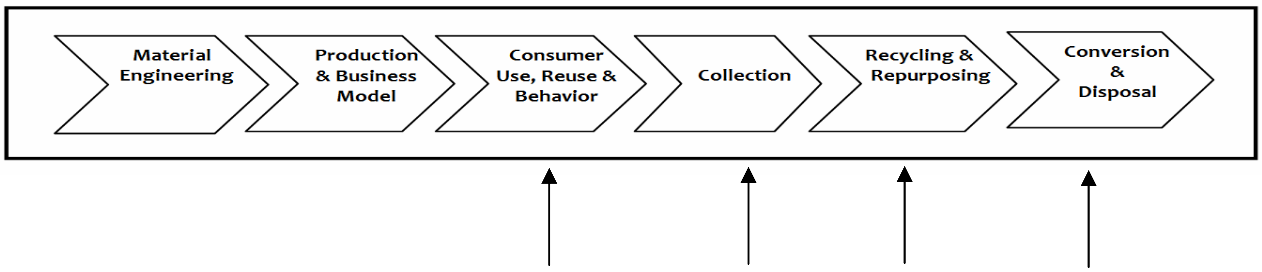


Figure 5.3: Major Data Points for Data Collection, Interpretation and Analysis
Source: Prepared by Amit Jain (2020); Managing Director - IRGSSA

Step 3: Carrying out macroplastic survey in water body

This step involves usage of barrier technique e.g. floating barriers to block macroplastics floating in the flowing water **(Figure 5.4)** and their assessment based on visual inspection i.e through high resolution 360 degrees camera or drones etc. **Appendix 5.1** and **Appendix 5.2** can be used to identify the macroplastic characterization and composition. Data from industry association can also assist in their identification. In case these macroplastics are retrieved from the waterbody 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 waterbody.

Figure 5.4: Barrier/ Trash Booms
Source: Prepared by Dr. Shukla Pal Maitra (2020); National Productivity Council (NPC)

5.2 Methodology

The conceptual understanding gives the three step approach to carry out macroplastic survey. The different activities to be carried out under each steps are given below.

5.2.1 Step 1: Identification of Locations to Carry Out on Land Macroplastic Assessments

Activity s1.1: Develop the risk map of the entire geographical area as shown in Figure 5.1 based on GIS techniques described in Chapter 3. The output of this activity will give tentative vulnerable areas from where leakage could occur as marked in oval shapes in **Figure 5.1.**

Activity s1.2: Compare the risk map with land use map/ waste map of the study area to identify the areas i.e. residential, commercial, industrial or any other and the tentative hotspots

Activity s1.3: Validate the outputs of the risk map and land use map by undertaking field survey of the tentative hotspots shown in **Figure 5.2.**

The activity wise procedure is shown in **Figure 5.5.**

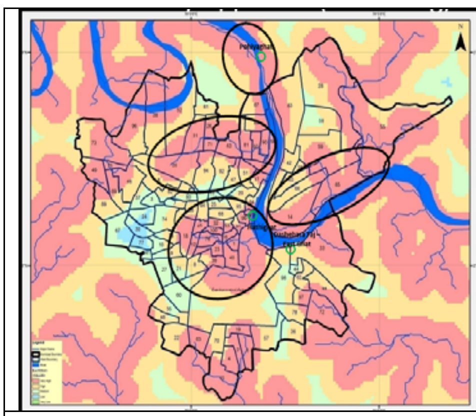
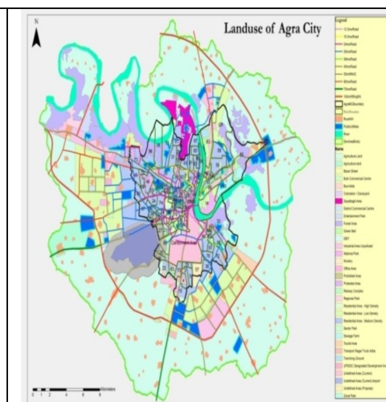
		
Plastic leakage vulnerable areas identified using GIS fuzzy logic approach	**Land use map of the area**	**Validation of the hotspot**

Figure 5.5: Activity wise procedure of Step 1

Source: Prepared by Amit Jain, Sanjeev Satyanarayan & Apoorva Agrawal (2020); IRGSSA

5.2.2 Step2: Carrying out the On Land macro plastic Sampling and Clean Up Surveys

Two different types of on land macro plastic sampling and surveys methodologies have been designed to cover the catchment areas where plastics are littered and areas close to the river/ water body banks addressing plastics leakage source hotspots. The two types of macro plastic sampling gives an idea about the plastics which are generated at source and the plastics, which have found its way from the carrier close to the banks of river/ water body.

(1) Catchment Areas where plastics are littered
(2) Plastics close to the river/ waterbody

The basic aim of macro plastic assessment is to identify the composition and type of plastic litter. The important aspects covered under the methodology are:

1. Preparation for macro plastic assessment
2. Implementation of methodology

The details of activities required for preparation and implementation activities are summarized below.

5.3 Preparation for macro plastic assessment

The preparation for macro plastic assessment includes team formation, selection of location and grid, timing of sampling and tools required for assessment.

Activity 5.3.1: Teams Formation

Three teams are to be formed for organizing the successful cleanup activity for the assessment of macro plastic littering. These teams will involve the experts for visual inspection and directing the activity, volunteers for collection and segregation of waste, photographer to capture the entire cleanup activity, data recorder, field surveyors, and activity coordinators/organizers.

Teams to be formed are:

1) **Survey Team:** Survey team will constitute of the field surveyors who are relied on identifying the hotspots within the city where cleanup activity can be organized for the assessment. This team will be consulting with the local government officer in charge of waste management and the experts to finalize the cleanup location and the grid (100mX100m) or bigger dimension as discussed in section 5.1.

2) **Cleanup team:** Cleanup team will constitute of the experts, volunteers, and activity coordinators/organizers. This team will be relied on conducting the entire cleanup activity from collection, segregation and analysis of the plastic litter. This team will be sub divided into 3 sub teams, namely Collection Team, Segregation Team and Visual Inspection Team.

a. **Collection Team:** Collection Team is comprised of volunteers and will be collecting the waste which is littered in demarcated area. This waste is to be collected in the collection bags (such as *Gunny Bags*) provided to them. The team has to collect the entire litter which is present in the selected area. The team has to ensure that they are equipped with proper personal protective equipments (PPE) and that has to be wear throughout the activity. It was advised, in case of any minor injuries, the team/volunteer has to immediately inform the organizer/coordinator for the same. For a pilot scale cleanup (say for 100 m^2 of area), 8-10 volunteers can be part of the team.
b. **Segregation Team:** Segregation Team is a group of volunteers involved in segregating the waste collected by collection team. This team is relied on segregating the waste as per the categories listed in the trash data sheet. The team has to ensure that they are equipped with proper personal protective equipments (PPE) and that has to be wear throughout the activity. It was advised, in case of any minor injuries, the team/volunteer has to immediately inform the organizer/coordinator for the same. For a pilot scale cleanup (say for 100 m^2 of area), 5-6 volunteers can be a part of the team.
c. **Visual Inspection Team:** Visual Inspection Team will be comprised of experts, activity coordinators/organizers and support staffs. This team will be relied on successfully organizing and proper procedure to be followed during the cleanup activity so that reliable data can be procured. The team will be responsible for coordinating each task from collection, weighing of the trash, segregation, quantification and final handing over of the collected waste to the waste management department of the local government ensuring the proper treatment/disposal. Also, the team has to prepare for all the materials or equipment required during the activity.

3) **Documentation and Photography Team:** Documentation and Photography Team will comprise of data recorder and photographers & videographers. The team will ensure that the entire cleanup activity is covered /recorded for reporting. The proper data recording to be done by the team of the data extracted during segregation process in the trash data sheet. This team is to coordinate with both survey team and cleanup team.

Activity 5.3.2: Time and Date

Proper management of the entire cleanup activity is to be ensured. For this, the time and date is to be scheduled to ensure that preparations can be done before the day of the event. It is suggested, the time should be arranged in the early morning to avoid strong sunlight

Activity 5.3.3: Tools Required

A list is prepared for the equipments and materials that will be required during the activity and is given below in **Table 5.2**

Table 5.2: List of Equipments/items required

S. No.	Equipment/items	Use
1	PPE Kits containing Hand gloves, masks, Safety Boots.	To ensure safety of volunteers and to avoid injuries and infection. Safety boots to be used in wet areas.
2	A measuring Tape	To measure the area of cleanup for demarcation.
3	Stationary Items such as Pens, clips boards, Trash data forms, staplers, Stickers, markers etc.	These items will be used for labeling the collection bags and recording of the data.
4	Ground Sheet, if possible blue colored sheet is recommended. (Recommended Size: 24 ft. X 18 ft.)	To spread the collected waste/litter on the sheet to segregate, show and to take photographs. This sheet will also ensure that there is no loss in the weight of the collected waste, as the entire waste is to be kept on it.
5	Scale of different capacities (One to measure from 1 g and another to measure up to 50 kg)	To weigh the amount of waste/litter collected. Two weigh balance are required to weigh large as well as tiny litter ranging from 1 g to 50 kg.
6	A First Aid Kit	To be used for minor injuries (such as cuts).
7	Mid-Size Bags or containers	To store light items/litter so that winds can't blew away tiny litter particles while segregation.
8	Large collection bags	To collect waste/litter, recommended to use bags such as Gunny Bags.
9	Brooms and Dustpans	To collect tiny particles as it is difficult to collect and count those tiny litter.
10	Sanitizers and Hand wash	To ensure cleaning of hands after the cleanup activity.
11	Refreshment (Water and Food) for volunteers	Refreshments to be provided for the volunteers.

Source: Prepared by Dr. Harsh Thukral (2020); National Productivity Council (NPC)

5.4 Implementation of Methodology

Implementation of methodology includes activities like demarcation of site, usage of personal protective equipment (PPE), labelling of the bags, waste collection, segregation, weighing, counting of segregated waste and handing over the waste for treatment and disposal.

Activity 5.4.1: Demarcation of the site

The sampling unit should be a fixed section of river/ocean shore or point in the collection, treatment and disposal stage of plastic value chain. The size of an areas to be chosen considering the amount of litter and the number of volunteers/participants who are engaged in the activity. However, it is suggested to adhere a standard length of about 100 m, as it enhance data comparability. Shorter area can be sampled on highly contaminated areas. The site identification and demarcation decision depends on sampling sufficient items to obtain a representative indication of litter abundance and composition. In these types of survey all litter items above a certain size are recorded.

Activity 5.4.2: Wearing of Personal Protective Equipments (PPE)

Wearing of Personal Protective Equipments (PPE) is mandatory for all the participants/ volunteers taking part in the cleanup activity. PPE will help participants/volunteers from injuries, infection and unpleasant odor.

Activity 5.4.3: Labelling of the Bags

Collection Bags which are to be used for collection of litter/waste is to be labelled before use. This label should consist place of cleanup, date of cleanup and bag number.

Activity 5.4.4: Waste Collection

This step includes the collection of waste from the demarcated site. Each and every litter/waste items has to be picked up irrespective of their size and material. This will also include quartering technique at the source of generation of plastic waste.

Activity 5.4.5: Waste Segregation

This steps includes the segregation of different waste (categories wise) from the collected waste. This is to be ensure that waste doesn't spills out of the ground sheet on which the segregation process is to be taken place.

Activity 5.4.6: Weighing

The weighing is one of the essential steps that has to be carried seriously. Weighing is to be performed at various steps to ensure proper data recording. Steps which includes weighing are:

- Collection Bags has to be weighed before use so that the proper weight of the waste can be calculated.
- After collection of waste, each collection bags are to be weighted separately with the collected waste in it and the same is to be recorded
- After segregation of waste, each waste categories are to be weighed separately and the same has to be recorded.

Activity 5.4.7: Counting of Segregated Waste

This steps includes counting of each segregated waste categories separately. A rough count is to be done for the categories which are found in huge numbers and are unable to count because of tiny/torn pieces. Count for each categories are to be recorded.

Activity 5.4.8: Handing over of the collected waste

The entire collected waste (either it is plastic waste or it is non-plastic waste) is to be handed over to the waste management team of local government and ensure that the entire waste is to properly treated/disposed as per the rules/guidelines.

5.5 Carrying out macro plastic survey in water body

Macroplastic assessment in water body or river, which is plastic accumulation hotspot can be carried out by implementing the following activities.

Activity 5.5.1: Identify the river stretch, which has an active channel and where the floating plastics can be trapped.

Activity 5.5.2: Install the plastic barrier where both upstream and downstream of the water body. It can also be the artificial barrier as well.

Activity 5.5.3: Identify the grid as shown in **Figure 5.4**. It can be of feasible dimensions depending on the accumulation of plastic waste near the bearer.

Activity 5.5.4: Sample the grid at different timeline using visual aids like high resolution 360 degrees camera or drones.

Activity 5.5.5: Sample the grid at different timeline using collection by boats and bringing the plastic waste/ litter to the shore. Dry the collected waste and follow the procedure given in **Activities 5.4.2 to Activities 5.4.8** to determine the composition and characterization of waste.

Activity 5.5.6: In case of visual sampling the plastic waste can be characterized and the composition can be determined using **Appendix 5.1** and **Appendix 5.2**.

5.6 Guidance Notes

Objective: The major objective of guidance notes is to carry out the macro plastic assessment to generate required data consisting of composition and characterization of macro plastics to guide policymakers, decision makers to identify and adopt counter measures to address plastic leakage into riverine ecosystem.

Guidance Procedure: Guidance procedure includes completion of following six steps as given below.

Step 1: Identification of locations to carry out on land macro plastic assessments

Carry out activities s1.1 to s1.3 to identify locations for on land macro plastic assessment. The activity wise procedure is shown in **Figure 5.5.**

Step2: Carrying out the On Land macro plastic Sampling and Clean Up Surveys in Catchment Areas where plastics are littered and areas close to the river/ water body

Step 2.1: Carry out **activities 5.3.1 to 5.3.3** for preparation for macro plastic assessment which includes team formation, selection of location and grid, timing of sampling and tools required for assessment.

Step 2.2: Carry out **activities 5.4.1 to 5.4.8** for implementation of macro plastic assessment and clean up surveys. Some of the major items covered under these activities are given below.

Labelling of the Bags

Collection Bags which are to be used for collection of litter/waste is to be labelled before use. This label should consist of place of cleanup, date of cleanup and bag number.

Waste Collection

Each group of volunteers has to collect the waste littered in the demarcated area and ensure picking up of the entire waste from tiny pieces to a large pieces of waste. The collected wasted to be filled up in the collection bag provided to them and each group has to ensure that after collecting the waste, the bag is to be weighed separately. In case of any injuries, the team has to report directly to the Visual inspection team so that immediate treatment can be given.

Note: During this task, Collection Team will be collecting the waste and Visual Inspection Team will be weighing the collected bags & recording the data as per trash data form given below.

Waste Segregation

For segregation, the ground sheet is to be used. Collected mixed waste is to be spread over the blue sheet. Now, volunteers will be segregating the mixed waste as per the categories listed in standard trash sheet under supervision of the experts and coordinators so that the proper segregation can be done for better results. The segregated waste will again be weighed separately and a rough count will be made for each categories of waste. It is recommended that an actual count to be made for a categories for which it is possible to be done (such as PET bottles, etc.). Standard trash sheet form is given below which is to be used in recording of the data.

Note: During this task, Segregation team will be segregating the waste and visual inspection team will be directing for proper segregation and recording the data for analysis.

VOLUNTEER

(Trash Data Form)

Ocean and waterways trash rank as one of the most serious pollution problems choking our planet. Far more than an eyesore, a rising tide of marine debris threatens human health, wildlife, communities and economies around the world. The ocean faces many challenges, but trash should not be one of them. Ocean trash is entirely preventable, and data you collect are part of the solution. The international cleanup is the world's largest volunteer effort on behalf of ocean and waterway health.

Site Information

Cleanup Site Name:
State
Zone or Country:
Country:
Landmark:

MOST UNSUAL ITEM COLLECTED	
Type of Cleanup **Land** **Water** **Under Water**	**Number of Volunteer Engaged** **Adults** **Children (under 12)** e

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

TRASH COLLECTED

Citizen Scientist: Pick up all trash and record all items you find below. No matter how small the items, the data you collect are important for Trash Free Oceans/rivers.

S. No.	MOST LIKELY TO FIND ITEMS:	Total weight in Kg	Total No.
1	Cigarette Butts		
2	Food wrappers (Biscuits, Chips etc.)		
3	Take Out/ Away containers (Plastic)		
4	Take Out/ Away containers (Food)		
5	Bottle Caps (Plastic)		
6	Water Pouches		
7	Lids (Plastic)		
8	Milk Pouches		
9	Beverage Bottle (plastic)		
10	Beverage Bottle (glass)		
11	Beverage Cans		
12	Grocery Bags (Plastics)		
13	Other Plastic bags (katta, nylon bags)		
14	Paper		
15	Cups & Plates (paper)		
16	Cups & Plates (plastics)		
17	Cups & Plates (foams)		
FISHING GEAR			
1	Fishing Buoys pots & traps:		
2	Fishing Net & Pieces:		
3	Fishing Line (1 Yard/ meter)= 1 piece		
4	Rope (1 Yard/ meter)= 1 piece		
OTHER TRASH			
1	Appliances (refrigeration, washers etc.)		
2	Balloons		
3	Cigar tips		
4	Cigarette Lighters		
5	Construction Materials		
6	Fireworks		
7	Tires		
PACKAGING MATERIALS			
1	6- Packs Holders		
2	Other Plastic/Foam Packaging		
3	Other Plastic polythene (light)		
4	Other Plastic polythene (Hard & Big)		
5	Tobacco Packaging Wrap		
PERSONAL HYGIENE			
1	Condoms		
2	Diapers		

S. No.	MOST LIKELY TO FIND ITEMS:	Total weight in Kg	Total No.
3	Syringes		
4	Tampons/Tampon Applicators		
TINY TRASH LESS THAN 2.5 CM			
1	Foam pieces		
2	Glass pieces		
3	Plastic pieces		
ITEMS OF LOCAL CONCERN			
DEAD/INJURED ANIMAL		TYPES OF ENTANGLEMENT ITEMS	ENTANGLED
			Yes or No
CLEANUP SUMMARY			
Number of Bag Filled: No.	Weight of Trash Collected: Kg		Area Cleaned: Sq. m.

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

Weighing

The weighing is one of the essential steps that has to be carried seriously. Weighing is to be performed at various steps to ensure proper data recording. Steps which include weighing are:

- Collection Bags has to be weighed before use so that the proper weight of the waste can be calculated.
- After collection of waste, each collection bags are to be weighted separately with the collected waste in it and the same is to be recorded
- After segregation of waste, each waste categories are to be weighed separately and the same has to be recorded.

The completion of activities in steps 2.1 and 2.2 will give the two types of outcomes as given below.

Outcome 1: Results on the type and material of the product. Also, this will help to find the prominent plastic waste category generated in the city, percentage of composition of plastic in the mixed waste and what is the density of plastic waste/litter in per square meter of area. **Table 5.3** given below summarizes some of the outcome 1 of the assessment.

Table 5.3: Outcome 1 summary of findings

a)	Number of Gunny Bags opened for segregation:		No.
b)	Weight of Gunny Bags opened for segregation:		Kg

c)	**Weight of Plastic segregated from Gunny Bags used for segregation:**		Kg
d)	**Percentage of aggregate plastics of the site vis. a vis. mixed waste collected (based on bags used for segregation)**		%
e)	**Weight of Total Mixed Waste / Area Cleaned**		Kg/sq.m.
f)	**Plastic Waste = Weight of Trash Collected X (d) percentage of aggregated plastic**		Kg
g)	**Plastic weight/Area for Clean Up**		Kg/sq.m.

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

Outcome 2: Count for each category is to be recorded which will give qualitative and quantitative analysis of the plastic waste generated in the area. **Table 5.4** given below will help in categorization of the segregated plastic waste and results in macro plastic assessment.

Table 5.4: Outcome 2 Summary of Findings

Brand Name (enter unknown if not clearly marked)	Item Description	Type of product* (Circle one)	Type of material+	Layers^	Recycled Locally?	Count	Total
		FPPCHPSM FGPMO	PET HDPEPVC LDPE PP PSO	ML Unsure	☐		
		FPPCHPSM FGPMO	PET HDPEPVC LDPE PP PSO	ML Unsure	☐		
		FPPCHPSM FGPMO	PET HDPEPVC LDPE PP PSO	ML Unsure	☐		
		FPPCHPSM FGPMO	PET HDPEPVC LDPE PP PSO	ML Unsure	☐		
		FPPCHPSM FGPMO	PET HDPEPVC LDPE PP PSO	ML Unsure	☐		
		FPPCHPSM FGPMO	PET HDPEPVC LDPE PP PSO	ML Unsure	☐		
		FPPCHPSM FGPMO	PET HDPEPVC LDPE PP PSO	ML Unsure	☐		

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

*Type of Product (Circle one in column above)			
FP	**Food Packaging: e.g.:** bottles, cans, cutlery, foam, tubes, wrappers, chip, bags, cup, and straws.	SM	**Smoking Materials: e.g.:** cigarette butts, lighter, cigar, tips, tobacco, and packaging.
PC	**Personal care: e.g.:** soap, shampoo, medical, diapers, makeup, dental, sanitary napkins.	FG	**Fishing Gear: e.g.:** nets, baits, lures, hooks, buoys, floats, ropes, fishing line, traps

HP	**Household products: e.g.:** cleanser, shoes, textiles, bags, toys, crates, tarps, pens.	**PM**	**Packaging Materials: e.g.:** boxes, Styrofoam (non- food), film, bubble wrap, delivery envelope tape.
O	**Other / unknown: e.g.:** pellets, metals, fragments and pieces, tyres, zip ties, papers		
+Type of Material (Circle one in column above)			
PET	**#1 plastic: e.g.:** clear or tinted drink, bottles, cups or Containers.	**LDPE**	**#4 plastic: e.g.:** trays, films, six-pack rings, snap on lids, wraps
HDPE	**#2 plastic: e.g.:** hard and opaque bottles, milk jugs, polythene bags	**PP**	**#5 plastic (polypropylene) e.g.:** food tubs, bottles, caps &hinged lids, pill bottles
PVC	**#3 plastic: e.g.:** pipes, shower, containers, and toys.	**PS**	**#6 plastic (polystyrene) e.g.:** foam or hard plastic food containers, cups, lids
O	**Other/Unknown:** e.g.: #7 plastics paper, metals or any other material not caught above, including Unknown or unidentifiable material.		
^LAYERS (Circle one in column above)			
SL	Single layer, e.g. clear flexible plastic films, wrappers, polythene bags		
ML	Multilayer, e.g.: composites, laminates, sachets, packets, Tetra Packs.		

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

Step 3: Disposal of Collected Waste

The entire collected waste (either it is plastic waste or it is non-plastic waste) is to be handed over to the waste management team of local government and ensure that the entire waste is to properly treated/disposed as per the rules/guidelines.

Step 4: Data recording

A checklist given **Table 5.5** has been prepared for the photo documentation and data collection activities. This step will ensure the data viability and the documentation and photography team will ensure the completion of this step.

Table 5.5: Checklist for the Photo Documentation

S. No	Activity	Tick on completion
1	Actual site conditions (**before scenario**)	
2	Volunteer group photo and separate team photos with **Personal Protective Equipment** (PPE)	
3	Waste collection bag photos (**labeled and numbered - before use/clean up)**	
4	Volunteer photos during **waste collection** and during **weighing of collection bags**	
5	Group photo of volunteers with bags filled with garbage collected during the clean-up drive (**before segregation**)	
6	Photos of collection bags from which mixed waste is to be further segregated	
7	Photos **during segregating** mixed waste	
8	Photos of waste heaps (**segregated as per waste category**)	
9	Photos during **documenting and entering** data in data sheet	

S. No	Activity	Tick on completion
10	Volunteer group photo after finishing segregation	
11	Photos depicting **after scenario** of the same waste pick up locations	

Source: Prepared by K.D. Bhardwaj & Dr. Shukla Pal Maitra (2020); NPC

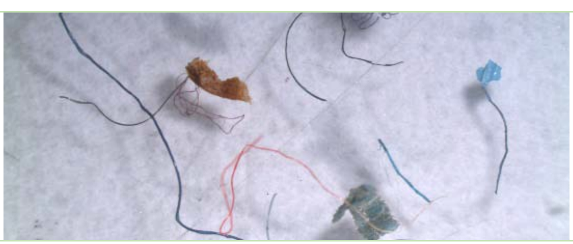
Step 5: Carrying out macroplastic survey in water body

Carry out Activities 5.5.1 to 5.5.6 by using all the formats given in Step 2.2 under step 2 for labeling, segregation, weighing and counting as given in guidance notes. After completion of activities complete step 3 and step 4 given above.

Chapter 6: Micro Plastic Waste Assessment

6.0 Introduction

Micro-plastics are tiny fragments of plastic smaller than a few millimeters, such as micro-beads used in exfoliators and injection moulding, or plastic debris resulting from the fragmentation of larger plastic objects. It has been indicated that essentially there are two categories of micro-plastics, i.e. primary micro-plastics and secondary micro-plastics. 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 fulfil a function. These also include microplastics 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, pellet losses, plastic dust from shredders or dust from handling of plastics in landfills etc.Different types of microplastics are shown in **Figure 6.1.** It has been demonstrated that microplastics interact with various organisms from different trophic levels, facilitating their entrance to (aquatic) food webs, also reaching humans, top consumers. Therefore, monitoring the aquatic and marine environment for the presence of microplastic is a necessary part of assessing the extent and possible impact of microplastic, devising possible counter measures to reduce inputs, and evaluating the effectiveness of such measures. This chapter describes the methodology for carrying out micro plastic assessment in a riverine ecosystem. The outcome of this assessment is to standardize the ongoing efforts for making the procedures and results comparable across studies and regions, for informing suitable policy making and developing and implementing interventions and countermeasures to address the growing microplastics problem. Guidance notes will assist in describing how to carry out microplastic assessment.

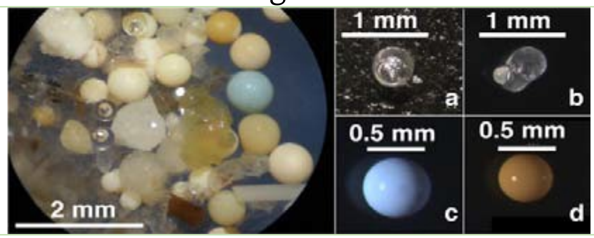

Fibres


Pellets

Films

Fragments

Foams



Microbeads

Figure 6.1 : Various Types of Microplastics by Shape

6.1 Conceptual Understanding

The conceptual understanding indicates the accomplishment of two steps approach for carrying out microplastic assessment. This methodology gives the guidance on how the micro plastic assessment is done by sampling from the river. The basic aim of micro plastic assessment is to quantify different types of microplastic 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 **(Figure 6.2)** from different carriers into the river/oceans.

Step 1: Identification of locations to carry out micro plastic assessments in river

This includes identification of locations in the river where micro plastic sampling can be done. These locations are based on various criteria including environmental conditions, wind speed, wave height etc. using the above criteria, two sites are to be identified, one in the upstream region and one in downstream region of the river with city catchment between the two locations.

Figure 6.2: Plastic Leaking into Riverine System

Step 2: Carrying out microplastic sampling from the river and its assessment

This step requires carrying out of micro plastic sampling at the identified site/locations. This step s is to be implemented considering seasonality and techniques used for sampling and various other activities that are to be performed for micro plastic assessment. This steps also deals with selection of sampling equipment which depends on the decisions about the size ranges to be targeted for sampling and analysis. It also depends on the limitations for different equipments that are to be used. Sampling for micro plastic assessment for the site identified depends on extraction of different micro plastic based on sizes and pretreatment process as per the study requirements, identification of different micro plastics with the help of various techniques such as pyrolysis, GC/MS, FTIR and many other, and finally quantification of the identified micro plastics. The flow chart given in **Figure 6.3** depicts the process of micro plastic assessment. It includes micro plastic sampling from the water, sediments and biota. Figure 6.3 shows that sampling and quantification steps are different while extraction and identification steps are the same.

Sampling: Sampling involves getting the sample from water by trawling & Pumping while samples from sediments are based on grab technique. Samples from biota include individual samples. After the samples are collected, they are pretreated either by density separation or dissection in case of biota.

Extraction: This step includes filtration and separation based on sieving and filtration across the three different types of samples.

Digestion: This step includes removal of bio/organic content either through chemical or biological digestion by using oxidizing agents like H_2O_2, KOH, HCl, NaOH, NaClO, enzyme.

Identification: This step includes identification of individual items using a series of others) Identification (pyrolysis, GC / MS, FTIR, Raman spectroscope).

Quantification: This step includes micro plastic items per unit volume or per unit area in case of sampling from water. In case of sediments it could be items per unit weight of the sample while in case of biota it is expressed as number of items or weight (gm) per individual.

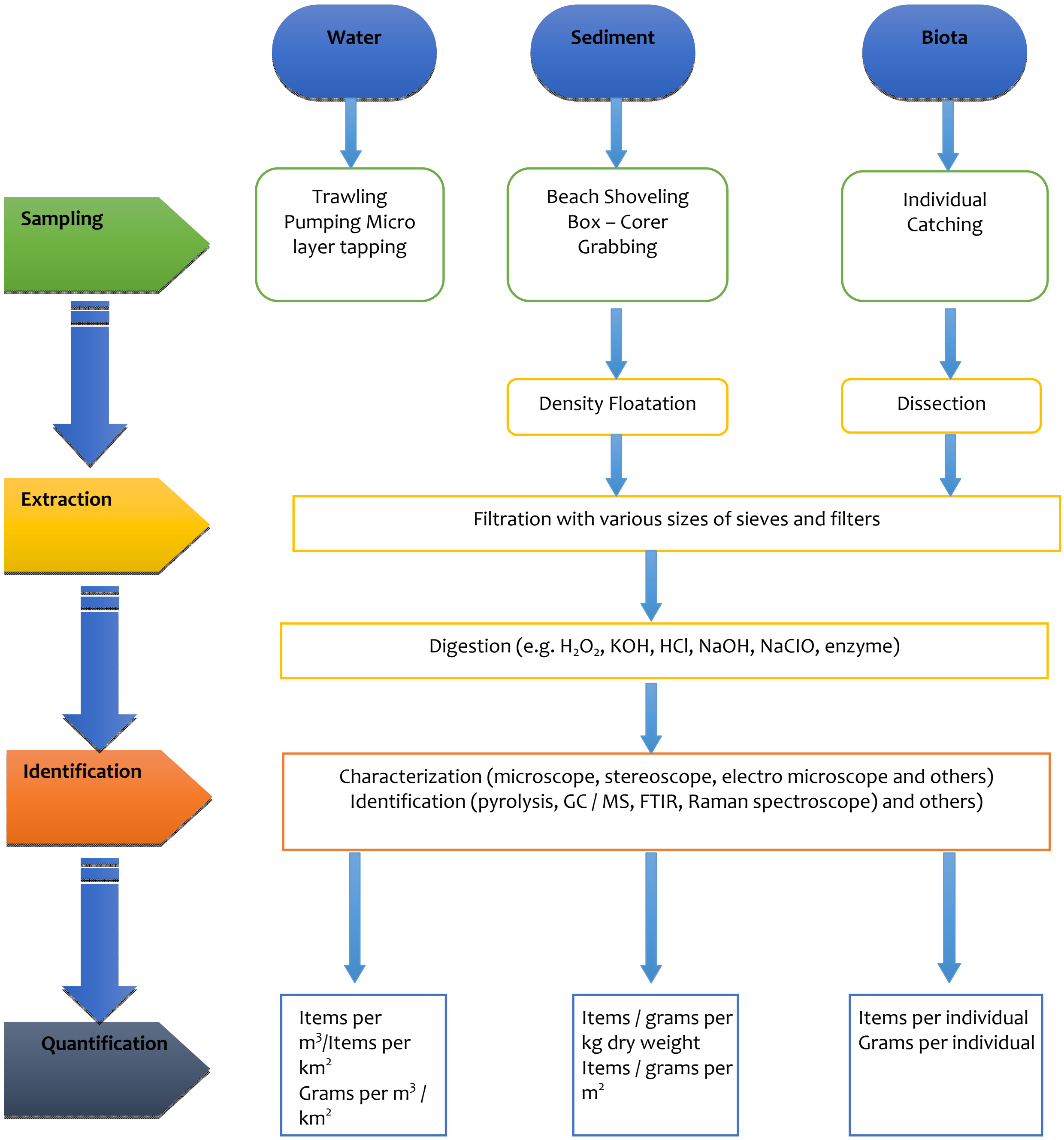


Figure 6.3: Flow Chart Depicts the Process of Micro Plastic Assessment

6.2 Methodology

The conceptual understanding gives two steps to carry out micro plastic survey. The different activities to be carried out under each steps are given below.

- **Step 1: Identification of location to carry out micro plastic assessment in river/ water body.**

Activity s1.1: Environmental Conditions - In general, wind speed and wave heights are known to influence the degree of vertical mixing of the ocean/river surface layer and affect the amount of micro-plastics collected. It has been indicated that Quantity of micro-plastics at the ocean surface greatly decreased in situations where both wind speed and wave height increased during sampling. It had been observed that density of Micro-plastics in the same sampling area changed by about one order within several hours, as sea/ river conditions, including wind speed and wave height, changed. (CMSM 2018)

Activity s1.2: For proper trawling and movement of boat, the river should have at least a depth of 1-2 meters.

Activity s1.3: For better results, the selection of site can be based on the macro plastic leakage in the riverine system, as where there is large amount of macro plastic leakage in the river from a period. This will results in increasing the density and composition of micro plastics particles in the river.

Activity s1.4: Indications for preferred Sea Condition in literature and actual river condition observed for micro plastic sampling **are given in Table 6.1.**

Table 6.1: Preferred Sea Conditions

Parameter	Standard	Reference
Sea / River Condition	Collection of Micro-plastics at the Ocean / river surface should be conducted under mild sea /river conditions. To avoid unfavorable timing and conditions for sampling, such as high concentrations of natural particles or organisms.	Guidelines for Harmonizing Ocean Surface Micro-plastic Monitoring Methods Version 1.0, May 2019 Ministry of the Environment, JAPAN May, 2019

Activity s1.5: Two sites are to be identified, one in the upstream of the river and another in the downstream part of the river.

- **Step 2: Carrying out micro plastic sampling from the river and its assessment**

The basic aim of the methodology of micro plastic assessment is to focus on sampling and assessment of floating particles/micro plastic present in the river. The important aspects covered under the methodology are:

1. **Preparation for micro plastic assessment.**
2. **Implementation of methodology.**

The details of activities required for preparation and implementation activities are summarized below.

- **Preparation for micro plastic Assessment**

Activity 6.3.1: Team formation
Three teams are to be formed for covering entire micro plastic assessment. These teams will involve experts for sampling and analysis, field surveyors, photographers, data recorder, coordinators and other support staff (if required).

Teams to be formed:

1) **Survey Team:** Survey Team will constitute of field surveyors who are relied in identifying the site/locations for sampling from the river. This team has to consider the all the conditions for identification of location as discussed in section 6.2.1.

2) **Sampling Team:** Sampling team will constitute of experts for handling of the equipment and sample collection and preservation, which will be transported to the lab, boat driver for driving boat, expert swimmer for safety purpose. This team also includes data recorders, photographers and other coordinators.

3) **Analysis Team:** Analysis team will constitute of the experts who are involved in analysis of the sample collected, key persons/experts for handling of the laboratory instruments and other support staff required in the laboratory.

Activity 6.3.2: Time and Date

Proper management of the entire sampling procedure is to be ensured as per the environmental conditions. So it is advised to schedule the sampling time and date considering the weather updates to avoid any rainfall or thunderstorm.

Activity 6.3.3: Selection of Sampling Equipment

The most common method of sampling floating micro-plastics is to use a towed net, such as a manta trawl with a fixed mesh size, usually 330 µm. This means that any particle < 330 µm in diameter will be under-sampled. One way of overcoming this problem would be to pump a water sample through a 1 µm filter, to provide a measure of all the particles in the micro-plastic size range (1 µm – 5 mm). However, this is not feasible for routine monitoring. This is an operational constraint but it should not detract from the utility of using towed nets for monitoring purposes, to detect trends in space and time (GESAMP, 2019). **Table 6.2** summarizes key methods in microplastics sampling/ observations and their advantages and limitations.

Table 6.2: Key Methods in Micro Plastics Sampling / Observations and their Advantages and Limitations

Method	Explanation	Advantage	Limitations	Sources
Net tows (Manta Trawl, Neuston Net)	Fine-mesh net attached to a large rectangular frame developed for sampling surface and water column waters for plankton, insects and other small biota. Manta trawl with floating wings to keep it on the surface.	Can be deployed from small to large vessels. Use of flow meter to estimate volume And flow over time	Use is weather dependent Care needed to minimize contamination from sampling vessel and tow ropes. Can only estimate volume of water filtered when flow meter is used and the frame completely immersed Towing speed and time must be limited to avoid clogging.	Virsek et al. (2016)
Visual observation from a ship	Visual survey of floating marine litter from the surface of a vessel at sea. Use either fixed width transects (assumes all items seen) or distance sampling (corrects for decrease in detection probability with distance from the vessel)	Easy to do from vessels of opportunity. Low cost, needs only binoculars (but ideally also a good quality digital SLR camera and telephoto lens)	Limited to water adjacent to the ship (up to 50 m typically). Bias against dark items and subsurface items white and buoyant items easier to spot.	Ryan (2013
Photographic and aerial surveys	Visual survey of floating marine litter from an airplane or drone	Cover large area, ideal for mega litter	High cost to charter, expensive photography equipment	Lebreton (2018)

Generally, to collect Micro-plastics particles floating at the river/sea surface, most researchers use nets that can efficiently filter a large mass of water (Neuston or Manta nets). *(Ref. Ministry of the Environment, JAPAN May, 2019, "Guidelines for Harmonizing Ocean Surface Microplastic Monitoring Methods - Version 1.0").* The features are reflected below and comparison of advantages and disadvantages indicated in T**able 6.3** given below.

(a) Neuston Net

Neuston nets **(Figure 6.4)** can capture the ocean surface layer even in wavy conditions, but it is difficult to estimate the volume of water filtered accurately because the net's immersion depth changes constantly. It can operate in rough waters.

Figure 6.4: Neuston Net

(b) Manta Net

Manta nets **(Figure 6.5)** can maintain a constant immersion depth under the sea surface and thus filtered water volume can be estimated fairly accurately providing there are no waves on the sea surface. If the wave height exceeds a certain level, the net tends to jump and skip on the water surface.

Figure 6.5: Manta Net

Table 6.3: Microplastic Sampling Nets and Relative Advantages / Disadvantages

Net	Advantage	Disadvantage	Reference
Manta net	Remains in surface water except in rough water.	Tends to jump and skip on rough water	*Guidelines for harmonizing ocean surface micro plastic monitoring methods version 1.0 May 2019, Ministry of Environment Japan May 2019*
Nueston net	Operates relatively in rough water	Needs some efforts to maintain the stable net immersion depth	

Mesh Openings

"Mesh openings" **(Figure 6.6)** as used in Japanese Guideline is expressed as the side length of a quadrangle separated by mesh thread and through which sea water passes (① in figure on right), but in some cases the length of the diagonal line (② in figure on right) is used as the mesh opening.

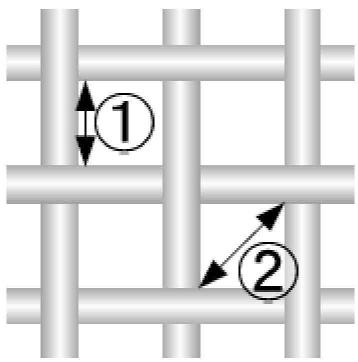


Figure 6.6: Mesh Opening

From a broader, global perspective, the use of the most common mesh opening (0.3 mm) is considered desirable.

Activity 6.3.4: Other Equipments/Tools Required during sampling.

A list is prepared for the equipments and materials that will be required during the activity and is given below in **Table 6.4.**

Table 6.4: List of Equipments/Items Required

S.No.	Equipment/items	Use
1	Safety Life Jacket (for each person riding on boat)	To ensure safety of everyone involved in sampling from the river.
2	Stationary Items such as Pens, notepad, markers etc.	These items will be used for labeling and recording of the data.
3	Vessel/ container	To store the sample collected which can be

S.No.	Equipment/items	Use
		transported to the lab properly.
4	Gloves	To ensure safety during sampling
5	A First Aid Kit	To be used for minor injuries (such as cuts).
6	A rope	To tie the equipment
7	Sanitizer and Hand wash	To ensure cleaning of hands after the cleanup activity.

Source: Prepared by KD & AJ

- **Implementation of methodology**

Implementation of methodology includes activities like sampling for microplastic from river, laboratory analysis which results in extraction of microplastic from the sample, identification of microplastics and quantification of the particles/microplastics found.

Activity 6.4.1: Sampling for microplastic assessment from river

The analysis of microplastics in the environment starts with sample collection. Selection of an appropriate technique 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.

Three main methods of sampling:

1. **Selective sampling**

   Items visible to the naked eye are directly extracted from the environment, such as on the surface of the water or sediment. 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 microplastic pellets and similarly shaped secondary microplastics. However, the main disadvantage of this technique is that the less obvious, more heterogeneous items are often overlooked, particularly when they are mixed with other contaminants

2. **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. Consequently, 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).

3. **Bulk sampling**

The entire sample is taken without reducing its volume. 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.

However, for floating plastic most common method of sampling is to use a towed net, such as a manta trawl with a fixed mesh size, usually 330 µm. This means that any particle < 330 µm in diameter will be under-sampled.

Figure 6.7: Schematic and plate of Microplastics sampling device by Pirika

Source: UNEP ROAP

This device consists of a battery and a screw, a filtered water counter and a plankton net. It sucks in water with driving screw, and collects solid that contains plastics. To estimate volume of sampled water, recording of values of the filtered water counter are made before submerging and after being pulled up.

There are some protocols that are to be followed for sampling. The chart below depicts the protocols for microplastic sampling.

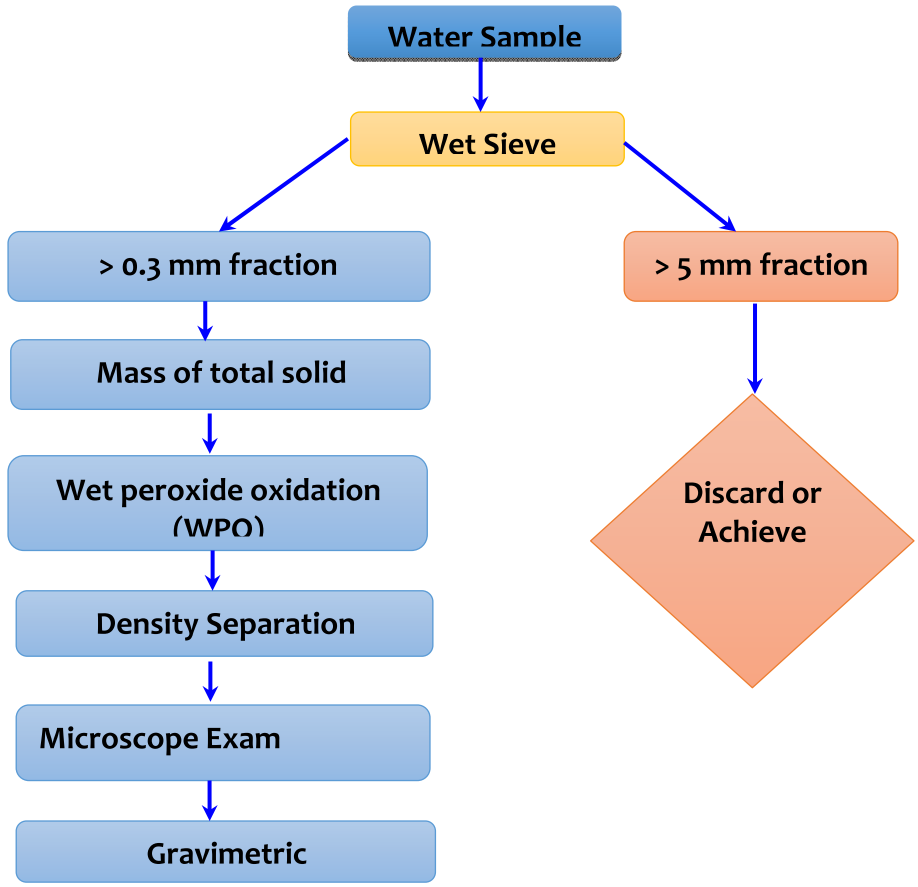


Figure 6.8: Protocol / Flow Diagram for the Analysis of Micro-plastics in Water Samples

Source: Prepared by K.D. Bhardwaj (NPC)& Amit Jain (IRGSSA)

Along with the above protocols, there are some tow parameters that are to be considered for as part of sampling procedure.

(a) Tow Duration

Tow duration has most commonly been set at about 10 to 30 minutes in past surveys.

(b) Vessel Speed

Vessel speeds at the time of towing were reported as approximately 1 to 3 knots in earlier surveys.

(c) Sweep area and filtered water volume

Micro-plastics observed at the ocean surface are often reported as quantity of particles or weight per unit area (/m2, /km2) and/or as quantity of particles per unit water volume (/m3). Therefore, it is necessary to obtain the swept area of the net tow and/or the amount of filtered water volume, as calculated by the following equations:

$$\text{Swept area} = \text{net width} \times \text{tow distance}$$

Filtered water volume = (net width × net immersion depth) × tow distance

* Net width is the horizontal dimension of the net aperture

(d) Tow Distance

There are three methods for obtaining tow distances, as follows:

- Calculate from ground speed obtained from position information measured by GPS, etc.
- Calculate from the relative speed of the vessel to seawater (log speed), measured with a current meter.
- Calculate using the rotation count of a flow meter installed in the net mouth and its calibration value.

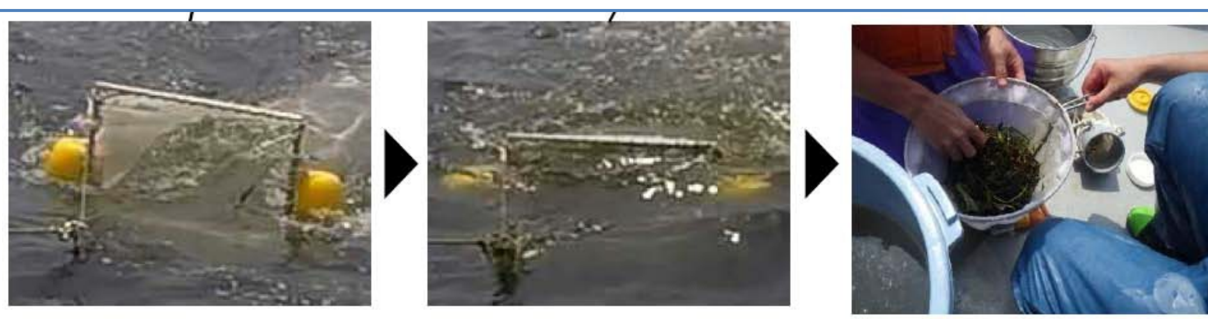
In the case of utilization of flow meter set at the net mouth for various purposes, it needs to be suitably calibrated. A calibrated and suitably functioning flow meter can facilitate accurate assessment of concentration of micro-plastics per swept area and also concentration of micro-plastics per filtered water volume. While calibration of the flow meter is important, Location / vessel position at the start and end of each tow should be accurately recorded for the distance assessments.

(e) Tow Position

In general, a sampling net is towed at one side of the vessel. However, in some cases it may be towed at stern by angling a rope to divert the net from the center line of the vessel and avoid its wake. It is desirable to conduct sampling at the side of the vessel with less influence from its turbulence.

(f) Net Immersion depth

Recording immersion depth of the net during sampling is important as the section area of the net mouth under the sea surface is multiplied by the tow distance to estimate the filtered water volume. Net immersion depths have been recorded between 10 cm and 100 cm. Manta net immersion depth is measured as the height of the net's mouth, whereas a Neuston net is often set at about 1/2 to 3/4 of the height of the net's mouth.



Net depth as normal immediately after tow starts (net immersion depth normal)	Net immersion depth 13 min. after tow starts (net immersion depth increased).	Sample inside net with increased immersion depth (a large amount of sea buckthorn (Zostera marina) has been caught).

Source: Guidelines for harmonizing ocean surface micro plastic monitoring methods version 1.0 May 2019, Ministry of Environment Japan May 2019

Activity 6.4.2: Extraction of micro plastic from the sample

In general, analysis of samples that include micro-plastics obtained by trawling a net through the ocean/river surface layer is carried out in the following order.

- Pretreatment (separation of non-plastic material other than micro-plastics), picking out micro-plastics, counting and measurement, and material identification.

Pretreatment process are selected based on purpose of the study

(A) Density Separation

Density separation may be performed to remove non-plastic material in the sample. Density separation is an effective method of fractionating low-density plastic particles and high-density natural particles of inorganic matter. In general, density separation is conducted by mixing the sample into a solution with a higher specific gravity than that estimated for the collected plastic particles, letting high-density inorganic substances settle out and recovering and fractionating the floating low-density plastic particles.

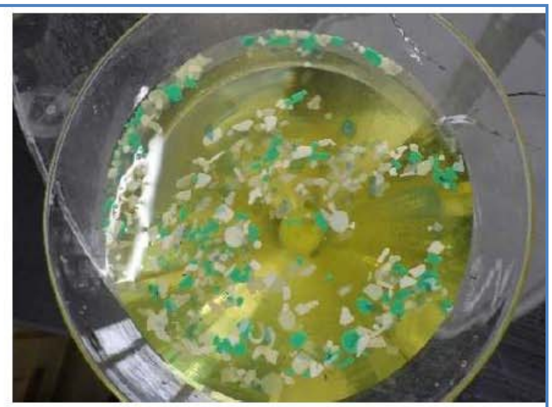
	
Density Separators	**Floating plastic particles in a density separator. Plastics with lower specific gravity than the solvent float on the surface**

Figure 6.9: Density Separation equipment / process

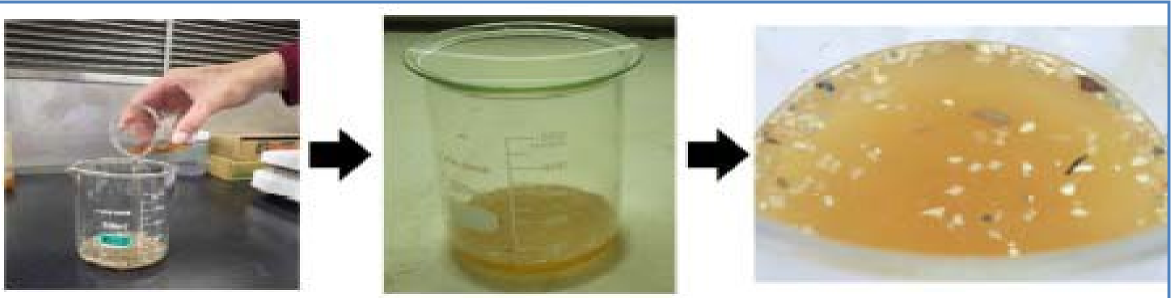
Source: Prepared by Dr. Shukla Pal Maitra (2020); NPC

Table 6.5: Solutions commonly used for the density separation of micro- plastics (reproduced from GESAMP, 2019)

Salt	Density (g / cm^3)	Reference
Sodium Chloride (NaCl)	1.2	Hidalgo-Ruz et al. 2012
Sodium Polytungstate (PST)	1.4	Hidalgo-Ruz et al. 2012
Sodium Iodide (NaI)	1.6	Claessens et al. 2013
Zinc Chloride ($ZnCl_2$)	1.7	Imhof et al. 2012
	1.6.	Zobkov & Esiukova, 2017

(B) Biological Digestion

When there are many non-plastic materials such as plankton (in the sample), pretreatment to digest organic substances with chemicals or enzymes is performed in many cases to remove the non-plastic material as well as biofilms that have formed on the surface of the sampled plastic particles. The intent is to minimize the possibility of misidentifying plastic particles, improving the accuracy of the picking out process and overall work efficiency. If improperly conducted, however, it may lead to deterioration (deformation and/or weight reduction) of plastic particles from chemicals added or from heating.



Add solution (H_2O_2 or formalin)	React in Covered Beaker	Reaction in Beaker

Figure 6.10: Photographs Depicting Digestion of Organic Matter through Biological Digestion

Source: Prepared by Dr. Shukla Pal Maitra (2020); NPC

<u>Different Methods for Biological Digestion</u>

The methods being utilized for biological digestion and their advantages / disadvantages are reflected in **Table 6.6.**

Table 6.6: Purification / Digestion Methods and their Advantages / Disadvantages

Purification method	Advantages	Disadvantages	Reference
Oxidative digestion	Inexpensive Temperature needs to be controlled	Several applications may be needed	Masura et al. (2015)
Acid digestion	Rapid (24 h)	Can attack some polymers	Claessens et al.

Purification method	Advantages	Disadvantages	Reference
			(2013)
Alkaline digestion	Effective Minimal damage to most polymers	Damages cellulose acetate	Dehaut et al. (2016)
Enzymatic digestion	Effective Minimal damage to most polymers	Time-consuming (several days)	Löder et al. (2017

(C) Sample Splitting

Sample splitting before counting is often performed in analyses for zooplankton, especially where the quantities sampled are large, but it is not common in the analyses of Micro-plastics.

(D) Picking out Micro-plastics

Picking out particles is an important process that greatly affects the accuracy of micro-plastics analysis. There are several methods of separating plastic particles from a sample, such as picking plastic particles out after fractionating the sample by size using sieves of various sieve mesh opening sizes such as 5 mm, 1 mm, and 0.3 mm, and picking the plastic particles from the filter paper after directly filtering the sample. Stereomicroscopes are commonly used to facilitate picking out micro-plastics.

The accuracy of picking out particles greatly affects micro-plastic analysis results, as plastic particles picked out from the sample, whether pretreated or not, are used for subsequent measurement and analysis.

Figure 6.11: Separating Microplastics by Picking and Using the Stereomicroscope (CMSM, 2018) Density

(E) Counting and measuring sizes of Micro-plastics

There are two common methods for counting the quantity of particles by size-

- Directly measuring the longest diameter (maximum Feret's diameter) of separated particles individually, and
- Counting the quantity of particles remaining in the sample after fractionating by size using sieves of various mesh opening sizes.

	
Measurement of Micro-plastics	**Multi-stage sieve with various mesh openings**

Figure 6.12: Counting and Measuring sizes of Microplastics

Feret's Diameter

The microplastic particles size is measured as Feret's diameter* that is generally defined as the distance between the two parallel planes restricting the object perpendicular to that direction. It is essentially the longest diameter !!

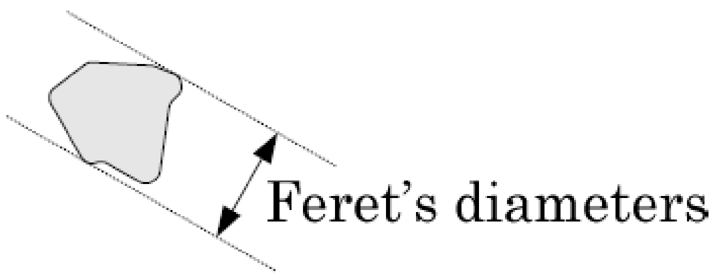


Figure 6.13: Depiction of Feret's Diameter

Among those measured Feret's diameter values, such that the area of the rectangle enclosing the particle outline becomes a minimum is called Minimum Feret's diameter" and the dimension perpendicular to it is called Maximum Feret's diameter" (Pabst et al., 2017).

Activity 6.4.3: Identification of microplastics

Micro-plastics are first identified visually, before an identification of the polymer type is undertaken. Larger particles can be identified with the naked eye, whereas small micro-plastics are identified by spectroscopic identification methods.

(A) Fourier transform infrared spectroscopy (FTIR)

FTIR spectrometer coupled with an Attenuated Total Reflection (ATR) accessory. The ATR allows the IR spectrum of a material to be obtained simply by pressing the sample against a transparent crystal, commonly diamond. The infrared light passes through the crystal into the sample where energy is absorbed by the sample, and the light is reflected back into the crystal to generate a spectrum.

Figure 6.14: Nicolet iS5 FTIR Spectrometer with the ID7 ATR Accessory in the Sample Compartment

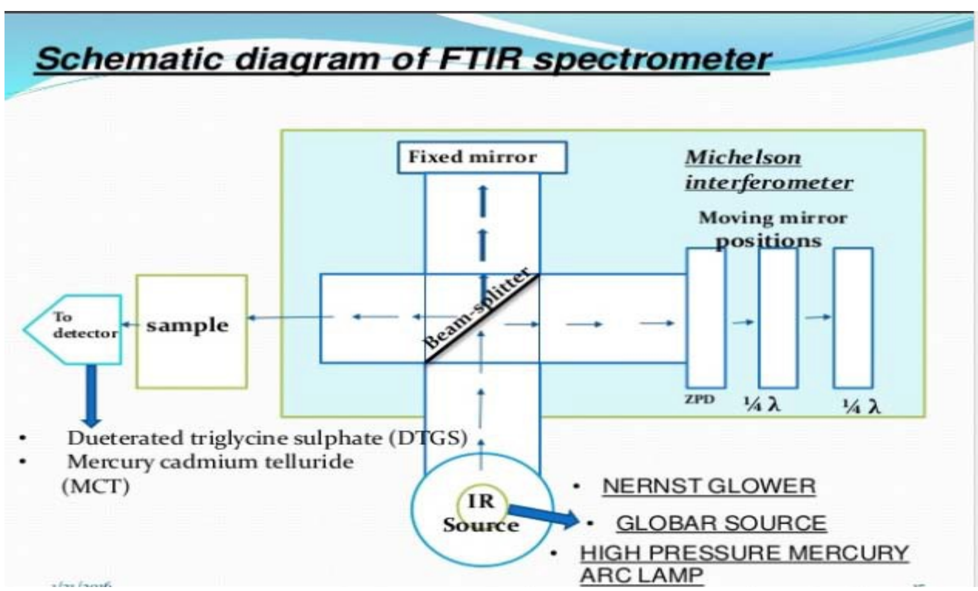


Figure 6.15: Schematic Diagram of FTIR Spectrometer

(B) Raman Spectroscopy

Raman spectroscopy uses sub-micron wavelength lasers as its light source and, as such, is capable of resolving particles down to 1 micron and less. Raman microscopes are built around research-grade, white-light microscopes, which facilitate easy viewing of the particles. The Raman system laser is focused on the sample, and the spectrum is simply acquired by collecting the scattered light.

Figure 6.16: DXR2 Raman Microscope for Analysis of Micro-plastics

(C) Thermo-analytical methods

Thermo-analytical methods are also routinely used in synthetic polymer analytics. Based on known thermo-analytical methods (thermogravimetry, differential scanning calorimetry etc.

Table 6.7: Micro-plastic Characterization Methods, including Identification of Polymer Types (reproduced from Shim et al. (2017))

Identification method	Advantages	Disadvantages
Microscopy	Simple	No chemical information for confirming composition
	Low cost	High possibility of false positives
	Color and morphological information	High possibility of missing small and transparent particles
Microscopy + spectroscopy (sub-set)	Polymer composition of a subset of the sample	Possibility of false positives
		Possibility of missing small and transparent particles
		Sub-set may not be representative
		Potential bias in sub-set selection
Microscopy + FTIR spectroscopy	No false positives – confirmation of all plastic-like particles	Manual selection of particles means some plastic may be missed
	Reduction in false negatives	Expensive instrument
	Non-destructive	Laborious and time-consuming for identification of all particles
	20 µm particle detection limit	Requires expertise in spectral interpretation
		Contact analysis (ATR)
		Need to transfer particles from filter paper to metal plate
		Removal of organic material a prerequisite
Microscopy + Raman spectroscopy	No false positives – confirmation of allplastic-like particles	Manual selection of particles means someplastic may be missed
	Reduction in false negatives	Expensive instrument
	1 µm particle detection limit	Laborious and time-consuming for identification of all particles
	Non-destructive analysis	Requires expertise in spectral interpretation
	Non-contact analysis	Interference by pigments

Identification method	Advantages	Disadvantages
		Risk of laser damage to particles
		Removal of organic material a prerequisite
		Exact focusing required
Semi-automated spectroscopy (mapping based)	No manual particle selection error	No visual image data on single particles
	High automation potential	Production of a large volume of data
	In principle no false negatives	Long post-processing time
		Still requires expertise in spectral interpretation
		Efficient removal of interfering particles a pre-requisite
		Still lacks validation for smaller particles
		Expensive instrument
Semi-automated spectroscopy (image Analysis directed point analysis)	High automation potential	Production of a large volume of data
	Fewer false negatives	Long post-processing time
	Potential for faster sample throughput	Still requires expertise in spectral interpretation
	Size and morphology of single particles	Efficient removal of interfering particles a pre-requisite
		Still lacks validation for smaller particles
		Expensive instrument
Thermal analysis	Simultaneous analysis for polymer type and additive chemicals (Pyro-GC/MS)	Destructive analysis
	Mass-based information	No quantity or size-based information
		Limited polymer type identification (DSC)
		Complex data (Pyro-GC/MS)

Source: Prepared by K.D. Bhardwarj (NPC) & Amit Jain (IRGSSA)

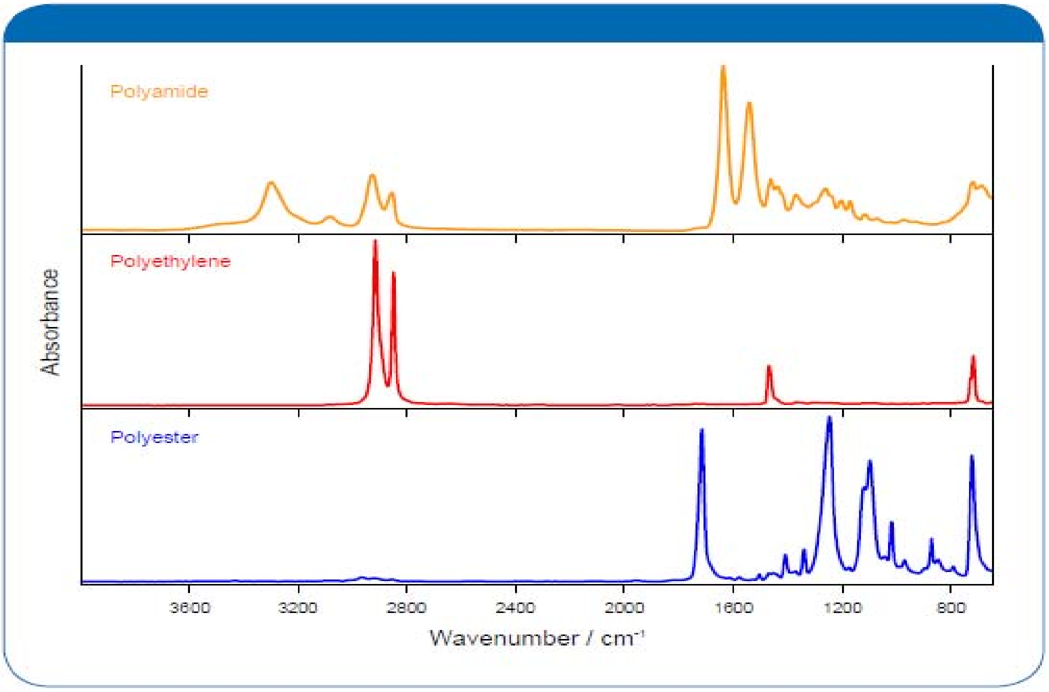


Figure 6.17: IR Spectra of Different Polymer Types (Bruker Optics Inc (2016), "Application Note AN M144 Analysis of Microplastics using FTIR and Raman-Microscopy)

Activity 6.4.4: Quantification of Microplastics

This step helps to give the analysis of the sample about the presence of microplastic along with classification of polymers, their count, size and the amount of MPs present in per liter of water. Also, Weight measurement is carried out because it is important to understand the mass balance and also due to the difficulty of estimating the actual abundance of micro- plastics from the quantity of the particles only, because even if the same amount of micro-plastics exists at the ocean surface by weight, the quantity of particles may differ depending on fragmentation processes.

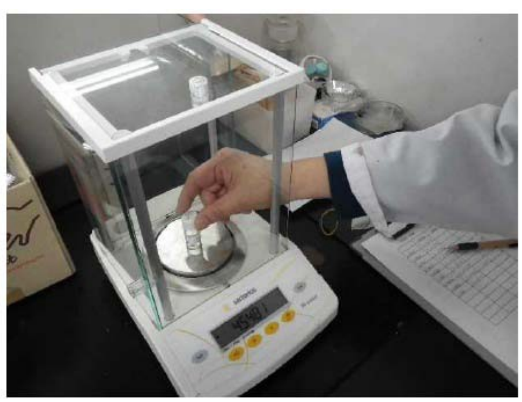


Figure 6.18: Weight measurement

- **Summary of the entire procedure/methodology of the microplastic assessment.**

Table 6.8 to **Table 6.11** gives the step wise approach for microplastic sampling and assessment (*Guidelines for harmonizing ocean surface micro plastic monitoring methods version 1.0 May 2019, Ministry of Environment Japan May 2019*).

Table 6.8: List of Data to be Reported when Sampling Floating Microplastics

Items	Data necessary to ensure comparability
Sampling date and location	Sampling date, time and location
	GPS coordinates at the start and end of trawl
	Season
	Tow time (daylight hours or night)
Sampling equipment	Net type (Manta or Neuston net), model number, manufacturer
	Shape and size of net aperture
	Length of net
	Mesh openings of net used for the survey *It would be preferable to confirm whether the mesh opening size of the net used in the survey indicates side length or diagonal length.
Tow parameter	Tow duration (minutes)
	Vessel speed (speed relative to water, knots)
	Trawl sweep area, filtered water volume and calculation formulas *Reporting the equations and numerical values used in calculating the swept area and filtered water volume is recommended.
	Tow distance (m) and calculation method (using flow meter or speed relative to water).
	Tow position (starboard, port, stern) *If towing is conducted at the stern, it is preferable to record measures for avoiding the influence of the vessels wake.
	Distance from vessel (m)
	Net immersion depth (cm, m) *Recording the following items is recommended when using a Neuston net: Percentage of net immersion depth relative to the size of the net frame and scale position on the net frame (cm), whether a video was shot or an investigator monitored, whether there was any change in the net immersion depth.
	Tow direction
	Whether or not blank tests were conducted and results

Table 6.9: List of Data to be Reported when Sampling Floating Microplastics

Items	Data necessary to ensure comparability
Metadata (Weather, sea conditions, water quality)	Wind direction and speed
	Significant wave height (measure using an onboard wave meter.) *When a wave-height meter is not available on the sampling vessel, wave height data from nearby tide stations or websites can be recorded instead.
	Beaufort scale (visual observation)
	Sea surface temperature and salinity
	Current direction and speed
	State of floating debris on the sea surface (large floating debris, drifting algae, etc.)
	Vessels movements （heave, pitch, roll)

Items	Data necessary to ensure comparability
	Other of types of water quality data (chlorophyll, fluorescence, etc.)
	*If there are other collected data, record them

Table 6.10: List of Data to be Reported for Laboratory Analysis of Microplastics

Items	Data necessary to ensure comparability
Density separation	Whether or not density separation conducted
	Type and concentration of solution used for density separation NaCl (%, g/kg), $ZnCl_2$ (%, g/kg), etc.)
	Density separation processing time (minutes or hours)
Biological digestion and chemical treatment	Whether or not biological digestion or chemical treatment conducted
	Methods used for digesting organic matter (acid treatment, alkali treatment, enzyme treatment, oxidation treatment, etc.)
	Temperature (°C) during processing and reaction time (hours)
Sample splitting	Whether or not sample splitting conducted *In the case of splitting the sample, it would be desirable to confirm and report the error caused by use of the splitter.
Picking out Microplastic particles	Pretreatment before picking out particles (fractionation by size including non-plastic material by sieve, etc.)
	Method of picking (whether or not a stereomicroscope was used)
Counting and Measuring sizes of particles	Method of size fractionation (whether maximum diameter was measured or sieves were used)
	Diameters of the measured particles (maximum and minimum Feret's diameter, area)
Identification of microplastics	Whether or not composition analysis was conducted
	Method of composition analysis (FTIR, Raman spectroscopy, etc.) *When checking the material using methods other than spectroscopy (pricking with a heated needle, grinding with a forceps, etc.), describe them.
Weight measurement	Temperature and processing time of sample drying
	Method of weight measurement (weighing the particles directly on a scale, weighing the mass of the vial and microplastics together and subtracting the mass of the tared vial to provide the mass of the microplastics)

Table 6.11: List of Data to be Reported for Results of Microplastic Survey

Items		Data necessary to ensure comparability
Weight and quantity of plastic particles	Plastic particles having a maximum Feret's diameter of less than 5 mm but 1 mm or more.	Weight and quantity of particles per unit area and unit water volume
		Weight and quantity of particles by size
	Plastic particles having a maximum Feret's diameter of less than 1 mm.	Weight and quantity of particles by size
		Weight and quantity of particles per unit area and unit water volume
Properties of the plastic particles		Shape (fragments, beads, etc.)
		Material (PP,PE, etc)
		Colors of microplastic particles

- **Laboratory analytical process quality control**

In laboratory analysis, countermeasures, for preventing predictable airborne contamination such as with fibrous matter and contamination from washing water in the fractionation and filtration processes, are important consideration to be avoided, and accordingly practice is made such as conducting blank tests in the laboratory or using filtered water to wash the equipment (EC, 2013, Masura et al, 2015).

Prevention measure to controlling contamination in micro-plastics (modified from Lusher et al. (2018)).

- All sample containers should be prewashed with filtered distilled water before use. Samples should be kept covered as much as possible using Aluminium foil or glass lids.
- All equipment used in the processing and analysis stages should be rinsed and checked under a microscope for any micro-plastic particles adhering to them. The vacuum filtering apparatus should be rinsed with filtered water between each sample. All reagents should be vacuum filtered through Whatman GF/D filter papers immediately prior to use.
- Sample processing should be performed in a sterile cabinet.
- Several procedural blanks should be performed as negative control samples through the sample processing and analytical stages in order to test for laboratory contamination.

Table 6.12: Examples of Contamination Risks and Preventive Measures

Contamination risks	Preventive measures
Contamination with plastic particles adhering to analytical instruments/ apparatuses	Pour purified water into the apparatus used for analysis beforehand and conduct the same analytical process as for sample treatment to confirm the presence or absence of micro-plastic particles
Contamination with fibrous micro-plastics during operations	Wear clothing that is not plastic-derived and remove any loose fibers from clothing with a lint roller before sampling and analysis. For example, wear clothing of a unique and visible color so that the fiber can be distinguished even if it contaminates the sample.
Contamination with plastics from air	Use of clean benches and clean rooms. Implementation of blank tests in the laboratory

6.6 Guidance Notes

Objective: The major objective of guidance notes is to carry out the micro plastic assessment to generate required data consisting of composition and characterization of micro plastics to guide policymakers, decision makers to identify and adopt counter measures to address plastic leakage into riverine ecosystem.

Guidance Procedure: Guidance procedure includes completion of following ….. steps as given below.

Step 1: Identification of locations to carry out micro plastic assessments in riverine or marine ecosystem. Carry out activities s1.1 to s1.5 to identify locations for micro plastic assessment in a river or sea. The activity wise procedure as per **Table 6.1** and described in **Figure 6.3.**

Step 2: Prepare for micro plastic assessment by carrying out **activities 6.3.1 to 6.3.4** for preparation for micro plastic assessment which includes team formation, selection of location, timing of sampling and tools required for assessment in line with **Table 6.2, Table 6.3 and Table 6.4.**

Step 3: Carry out sampling at selected locations by carrying out **activities 6.4.1 to 6.4.2.** Some of the major items covered under these activities are given below.

<u>Three main methods of sampling:</u>

- Selective sampling
- Volume reduced sampling
- Bulk sampling

<u>Criteria:</u>

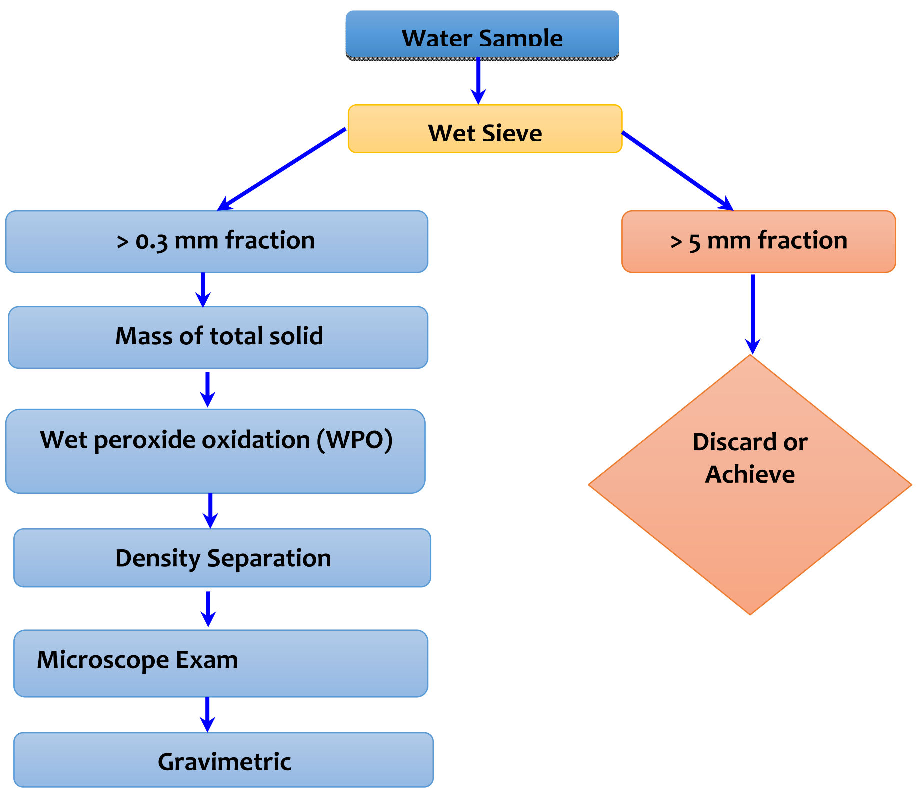


Figure 6.19: Protocol / Flow Diagram for the analysis of Micro-plastics in water samples

- Tow duration has most commonly been set at about 10 to 30 minutes in past surveys.
- Vessel speeds at the time of towing were reported as approximately 1 to 3 knots in earlier surveys.
- Sweep area and filtered water volume
- Tow Distance Calculated from (i)Calculate from ground speed obtained from position information measured by GPS, etc.; (ii) Calculate from the relative speed of the vessel to seawater (log speed), measured with a current meter and (iii) Calculate using the rotation count of a flow meter installed in the net mouth and its calibration value.
- Tow Position
- Net Immersion depth: Recording immersion depth of the net during sampling is important as the section area of the net mouth under the sea surface is multiplied by the tow distance to estimate the filtered water volume. Net immersion depths have been recorded between 10 cm and 100 cm. Manta net immersion depth is measured as the height of the net's mouth, whereas a Neuston net is often set at about 1/2 to 3/4 of the height of the net's mouth.

		
Net depth as normal immediately after tow starts (net immersion depth normal)	Net immersion depth 13 min. after tow starts (net immersion depth increased).	Sample inside net with increased immersion depth (a large amount of sea buckthorn (Zostera marina) has been caught).

Source: Guidelines for harmonizing ocean surface micro plastic monitoring methods version 1.0 May 2019, Ministry of Environment Japan May 2019

Step 3: Pretreatment of micro plastics using density separation, digestion

Pretreatment (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 using the following guidance on solution use.

Salt	Density (g / cm3)	Reference
Sodium Chloride (NaCl)	1.2	Hidalgo-Ruz et al. 2012
Sodium Polytungstate (PST)	1.4	Hidalgo-Ruz et al. 2012
Sodium Iodide (NaI)	1.6	Claessens et al. 2013
Zinc Chloride ($ZnCl_2$)	1.7	Imhof et al. 2012
	1.6.	Zobkov & Esiukova, 2017

Biological Digestion using the following methods to remove many non-plastic materials such as plankton (in the sample), pretreatment to digest organic substances with chemicals or enzymes is performed in many cases to remove the non-plastic material as well as biofilms that have formed on the surface of the sampled plastic particles.

Purification method	Advantages	Disadvantages	Reference
Oxidative digestion	Inexpensive Temperature needs to be controlled	Several applications may be needed	Masura et al. (2015)
Acid digestion	Rapid (24 h)	Can attack some polymers	Claessens et al. (2013)
Alkaline digestion	Effective Minimal damage to most polymers	Damages cellulose acetate	Dehaut et al. (2016)
Enzymatic digestion	Effective Minimal damage to most polymers	Time-consuming (several days)	Löder et al. (2017

Sample Splitting Sample splitting before counting is often performed in analyses for zooplankton, especially where the quantities sampled are large, but it is not common in the analyses of Micro-plastics.

Picking out micro plastics particles using one of several methods of separating plastic particles from a sample, such as picking plastic particles out after fractionating the sample by size using sieves of various sieve mesh opening sizes such as 5 mm, 1 mm, and 0.3 mm, and picking the plastic particles from the filter paper after directly filtering the sample. Stereomicroscopes are commonly used to facilitate picking out micro- plastics.
Counting and measuring sizes of Micro-plastics by common methods for counting the quantity of particles by size-

- Directly measuring the longest diameter (maximum Feret's diameter) of separated particles individually, and
- Counting the quantity of particles remaining in the sample after fractionating by size using sieves of various mesh opening sizes.
- The microplastic particles size is measured as Feret's diameter* that is generally defined as the distance between the two parallel planes restricting the object perpendicular to that direction. It is essentially the longest diameter !!

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 Microplastics 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 in accordance with **Table 6.8** to **Table 6.11.**

Chapter 7: Case Study Agra

7.0 Introduction

Practitioners designing a plastic waste assessment and leakage scenario project need knowledge about application of assessment methodology in a real developing country context. The summary of guidance notes have been described in from Chapter 2 to Chapter 6. This chapter describes case studies from India where application of plastic pollution and leakage assessment methodology has been demonstrated. It is recommended that the case study should be studied be referred in the context of guidance notes.

7.1 Case Study Agra

Agra is geographically located at 27°12' North latitude and 78°12' East longitude. The city is situated on the Western Bank of river Yamuna at about 200 Kms from Delhi in the state of Uttar Pradesh. It is a Class I town, municipality and administrative headquarters of Agra District and falls under Agra division of Uttar Pradesh. The climate of Agra is extreme and tropical in nature. The temperature drops to 3°C in winter and rises to 47°C in summer. The city experiences three seasons, the summer, rainy and winter seasons. The summer season starts from April and ends in June, the rainy season starts from June and ends in September with an annual rainfall of 686 mm while winter starts in November and lasts till February. Agra has an extremely strategic location on the confluence of three distinct geo-physical regions namely the plain of Uttar Pradesh, the plateau of Madhya Pradesh and the desert of Rajasthan. It falls in Great Indo-Gangetic Plain region and its strata consist of mainly sandy soil. The ground water level varies generally 6 to 8m below ground level. The altitude varies from RL 150 m to 170m above mean sea level. The city stretches for about 9.0 kms along the Yamuna River. The contour and the major drainage pattern along with the river flow indicate west to east direction (Figure 7.1). This indicates that any waste leakage from the catchment area will follow the slope and flow pattern of the river.

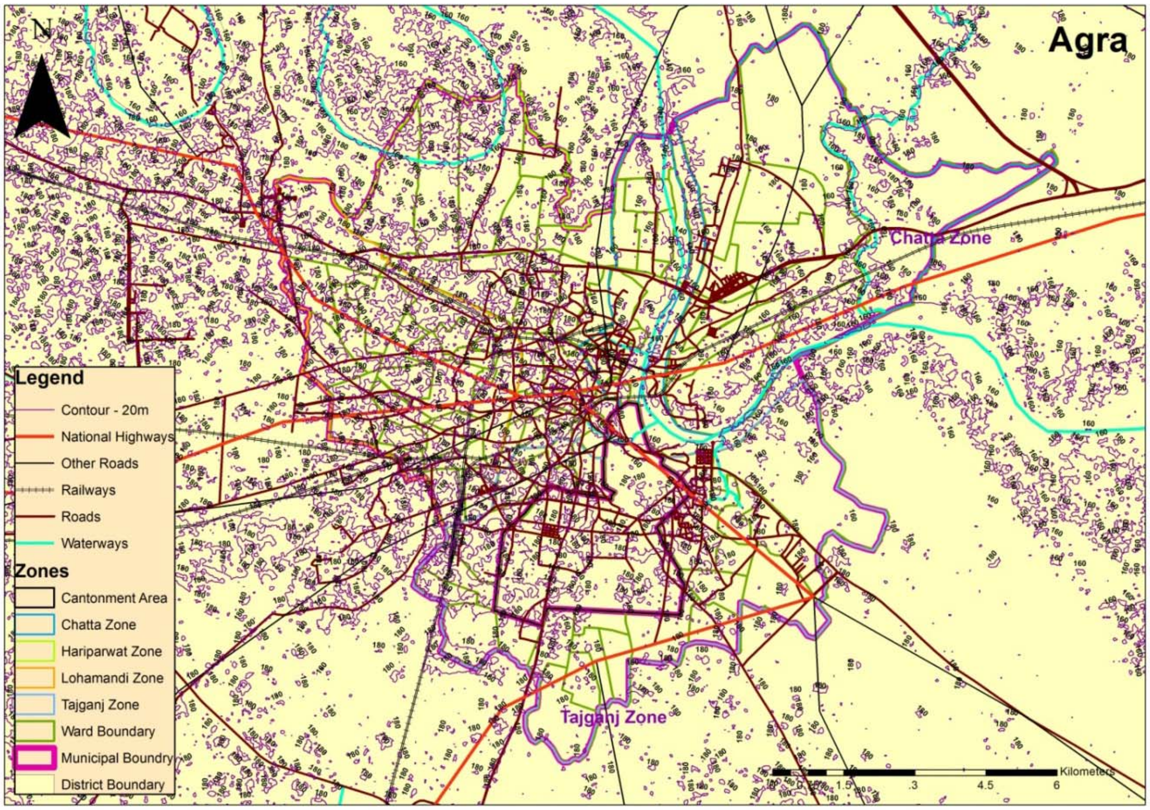


Figure 7.1: Drainage and Contour Pattern of the Agra City

Source: Prepared by Sanjeev Satyanarayan (2020); IRGSSA

7.2 Context (Demography, Land Use & Waste Management)

Agra has a population of 1.77 million with about 264,053 households located in 100 wards in 4 zones. Agra receives about 391037 floating population annually. The city has 417 slums constituting about 56% of the city population. The major part of the city is on the Western side of Yamuna and has grown beyond the river on the eastern side and is called the Trans Yamuna area while the original part is called as CIS Yamuna. Demographic trends indicate that western side of the river is densely populated while eastern side is an upcoming area. Figure 7.2 shows the land use plan for an area of 20036.97 Ha as per the approved master plan period of 2001-2021. Demographic pattern tally with land use pattern of the city with majority population residing in the western area. Land use pattern also 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.

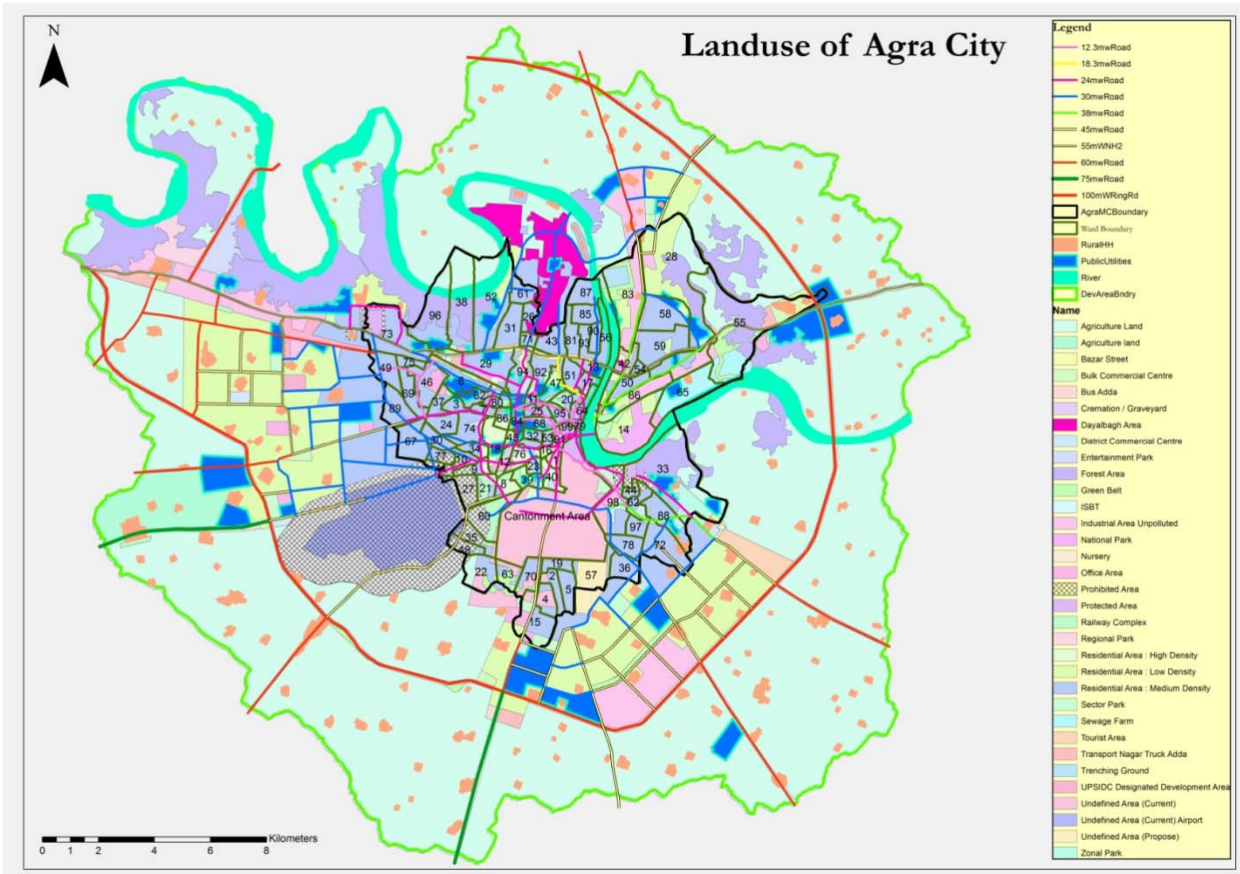


Figure 7.2: Demographic, Administrative and Land Use Map of Agra

Source: Prepared by Amit Jain, Sanjeev Satyanarayan, Apoorva Agrawal & NPC team (2020)

The primary data from Agra Nagar Nigam indicates that the total municipal solid waste generation in the city is about 850-870 metric tons per day. This is based on per capita generation of 400 gm. This waste is transferred to material recycling facility and finally dumped into landfill site at Kuberpur. 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. An understanding of the root cause analysis led to identification of hotspots and determination of their loss/ leakage rate in Agra city.

7.3 Identification of Hotspots and Plastic Leakage Pathway

A combination of hybrid MFA-LCA was applied within Agra's municipal limits to assist in identification and classification of hotspots. The study boundary includes different stages where input-output analysis has been carried out within the city boundary. Further, IUCN's approach for defining the plastic leakage as a function of loss rate and leakage rate has been used to determine the leakage pathway.

Methodology

A step wise approach given below has been adopted to identify the hotspots, which serve as source of plastic leakage into the river. These include:

Step 1: The first step included field reconnaissance survey using GPS within the municipal limits of Agra. Figure 1 and Figure 2 assisted the field team to determine city/ watershed and identify the physical features/ benchmarks in the city's context. A photographic technique using 360 degrees camera, still photography was used for reconnaissance survey.

Step 2: A perception survey was conducted using qualitative (Focused group discussion & Interview with stakeholders) and quantitative survey (Household / plastic waste generator survey, Collector end survey). Based on socio economic category, various areas were selected

Step 3: GIS Technique and Fuzzy Approach was used to develop layers of physical features (slope, contour, rivers, drainage etc.) as well as human interventions (land use, demography, socio-economic layers, points of interests, commercial, agriculture, industrial areas etc.) using Geographical Information Systems (GIS).

Step 4: Macroplastic Clean up Technique gave information about major polymers, plastic products as well as unmanaged waste (Qualitative and quantitative), which is getting leaked into the environment from the techno sphere.

Step 5: Microplastic Survey & Assessment technique gaves 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.

Step 6: Waste Management Data Templates gave information related to waste generation, collection, transportation, treatment and disposal. This will also give information related to money flow related to waste management.

Step 7: 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. Environmentally extended input output information can be used to identify hotspots and causal links through a supply chain.

Major Findings

The findings of the reconnaissance survey and consultations with the stakeholders indicate that though collection efficiency is good, the city experiences littering during collection and transportation.

Industrial waste consists of thin white plastic covers for covering Petha boxes that are littered in significant amount after single use and thrown in drain (nallah) and nearby secondary collection points. The synthetic leather and rubber trimming from footwear industry also accounted for the plastic pollution. It was also observed that accumulated waste at open dump or dustbins was burnt in order to reduce the volume when it remains unattended for several days. The findings give insights into plastic value chain hotspot.

Inferences drawn from the perception survey indicate that plastic water bottle, milk pouches and multi-layered plastic Packs make up more than 60 percent of the plastic item used and disposed. Next comes plastic pump bottles for cosmetic liquids with more than 50 percent households having disposed the same. Lesser numbers of respondents have disposed plastic containers from their kitchens. Further, households from different socio-economic strata indicate that 32% to 46% throw the plastics items like milk pouches, multi-layered plastics plastic bottles used for packaging of cosmetics and groceries while 68% to 54% reuses them. For carry bags, 29% to 50% throw them into dustbin, while 71% to 50% reuse them. The findings give insights into consumer behavior as well plastic application, plastic source and plastic accumulation hotspots.

Though waste generation is low in slums, it's littering into drainage and banks of water bodies are rampant. Slums which are in close vicinity of the river are more likely to contribute to the plastic pollution. Therefore, the drainage and water bodies may serve as carrier of plastic waste to the river. The findings give insights into waste management inefficiency as well plastic plastic source and plastic accumulation hotspots.

The usage of fuzzy logic approach included identification of vulnerable areas and identification of leakage points. The output of this approach led to the development of risk map of the city (Figure 7.3) and formed the basis of followed by field reconnaissance & verification and cleanup activities. Figure 7.3 indicates that high density areas as well as the slum population are the major source of plastic leakages into the river. During the field survey at Agra, littering of solid waste comprising majority of plastic waste was observed in abundance. This was followed by discussion with ANN, which suggested hotspots, which were in line with predicted vulnerable areas (Figure 7.4).

Clean up activities were undertaken at Hathi Ghat, Pohiyaghat& again at Hathi Ghat after a gap of three months. The accumulation of waste again within a period of three months at Hathi ghat validated the identification of the hotspots. It was found that on the basis of count maximum number of plastic waste in decreasing order are Polythene bags, multilayer plastic bags, plastics pouches used for water and milk, mono layer plastics, disposable plastic cups and glasses, woven bags and others. In terms of weight polythene bags contributes the maximum followed by woven bags, plastic sheets and thick plastic bags, monolayer plastics, plastic pouches and multi layer plastic containers.

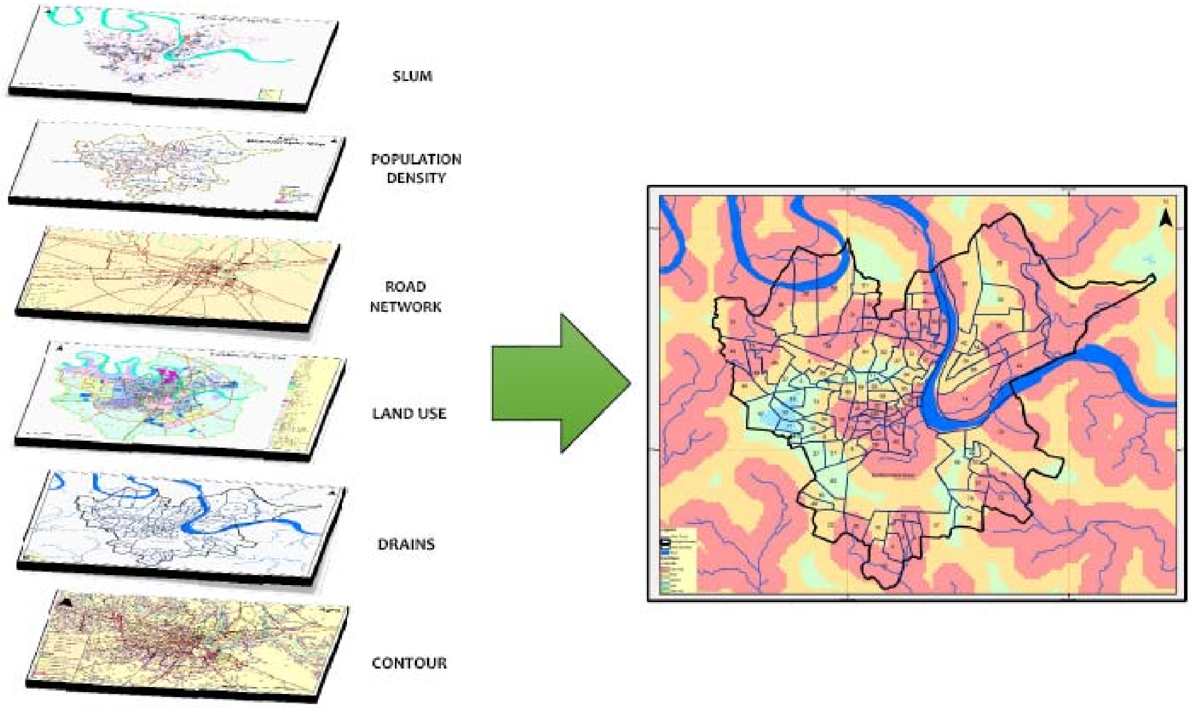


Figure 7.3: Plastic Leakage Vulnerable Areas identified using Fuzzy Logic Approach
Source: Prepared by Amit Jain, NPC team

Figure 7.4: Field Reconnaissance& Verification
Source: Prepared by Amit Jain, NPC team

Micro plastic sampling and analysis was undertaken in Yamuna in Agra (near Dussehra Ghat). 46 types of polymer have been found in the sample. 71% in fibre form, and 12% in film. Most of them are below 300 m. The major polymers with respect to sources are depicted below in Table 7.1.

Table 7.1: Major Polymers found in Micro Plastic Study

Waste	Polymer
Multi-layer packaging waste	EVOH, PVAL, EVA, PVC, Polyimide, PP, LDPE, Polyacrylamide, Acronitrilefilm, PE/PP, Polyesterfilm, HDPE, Polyethyleneoxide
Other packaging waste	Poly(alpha-methylstyrene), PVC, Polyimide, PP, LDPE, PVB, PE/PP, Polyesterfilm, HDPE, PVDF, Styrene/Butadiene, Styrene/Maleicanhydride
Disposable cups, plates, take away food containers	Polyamide, Styrene/Isoprene, PIP, PES, Polyesterfilm, HDPE, Styrene/Butadiene, Styrene/Maleicanhydride
Laminated film such as silver foil, laminated disposable plates	PET, LDPE
foams	Polyurethane
toys	polybutene
Other plastic pieces such making basins, bathroom fixtures, sinks,etc.	PMMA(Polymethylmethacrylate)
automobile parts, window glass	Polycarbonate, Polysulfone, Polyetheretherketone (PEEK), PC/PBT
Non stick cookware coating	PTFE
Skin care product	Poly1-butene

Source: NPC team

Waste management and material flow data analysis indicated that only 2 to 3 % waste is collected from the slum. The high value recyclables solids are extracted by the rag pickers from the transfer stations. Out of this 4-5% of high value plastic is taken away by the rag pickers and 80-90 tonnes of flow plastic in dry waste reaches to MRF facility. Thus 80-100 TPD of plastic is attempted to bring back into the value chain. The remaining 10-3- tons per day plastic is directly disposed, open burned or littered into streets, drains etc. finally its way into the land and river ecosystem by various means. About 700 to 750 tons mixed MSW is being dumped at the site on daily basis. From the field study it was inferred that presently around 22 % of plastic waste was found in mixed waste in Kuberpur dumpsite. These include single use plastics and polythene carry bags. Based on the material flow analysis, the leakage pathway of plastics in the city has been depicted in Figure 7.5.

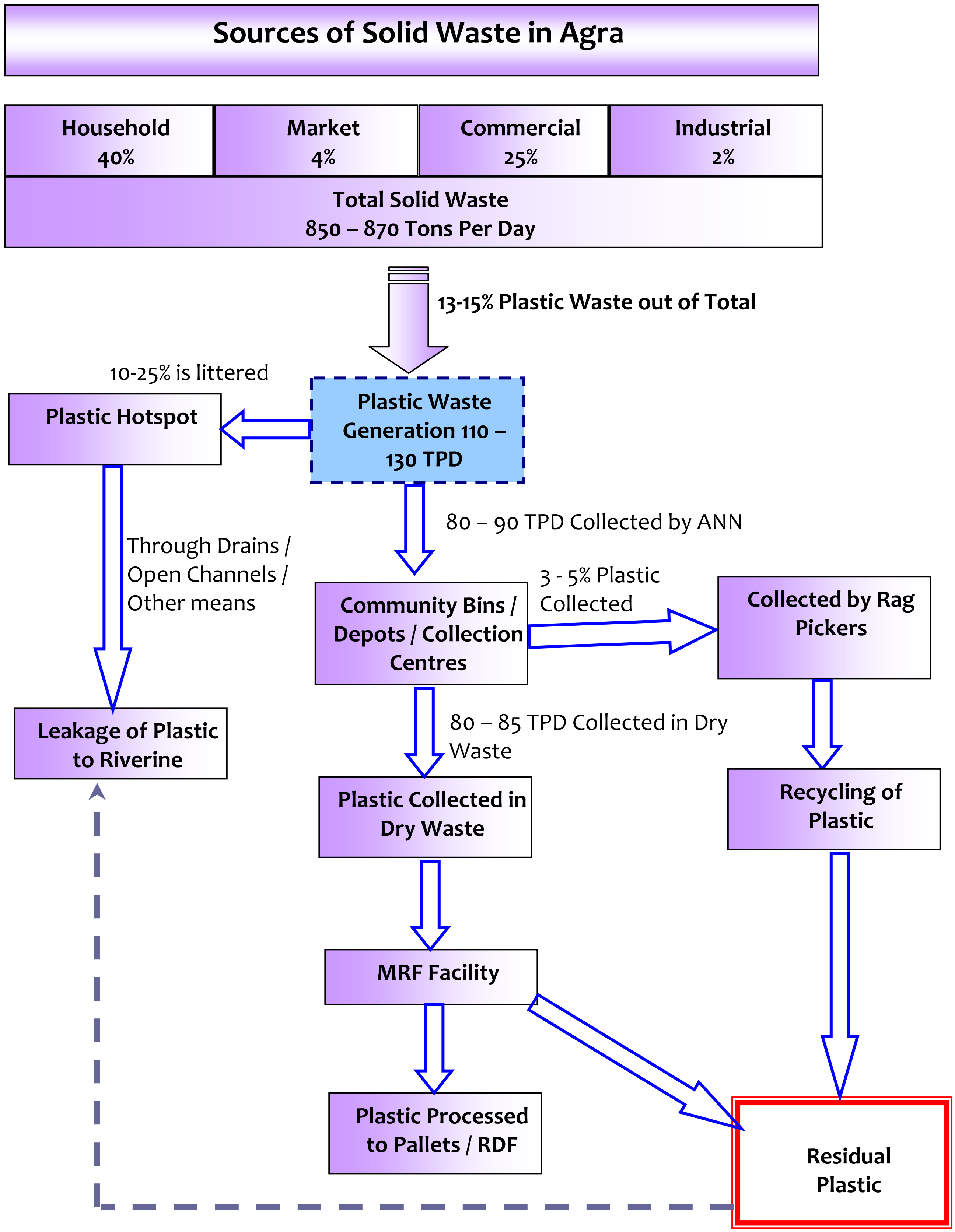
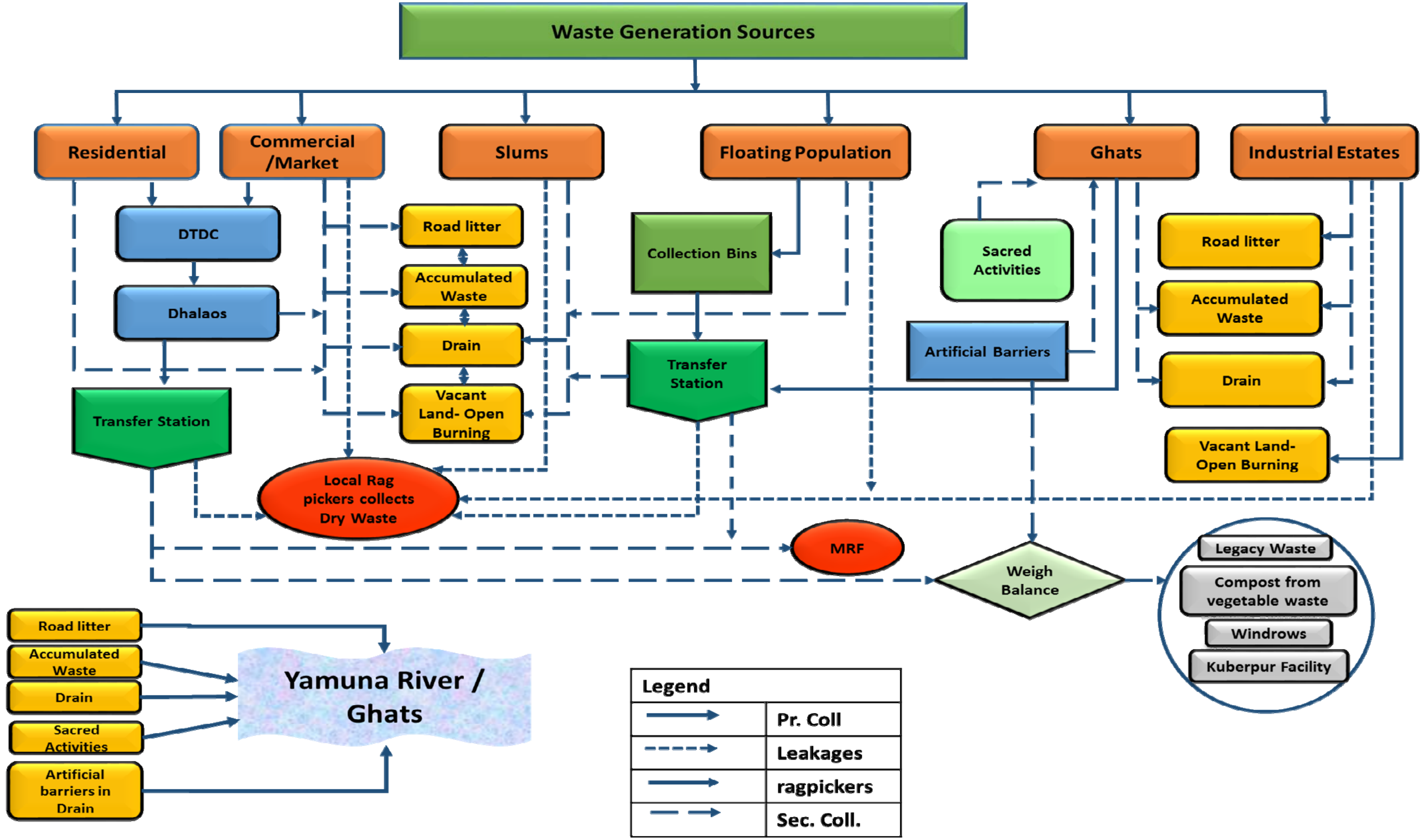


Figure 7.5: Plastic Leakage and its Pathway in Agra

7.4 Conclusions

Major hotspots have been identified, which trigger plastic leakage into river Yamuna through carriers like air, drains and run off. These include all the four types of hotspots. These include: (i) Plastic Value chain hotspots like plastics processed in leather factories; (ii) Plastic Leakage Source Hotspots in major wards in the city; (iii) Plastic Accumulation Hotspots in major drains of the city; and (iv) Plastic Application Hotspots considering poly bags found in macroplastic as well as microplastic. Massive amount of plastic was observed to be littered during the field study at various locations in Agra. Littering ranges 10% to 25% against 2% assumed in major studies carried abroad. Therefore, littering is one of the major reasons for the plastic not being collected and brought back into the value chain. However, majority of the waste categories found during Clean Up include plastic bags, Multi layer packaging, Plastic Sheet & other thicker plastic bags in black & white color, water pouches, Packaging Material e.g. Tobacco sachets, Biscuit packets, Surf excel, Rusks etc. as per clean up report. The findings of micro plastic survey confirm the findings of on land survey. A schematic diagram representing the leakage pathway has been described in Figure below.



Source: NPC team

Appendix 2.1: Information Guide/ Meta Data Sheet

Data Inventory

Data Inventory			Unit/Format	Description	Feature class	Attribute Table	Priority	Responsibility		Purpose: Relation to the plastic leakage	Remark
1	Demographic information							GIC	Local Partner		
	1.1	Population	Number	Total population in the selected district, city, community, with disaggregation by sex (male and female)	Polygons	GID_x: Unique ID across all geometries inside a specific feature at the level x of subdivisions NAME_x: Official Name of the level x of subdivision (English) POP_yyyy: Total number of population in the year of yyyy POP_M_yyyy: Total number of male population in the year of yyyy POP_F_yyyy: Total number of female population in the year of yyyy POP_Urban_yyyy: Total number of population in urban area in the year of yyyy POP_Rural_yyyy: Total number of population in rural area in the year of yyyy			○	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.	**Commune level/Finer level**
	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.	**Statistical yearbook?**
	1.3	Floating Population	Location	Density of restaurants/hotels. Information will be extracted from booking.com/agoda.com and/or google earth	Points	GID_x: Unique ID across all geometries inside a specific feature of hotels/restaurants NAME: Name of the hotel (English) ADDRESS: Address of the hotel CONTACT INFO: Contact information will be a phone number or email address or website LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.		○		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		GID_x: Unique ID across all geometries inside a specific feature at the level x of subdivisions NAME_x: Official Name of the level x of subdivision (English) HOUSE_Total_yyyy: Total number of household in level x of subdivision in the year of yyyy			○	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	**Commune level/Finer level**

Data Inventory			Unit/Format	Description	Feature class	Attribute Table	Priority	Responsibility		Purpose: Relation to the plastic leakage	Remark
	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.	Polygons				○	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.	Local partner
	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.	Sanitation facility data **shall try derive from Census data** (if available): flush toilet, traditional pit toilet or latrine, ventilated improved pit toilet or latrine, and no facility, bush field. Level of income based on country criteria (shall try derive from Census data)
2	Topographic/Basin characteristics information										
	2.1	River networks: Main stream and Tributary of rivers,	Shapefile	The network of main river, stream and the tributary in the watershed	Lines or Polygons	GID: Unique ID across all the stream network GRID_CODE: stream order Stream_Length: the length of the stream in kilometer(km)			○	This is very useful for hydrological correction of the digital elevation model (DEM) in the purpose of extraction of the river basin.	Specially needed in Phnom Penh and Cantho as the study area is almost flat and may not reflect the terrain properly in freely available DEM
	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.	Raster feature			○	△	Plastic leakage must be affected by the topographic feature described by DEM according to the water flow direction in the watershed.	Will be collected by GIC

Data Inventory			Unit/Format	Description	Feature class	Attribute Table	Priority	Responsibility		Purpose: Relation to the plastic leakage	Remark
	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	Point	ID: station ID NAME_STA: Name of the station FLOW: flow data in cm/s LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.			○	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	Polygons	GID: Unique ID of sub basin AREA: Area of sub basin RUNOFF: runoff in each sub basin. Unit is in cm/s			○	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	Polygons			○	△	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.	Polygons	Object ID: Unique ID of catchment Area: Area of catchment Inundation: flood depth			○	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										Map scale: 1:2000? 1:5000?
	3.1	Industrial area/ Economic zone/ Factory location	Shapefile	Industrial zone, development zone	Polygons	GID_x: Unique ID across all geometries inside a specific feature of industrial areas NAME: Name of the industrial area (English) INDUSTRY_TYPE: The type of industry (if possible): primary industry (extract raw materials from land or sea: mining, timber, fishing,...); manufacturing industry (involve the manufacture from raw materials into another products); ...			○	As a potential plastic leakage source	
			Shapefile	Location of factory with their information: type of factory (ex: companies producing plastic raw materials, cosmetics, shampoo, hygiene products), size,…	Points	GID_x: Unique ID across all geometries inside a specific feature of factory locations NAME: Name of the factory (English), if possible FACTORY_TYPE: The type of factory REMARK: can add any additional information related to the factory, if any.			○	As a potential plastic leakage source	
	3.2	Tourism area	Shapefile	Urban, nature, culture and history, beach	Polygons	GID_x: Unique ID across all geometries inside a specific feature of the areas NAME: Name of the area (English) TYPE: the type of tourism area, ex: urban,			○	As a potential plastic leakage source	

Data Inventory			Unit/Format	Description	Feature class	Attribute Table	Priority	Responsibility		Purpose: Relation to the plastic leakage	Remark
						beach,…					
	3.3	Other Point of Interests	Location, Type	Including: pagoda, temple, school, hospital, hotel, market,…	Points	GID_x: Unique ID across all geometries inside a specific feature of the point of interest NAME: Name of the point of interest (English), ex: ABC university TYPE: the type of the area, ex: school, market,... LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.			○	As a potential plastic leakage source	
	3.4	Road network	Shapefile	Including alleyway	Lines and/or polygones	GID_x: Unique ID across all geometries inside a specific feature of the roads NAME: Name of the area (English)		△	○	(Please let me know why we need this parameter)	Road network will be derived from land use map and/or OSM (if available)
	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.	Polygones	GID_x: Unique ID across all geometries inside a specific feature of the features BUILDING_LEVEL: number of story of the building, ex: 1, 2,... WALL_TYPE: materials which used to construct the building, ex: timber, brick, concrete,...		△	○	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.	Ports: rail stations, bus terminals, airports, harbor,… Data will be derived from land use map and/or OSM (if available)
4	Land use information										Map scale: 1:2000? 1:5000?
	4.1	Administration		Boundary of study areas in difference level: province, district and sub-district	Polygons or lines	GID_x: Unique ID across all geometries inside a specific feature at the level x of divisions/subdivisions NAME_0: Official Name of country(English) NAME_1: Official Name of the provinces (English) NAME_2: Official Name of the districts (English) NAME_3: Official Name of the wards/communes (English)			○	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,…	Polygones	GID_x: Unique ID across all geometries inside a specific feature of land use types/units LAND_CODE: Alphabets or numeric or both alphabets and numeric prerESENTS the land use code, based on mapping rule of the country. LAND_NAME: name of land use types or units			○	To make recommendation with countermeasures to an administration level	Land use types maybe different base on its special of natural conditions
	4.3	Plastic manufacturer	Location, Type		Points	GID_x: Unique ID across all geometries inside a specific feature of plastic manufacturers			○	As a potential plastic leakage source	From statistical data?

Data Inventory			Unit/Format	Description	Feature class	Attribute Table	Priority	Responsibility		Purpose: Relation to the plastic leakage	Remark
						NAME: Name of the plastic manufacturers (English) TYPE: The type of plastic manufacturers (if possible) LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.					
	4.4	Agriculture	Location, Type		Polygons or points				o	As a potential plastic leakage source	
	4.5	Fishery and Aquaculture	Location, Type		Polygons or points				o	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.	Points	GID_x: Unique ID across all geometries inside a specific feature of the waste collection points NAME: Name of the points, if possible (English), LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.			o	As a potential plastic leakage source	Field survey?
	4.7	Intermediate treatment facility (transfer station, recycling facility, junkshop)	Location, type		Points	GID_x: Unique ID across all geometries inside a specific feature of the waste collection points NAME: Name of the points (English), if possible TYPE: the type of intermediate treatment facility, ex: transfer station. LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.			o	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.	Points	GID_x: Unique ID across all geometries inside a specific feature of the illegal dumping sites LOCATION_TYPE: type of location, ex: public space, private,.. LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system. REMARK: can add any additional information related to illegal dumping sites			o	As a potential plastic leakage source	Photo: need to take a photo at 4 directions: front, behind, left, and right of the dumping point.
	4.9	Disposal site	Location,	A site for the disposal of waste	Points	GID_x: Unique ID across all geometries inside			o	As a potential plastic leakage source	Photo: need to take a

Data Inventory			Unit/Format	Description	Feature class	Attribute Table	Priority	Responsibility		Purpose: Relation to the plastic leakage	Remark
		(dumpsite)	Photo	materials by burial or burning		a specific feature of the disposal sites NAME: Name of the disposal site, if possible (English) ADDRESS: Address of the disposal site, if possible LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.					photo at 4 directions: front, behind, left, and right of the disposal point.
	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	Points	GID_x: Unique ID across all geometries inside a specific feature of the wastewater facilities NAME: Name of the wastewater facility (English) TYPE: The type of wastewater facility LATITUDE: Latitude is the unit that present the coordinate at geographic coordinate system. LONGITUDE: Longitude is the unit that present the coordinate at geographic coordinate system.			○	As a potential plastic leakage source	
	4.11	Others		(Please list up the necessary data after the consultation with local partners)						N.A.	
5	Satellite imagery										
	5.1	Optical imagery		Freely imagery: Sentinel-2, Landsat	Raster feature			○	△	(Please let me know why we need this parameter)	10-30m spatial resolution
	5.2	Night time light imagery		Density of light at night	Raster feature			○	△	To identify settlement areas	Monthly product, cloud-free
6	Waste/ Wastewater management Information										
		See "WM Data"	Sheet-2					x		To identify the plastic value chain hotspots and local/regional accumulation hotspots	

General Data Collection on Waste Management

No.	Waste Management Chain	Location ID & Photo	Unit	Result	Year	Source	Note
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	Illegal dumping site	x (visual inspection, sheet-4)	number				
6-2	Waste condition in artificial barriers & drains	x (visual inspection, sheet-4)	number				
7	**Leakage to the environment**		t/d				
L-1	**Unmanaged waste**		t/d				
L-1-1	Open burning		t/d or %				
L-1-2	Burry (HH or Communal pit)		t/d or %				
L-1-3	Littering/dumping		t/d or %				
L-2	**Mismanaged waste**		t/d				
L-2-1	leakage from transfer station		t/d				
L-2-2	leakage from junkshop, recycling facility		t/d				

No.	Waste Management Chain	Location ID & Photo	Unit	Result	Year	Source	Note
L-2-3	leakage from disposal site		t/d				
L-3	**Artificial barrier/drainage**	x	t/d				
L-4	**Plastic load to the river**		t/d				

Visual Inspection for Illegal Dump

No.	ITEM		DETAIL	RESULT
1	Illegal dump			
	1-1	Estimate total amount of accumulated wastes		
		Estimated length	meter	
		Estimated width	meter	
		Estimated hight	meter	
		Volume	Cubic meter	
	1-2	Take photos with GPS	Panoramic & Foreground Photos	Photo

Visual Inspection for Illegal Dump

		Population (x1000)	Area (km2)	Density (people/km2)
Provinces				
1				
2				
3				
4				
5				
6				
7				
8				

Appendix 3.1: Perception Survey Questionnaire

1. DEMOGRAPHICS

Q1. Age of the respondent?

a. <20 years
b. 20-29 years
c. 30-39 years
d. >40 years

Q2. Gender of the respondent?

a. Male
b. Female
c. Other

Q3. Which stakeholder category does the respondent belong to?

a. Religious Group
b. School
c. Commercial
d. Resident
e. Rag Pickers
f. Other, please specify

Q4. What is the highest education level attained?

a. Illiterate
b. Dropout/no formal education
c. Primary / Class 5 pass
d. Upper primary / Class 8 pass
e. Secondary / Class 10 pass
f. Higher secondary / Class 12 pass
g. Graduate
h. Post graduate
i. PhD / post doctorate

Q5. What is the average monthly household income level?

a. Less than Rs. 10,000
b. Between Rs. 10,000 and 50,000
c. Between Rs. 50,000 and 1,00,000
d. More than Rs. 1,00,000

Q6. Address/ Locality: ______________________________

Q7. Email/Mobile No:

____

2. KNOWLEDGE ABOUT POLYMERS

Q8. Do you know that plastics are made of different polymers?

a. Yes
b. No
c. Partly

Q9. Which of the following polymers have you heard about? *Mark all that apply*

a. PET
b. PVC
c. PP
d. LDPE
e. HDPE
f. PS

Q10. Are you aware of any labeling scheme for different polymer content of plastic products?

a. Yes
b. No
c. Partly

3. KNOWLEDGE OF PRODUCTS AND PACKAGING MADE IN PART OR WHOLE WITH PLASTICS

Q11. How many products do you use every day that may have plastics in it?

Q12. How many products do you use every day that may have plastic packaging on it?

Q13. Which of the following products do you use? *Mark all that apply*

a. Plastic water bottle
b. Use and throw Plastic glass
c. Use and throw Plastic cup (for tea/coffee)
d. Ice cream cup
e. Use and throw Plastic plate
f. Use and throw Plastic cutlery
g. Plastic carry bags
h. Plastic Straws
i. Plastic storage containers (in kitchen)
j. Plastic food container from online food ordering
k. Plastic pump bottles for cosmetic liquids
l. Plastic medicine box
m. Plastic wrap for food
n. Milk or edible oil pouches
o. Multi layered plastic (Chips packet) / Tetra pack
p. Wax coated white polybag
q. Artificial jewellery plastic

r. Other, please specify

4. REASONS FOR PREFERRING PRODUCTS AND PACKAGING WITH PLASTICS

Q14. Why do you prefer using plastic products? ***Mark all that apply***

a. They are light weight
b. They are cheap
c. They are durable
d. They are easily available
e. They are waterproof
f. They are versatile
g. All of the above
h. Others, please specify

Q15. Will you use a product that is an alternative to plastic product even if it is more expensive?

a. Yes
b. No
c. Not sure

Q16. Do you think there is a lack of availability of alternatives in the market/local area?

a. Yes
b. No.
c. I am not sure.

Q17. Can you list some items you use that are alternatives to plastic products?

5. KNOWLEDGE ABOUT PLASTIC WASTE MANAGEMENT

Q18. Are you aware about waste segregation and recycling of plastics?

a. Yes
b. No
c. Partly

Q19. Do you think proper waste removal and disposal is important?

a. Yes
b. No
c. I am not sure

Q20.While throwing plastic wasteinto the dustbin,you use (choose one)

a. Green bin
b. Blue bin
c. Not aware of Blue or Green bin
d. I'm aware of Blue & Green bin but these bin are not available at my location

Q21. Do you think there are adequate dustbins in your locality?

a. Yes
b. No
c. I am not sure

6. KNOWLEDGE ABOUT EFFECTS OF PLASTIC ON HEALTH AND ENVIRONMENT

Q22. Are you aware about the effects that plastic has on the environment and health?

a. Yes
b. No
c. A little

Q23. In your opinion, on a scale of 0- 10 [0 – No affect, 5-Moderate affect,10-Major affect], what is the effect of plastic on environment and health in your locality?

Q24. What are the ill effects that plastic has on the environment and health in your locality?

a. It chokes the drains
b. It uses space in landfills
c. Animals die because of it
d. Releases toxic chemicals into the environment
e. It's not a problem
f. Others, please specify

Q25.In your opinion, does improper solid waste removal and disposal contribute to the ill effects that plastic cause to the environment and health?

a. Yes
b. No
c. I am not sure.

7. PERCEPTION ABOUT WHAT NEEDS TO BE DONE TO REDUCE PLASTIC POLLUTION

Q26. Do you think levying charges on plastic bags is a good idea?

a. Yes
b. No
c. Maybe

Q27. Who do you think is responsible for reducing plastic pollution? *Mark all that apply*

a. Municipality
b. We the people
c. State Government
d. Central Government
e. NGOs

f. I am not sure

Q28. Do you think the policies and programmes such as Swachh Bharat Mission have been effective in reducing plastic pollution?

a. Yes
b. No.
c. I am not sure.

Q29.Should proper waste disposal and removal methods be taught in schools and community?

a. Yes
b. No.
c. I am not sure.

8. STEPS TAKEN TO MANAGE PLASTIC WASTE AT INDIVIDUAL, COMMUNITY OR GOVERNMENT LEVEL:

Q30. What steps are you taking at a personal level to manage plastic waste in your locality, household or workplace?

a. Increasing awareness in the community
b. Reduce/ Reuse of plastic products
c. Carrying personal jute/cloth bags for shopping
d. Segregating waste at house/workplace
e. Installation of separate dustbins at house/workplace
f. Other. please specify

Q31. Do you or your housing complex/ society tie up with waste recyclers to recycle the plastic waste?

a. Yes
b. No
c. Maybe Sometimes

Q32. Are you aware of any steps taken by the government or local organisations to manage plastic waste?

a. Yes
b. No
c. I am vague on the matter.

Q33. What are the steps taken by the government and local organisations to facilitate plastic waste management in your city?

a. Awareness campaigns against the use of plastic items
b. Installation of separate dustbins to segregate waste
c. Ban on the use of Single use plastics.
d. Other, please specify

Q34. Do you think the steps taken to manage plastic waste have been effective?

a. Yes
b. No.
c. Party effective
d. I am not sure

9. AWARENESS ABOUT ALTERNATIVES TO PRODUCTS AND PACKAGING USING PLASTICS

Q35. Are you aware about different alternatives to plastic products?

a. Yes
b. No
c. I am not sure

Q36. Would you prefer the use of alternatives to plastic, if they were made easily available in the local community and markets?

a. Yes
b. No
c. Maybe

Q37. Do you think charging a price for plastic bags at shops is a good idea?

a. Yes, it will reduce use of plastic bag
a. No
b. Not sure

Q38.What are the alternatives for plastics that you are aware about and which you can adopt?

a. Paper cutlery
b. Edible cutlery made of organic products such as millets and other grains
c. Bamboo
d. Biodegradable plastic
e. Metals such as steel/ copper/brass cutlery
f. Wooden or fiber board materials
g. Cardboard
h. Ceramic
i. Others

Q39. What is/ are the main reason(s) for not switching to alternatives for plastics?

a. Not aware about them
b. Not easily available
c. Costly as compared to plastic
d. Other

10. WILLINGNESS TO FOREGO PLASTIC PRODUCTS AND PACKAGING

Q40.Would you prefer to forego the use of plastic products and packaging?

a. Yes

b. No
c. Maybe

Q41. In your opinion, what would motivate you to forego the use of plastic products and packaging in your chores?

a. Availability of alternatives
b. Availability of cheap and durable alternatives
c. Governments policies and programmes
d. Awareness about the ill effects of plastic
e. Other, please Specify

Q42. How would you feel if the government bans the use of plastic carry bag?

a. It does not bother me
b. I don't think that ban is necessary, only need to make people to put the bag in the dustbin
c. I think it's a great solution

Q43. Do you support the use of fabric bags as opposed to plastic bags?

a. Yes
b. No
c. I am not interested

11. PERCEPTION ABOUT IMPEDIMENTS TO EFFECTIVE ACTION ON REDUCING PLASTIC PRODUCTION CONSUMPTION AND MANAGEMENT

Q44. Are you aware of any hindrances to the effective action being taken to manage the use of plastic?

a. Yes
b. No.
c. I am not sure.

Q45. Are willing to comply with the Government rules and orders put in place to manage the use of plastic?

a. Yes
b. No
c. I am not interested

Q46. In your opinion, what are the hindrances to the effective action being taken to manage the use of plastic?

a. Lack of awareness
b. Lack of efficient action on part of the government authorities.
c. Lack of resources
d. Lack of action by the local residents and government.
e. Other, please specify

12. SOURCES OF INFORMATION ABOUT PLASTICS

Q47. Do you receive information related to plastic pollution?

a. Yes
b. No.
c. I am not sure.

Q48. What are your sources of information related to plastic pollution?

a. TV
b. Radio
c. Print media
d. Social Media
e. Awareness campaigns by the Nagar Nigam (Hoardings/Poster/Banners)
f. Awareness campaigns by NGOs (Hoardings/Posters/ Role play)

Q49. Are you aware about the initiatives that the government and other institutions are taking to increase awareness about plastic waste?

a. Yes
b. No
c. A little

Q50. What others sources of information do you think could be more effective?

Appendix 4.1: Methodology of data analysis – Fuzzy based approach

1. Background and objectives

The project on Promotion of Countermeasures Against Marine Plastic Litter in Southeast Asia and India (hereafter referred to as "CounterMEASURE") was officially launched in May 2019 aiming to identify a region-based model for monitoring and assessment of plastic leakage and pollution reduction. The target is land-based plastic leakage entering water ways such as rivers and canals or drainages to the sea. Based on the objective of the project, a suite of indicators which presents high correlation with plastic waste leakage (for example: population density map, industry/factory areas, dumping site (including illegal dumping), land use map, road network, public facilities: school, hospital, market, temple, etc.,) are collected. But the question here is how to map the potential plastic leakage among those collected data. The overlay weighted models using GIS is one of the most common techniques for predicting the location of something interest, and fuzzy based is a good approach to answer the question. Therefore, the scenario of plastic leakage is developed for the Mekong river using multi-source geospatial data (intermediate results) with fuzzy based approach.

To achieve the objective, whole flow chart of methodology is divided into 6 main components, with specific objectives as follow:

- To identify changes area of the riverbank along pilot sites, using Sentinel-2 optical imagery with GEE (Google Earth Engine).
- To map fine-scale spatial distribution of population using remote sensing, geospatial data and POIs (Point of Interest) with deep learning.
- To develop sub-basin hydrological characteristics based on morphometric parameters
- To extract customer database on the internet (booking.com, google earth).
- To collect ground truth data for validation the scenario using mobile application.

2. Methodology

The fuzzy model is based on the concept 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 continuous graduations from one class to another class, which has been applied in many research fields for predicting something of interest or for decision making. In this case study, fuzzy approach is applied to predict potential plastic leakage using geospatial data.

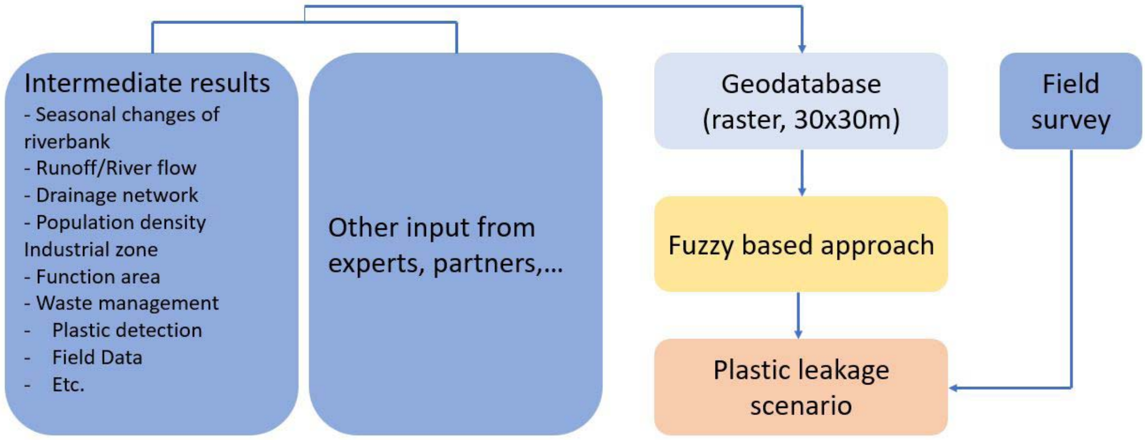


Figure 1

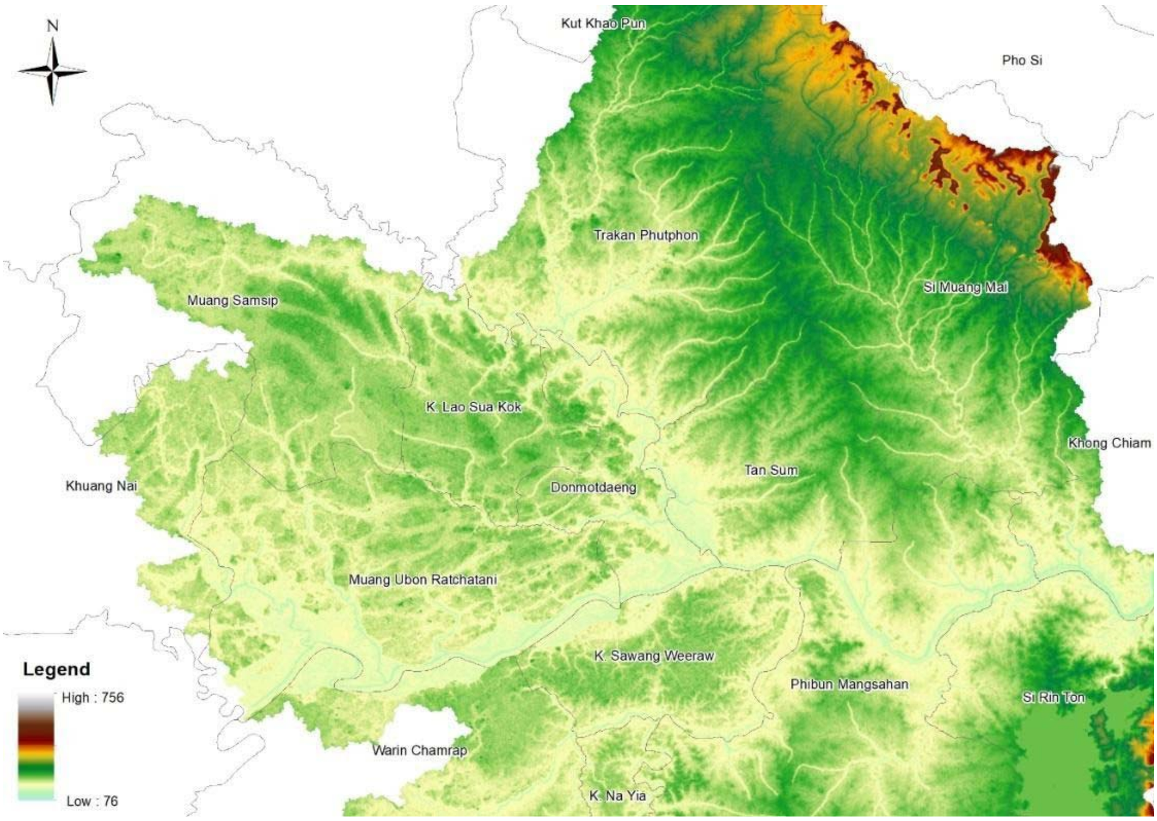


Figure 2

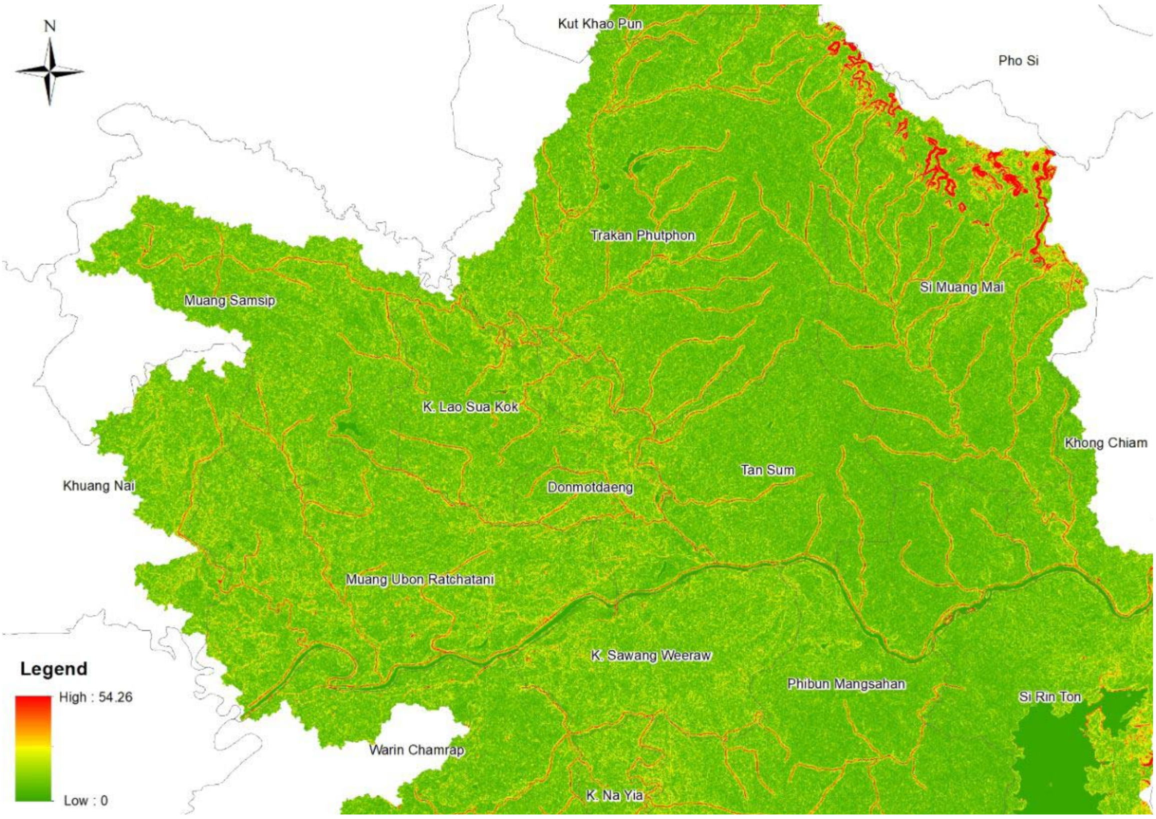


Figure 3

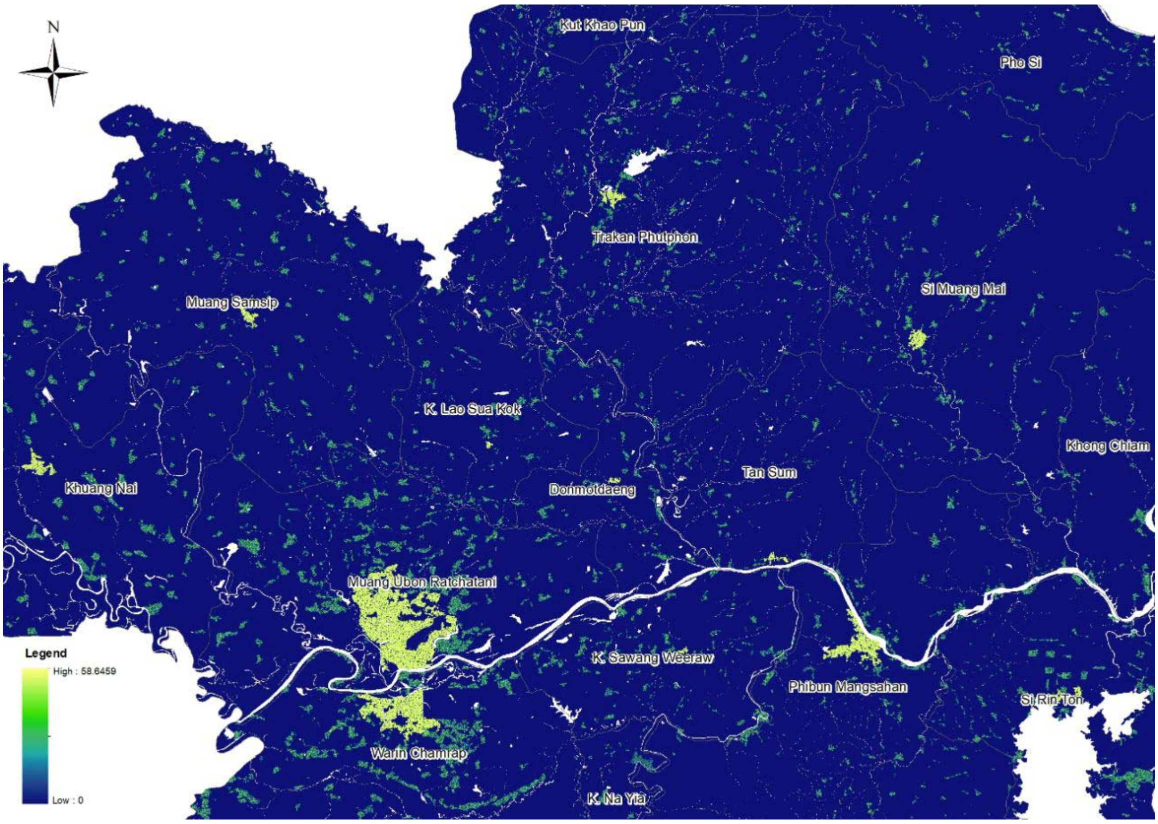


Figure 4

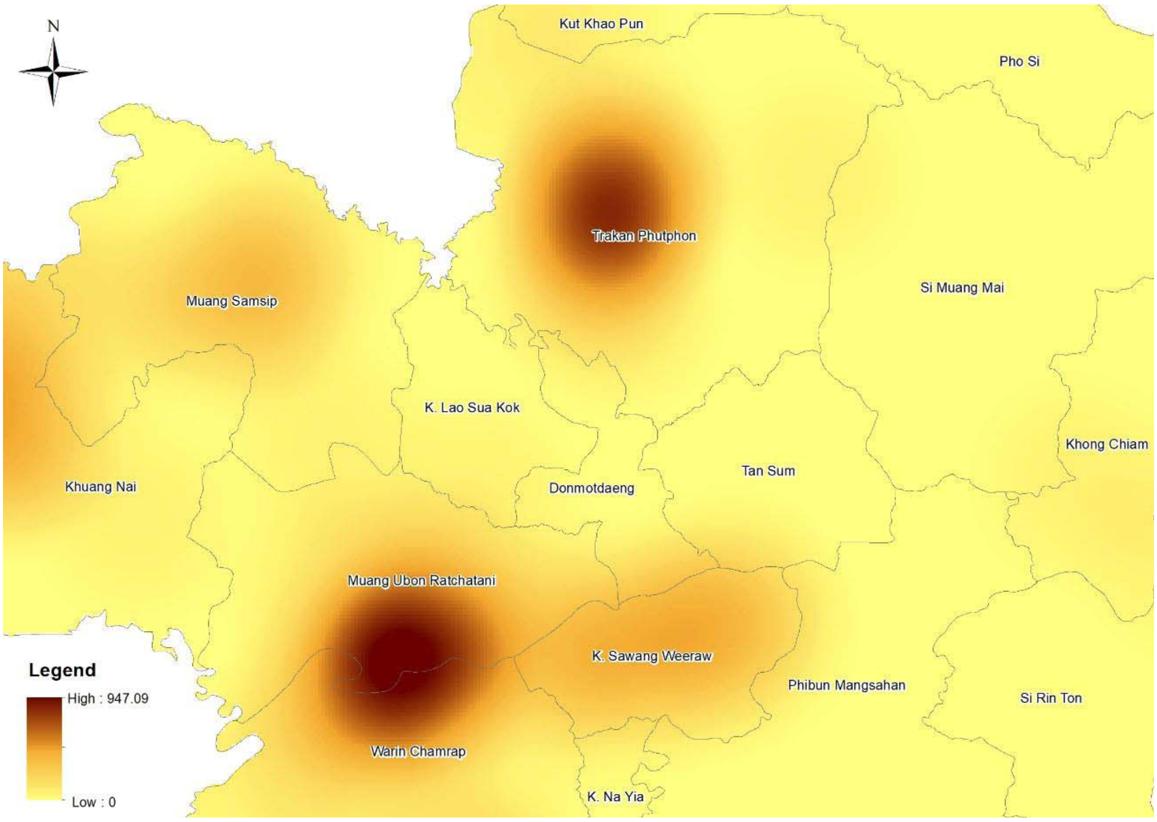


Figure 5

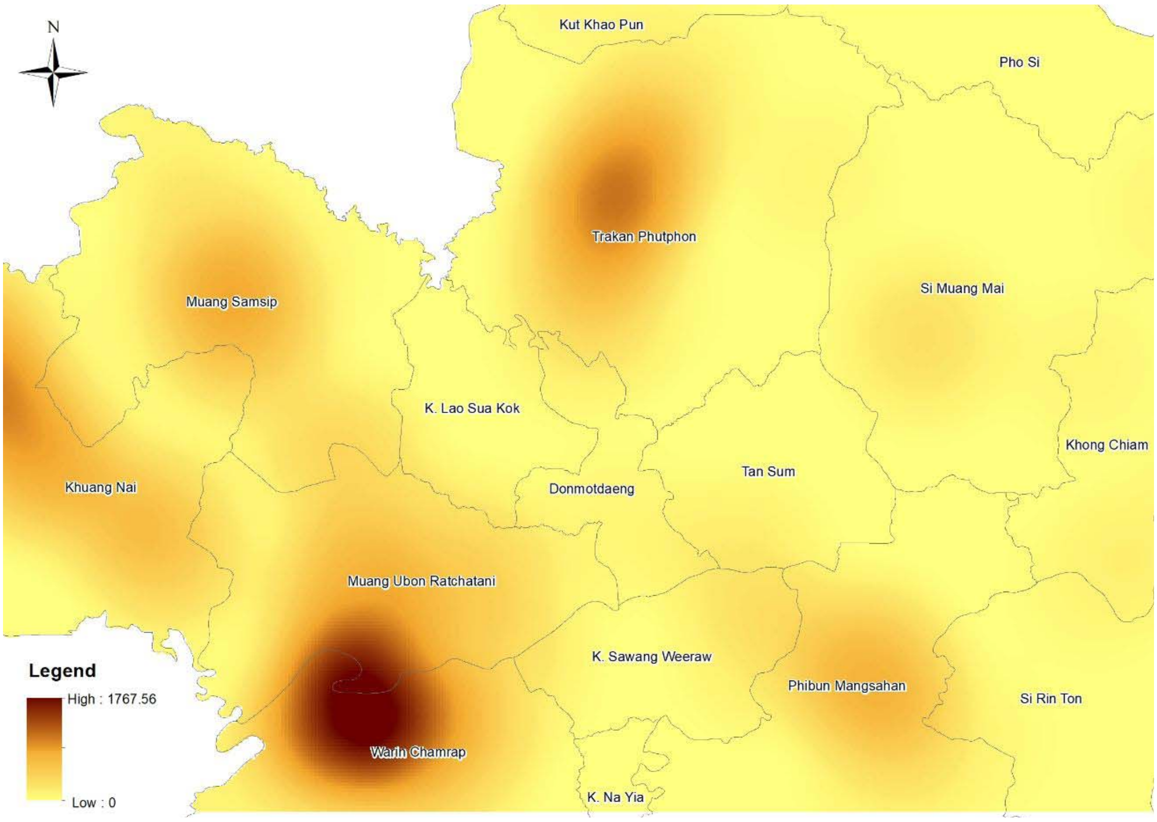


Figure 6

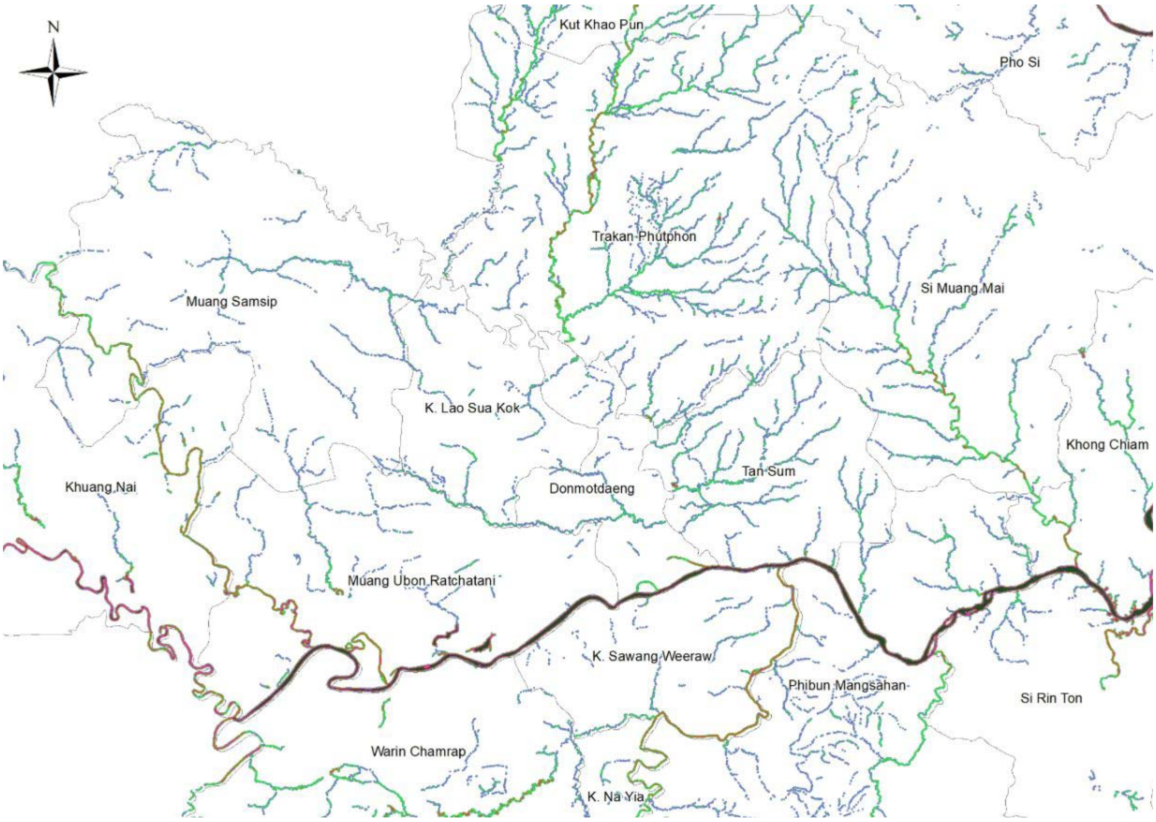


Figure 7

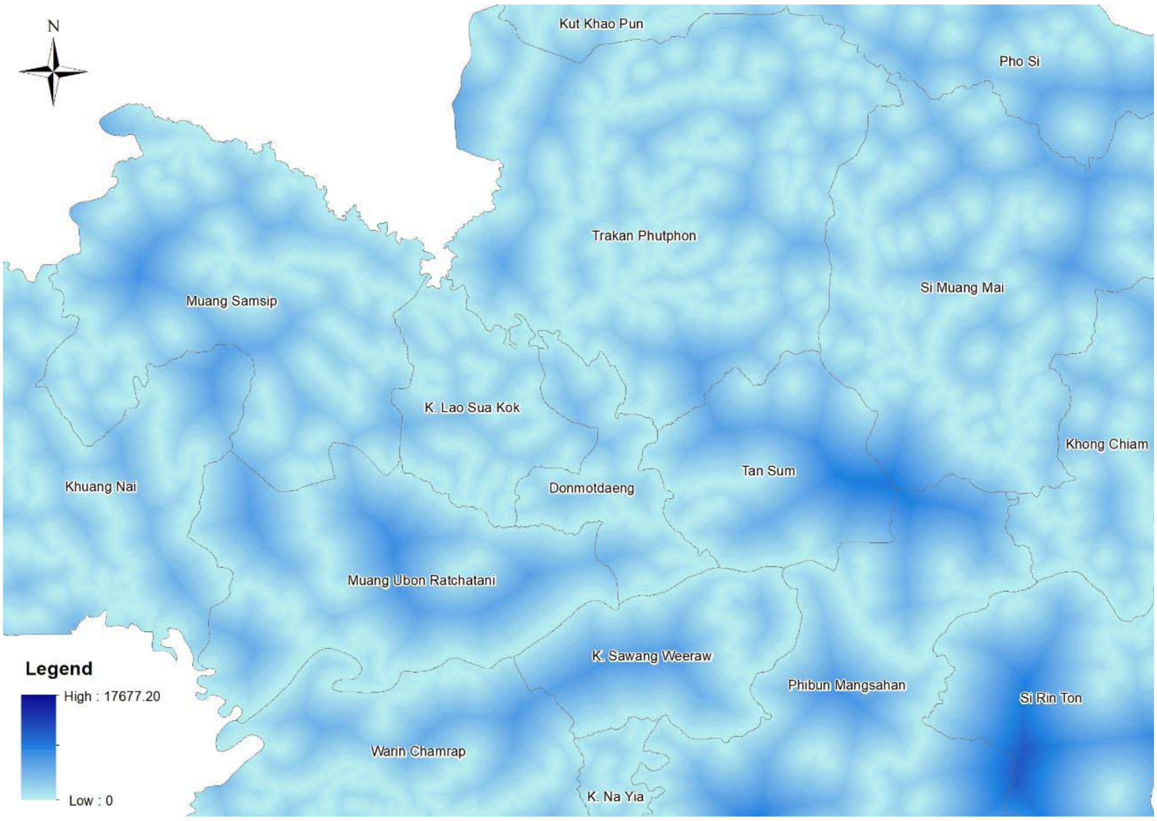


Figure 8

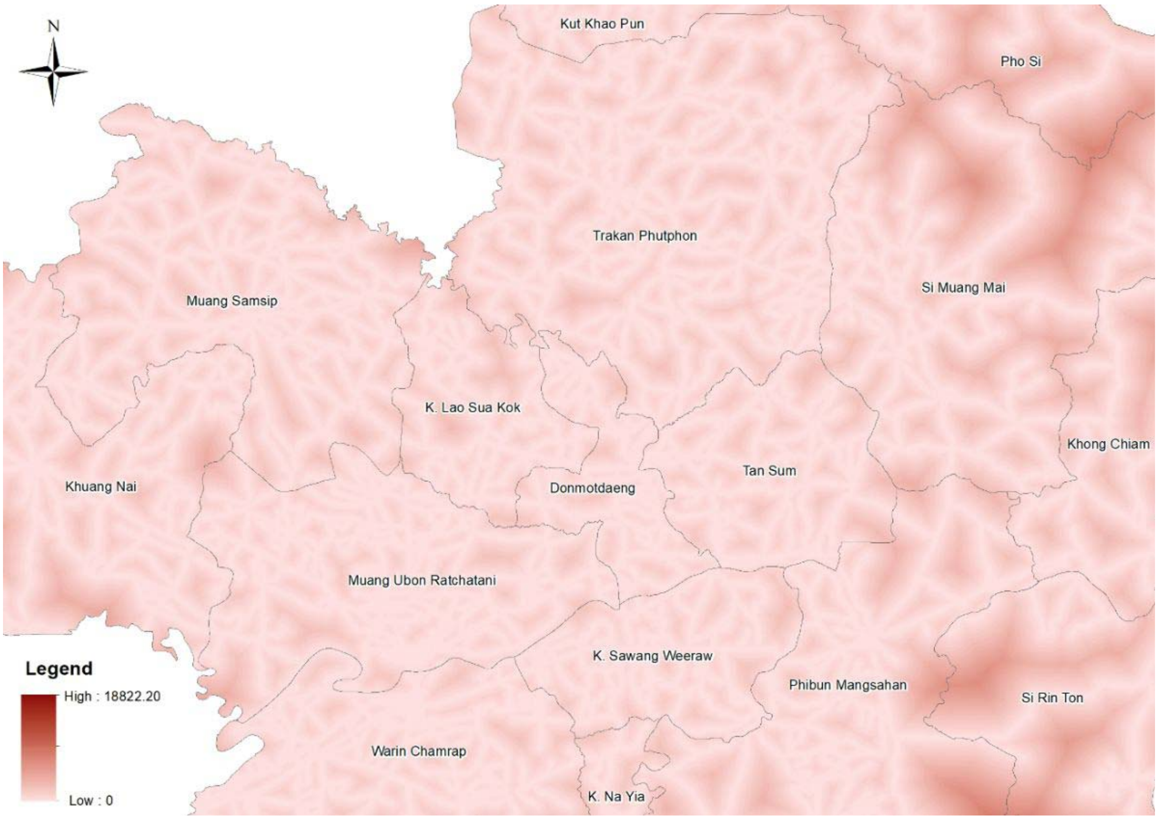


Figure 9

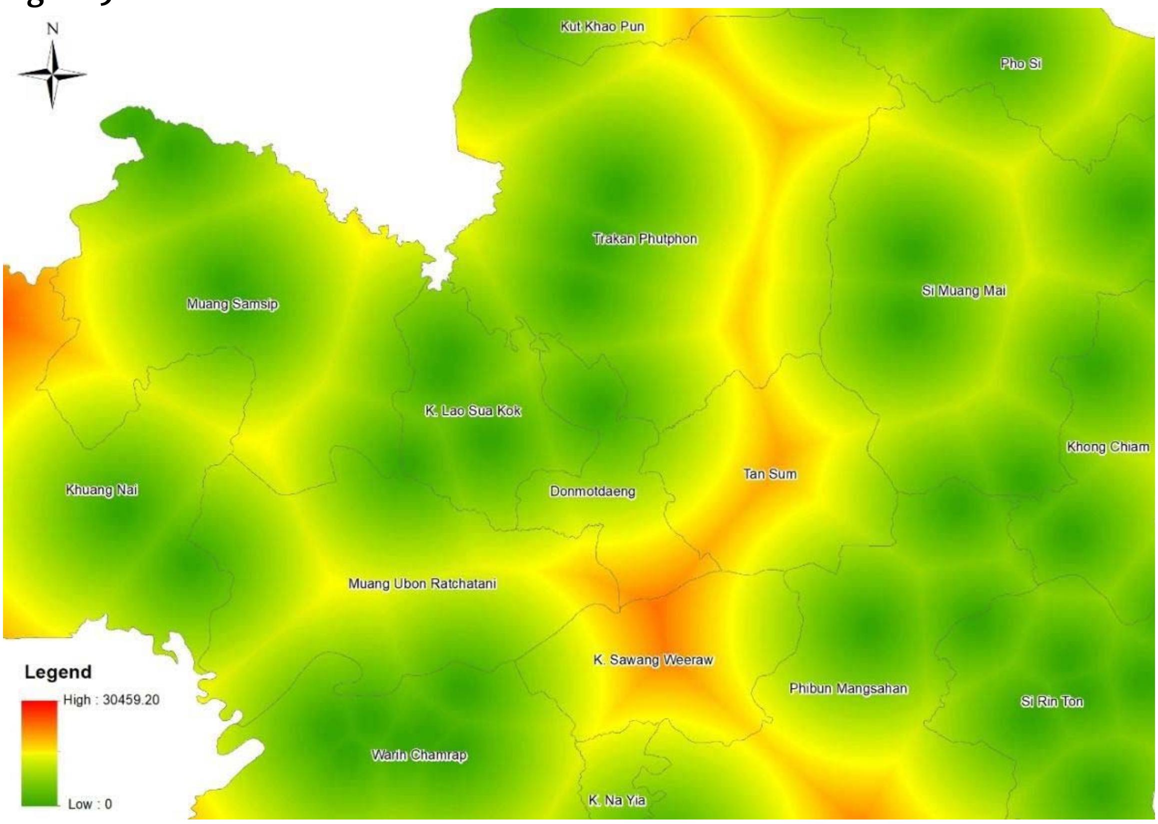


Figure 10

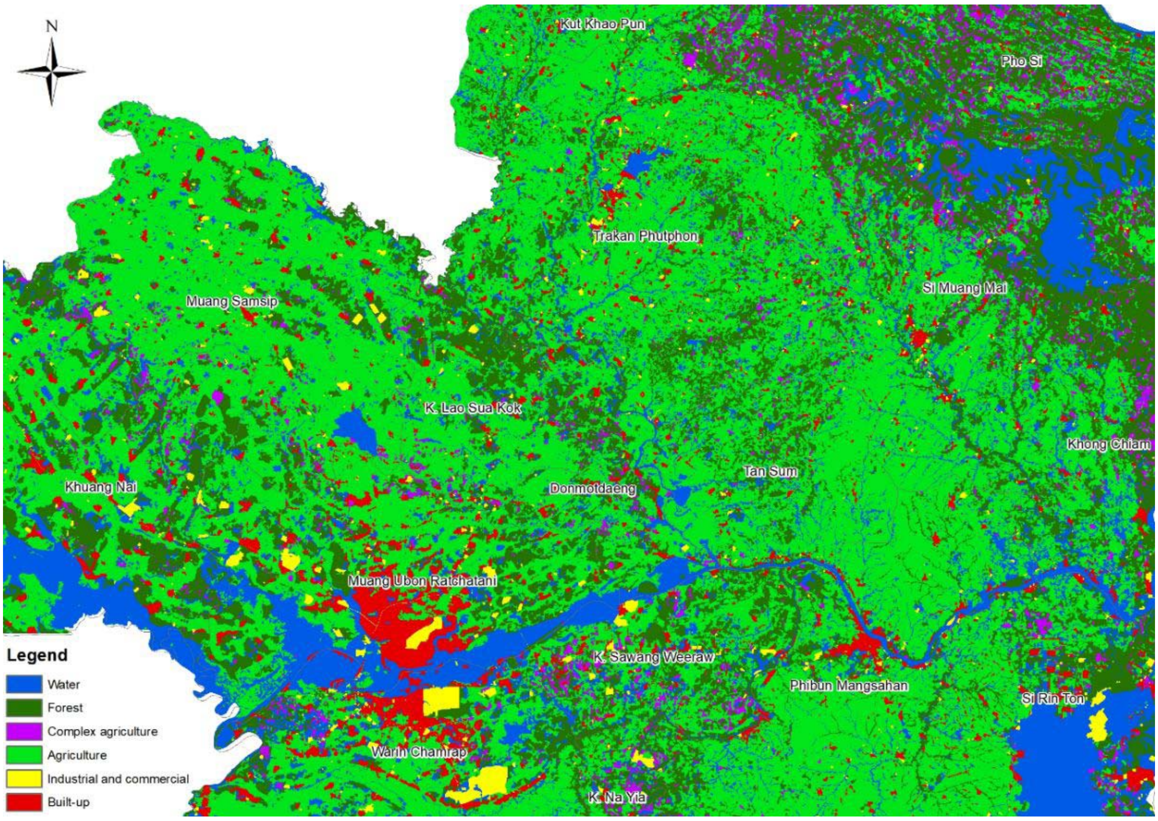


Figure 11

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

Before	After
Distance to river	
Distance to road	
Slope	

Figure 12

2.3 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.

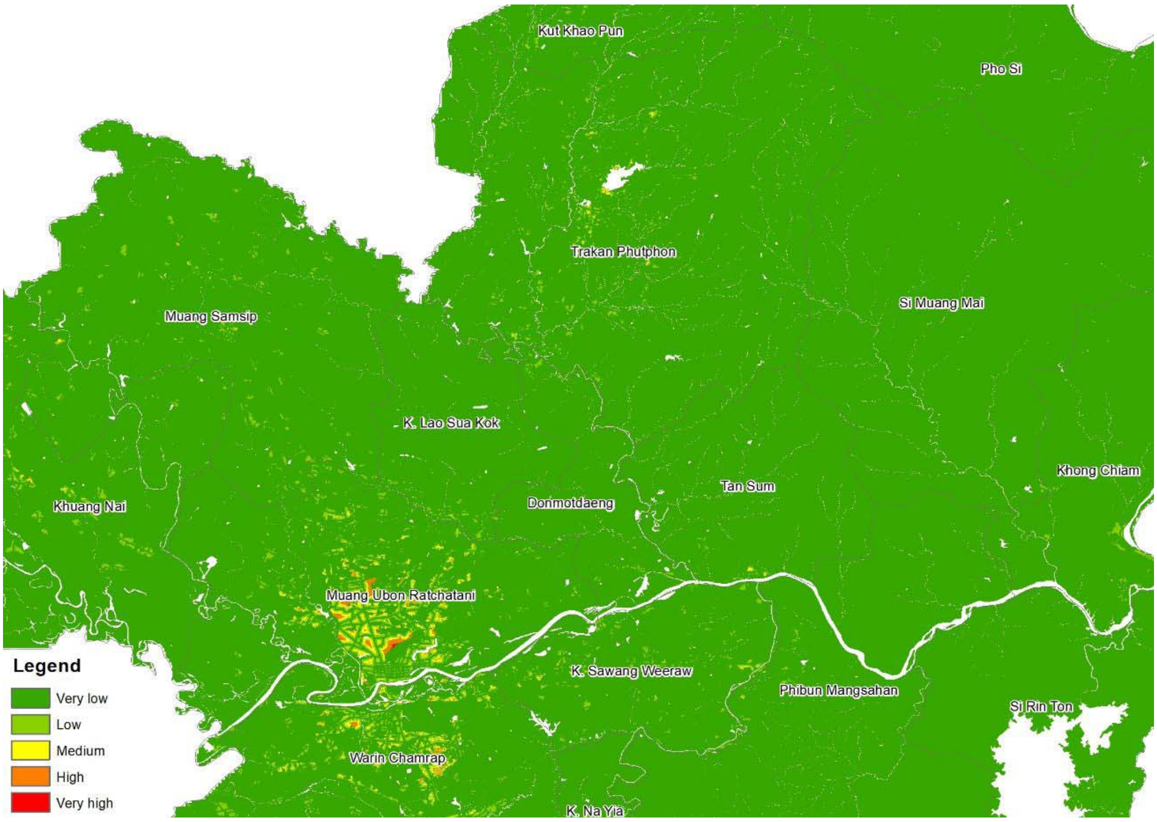
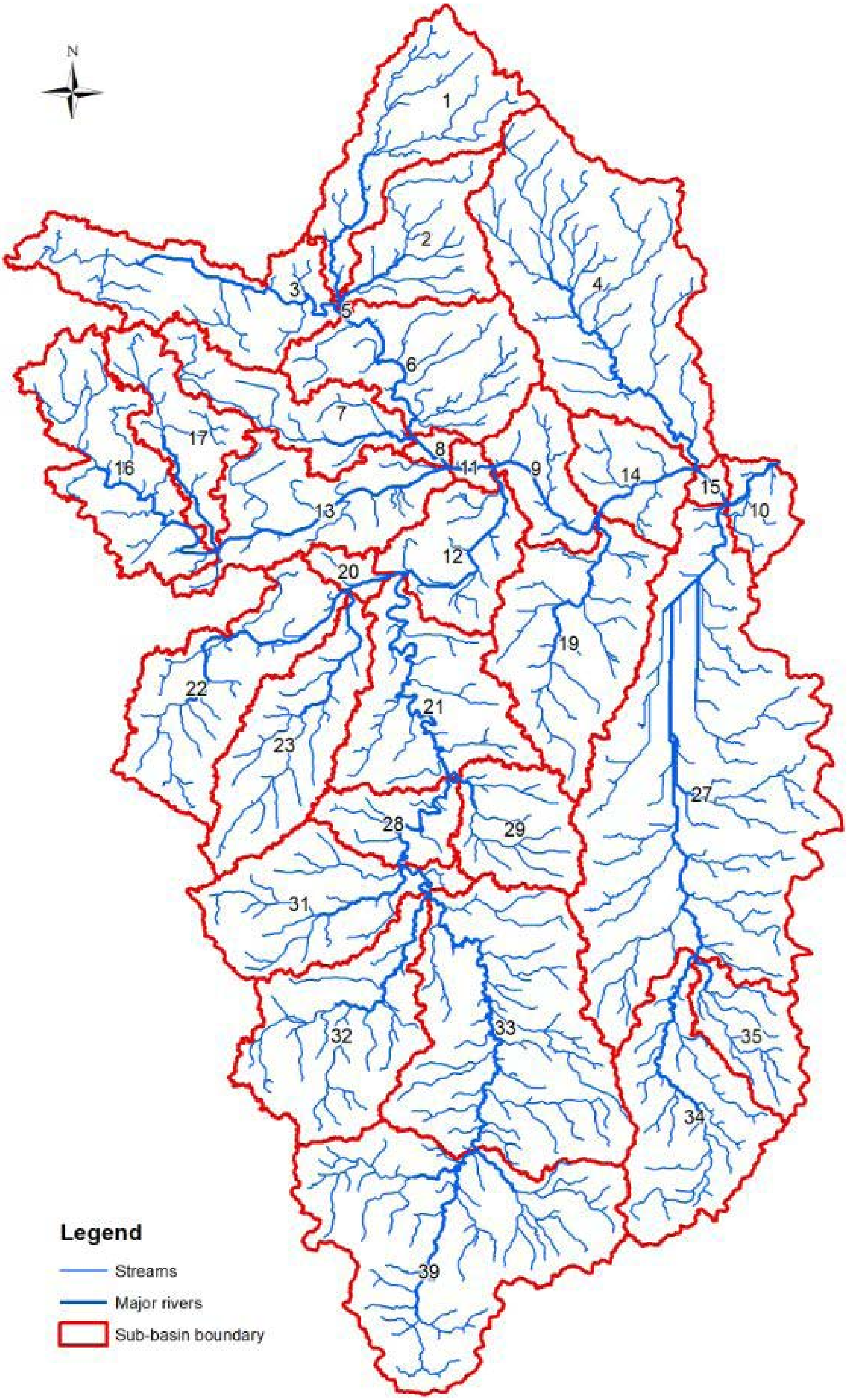


Figure 13

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

3.1 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 15.** In total, we extracted 31 sub-basins which are contributed into main river in the area.


N
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Legend
Streams
Major rivers
Sub-basin boundary

Figure 15

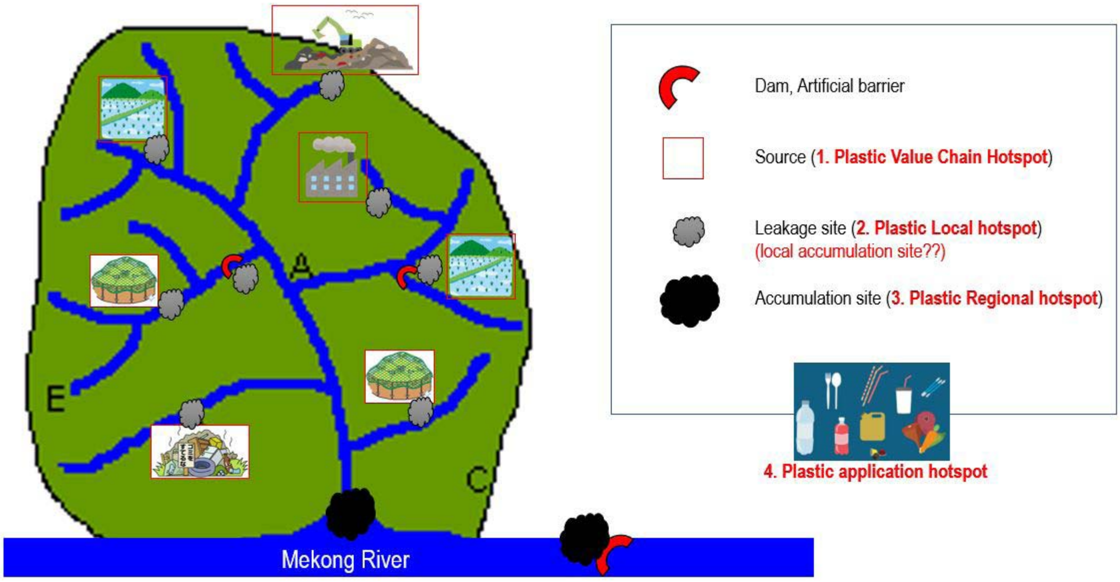


Figure 16

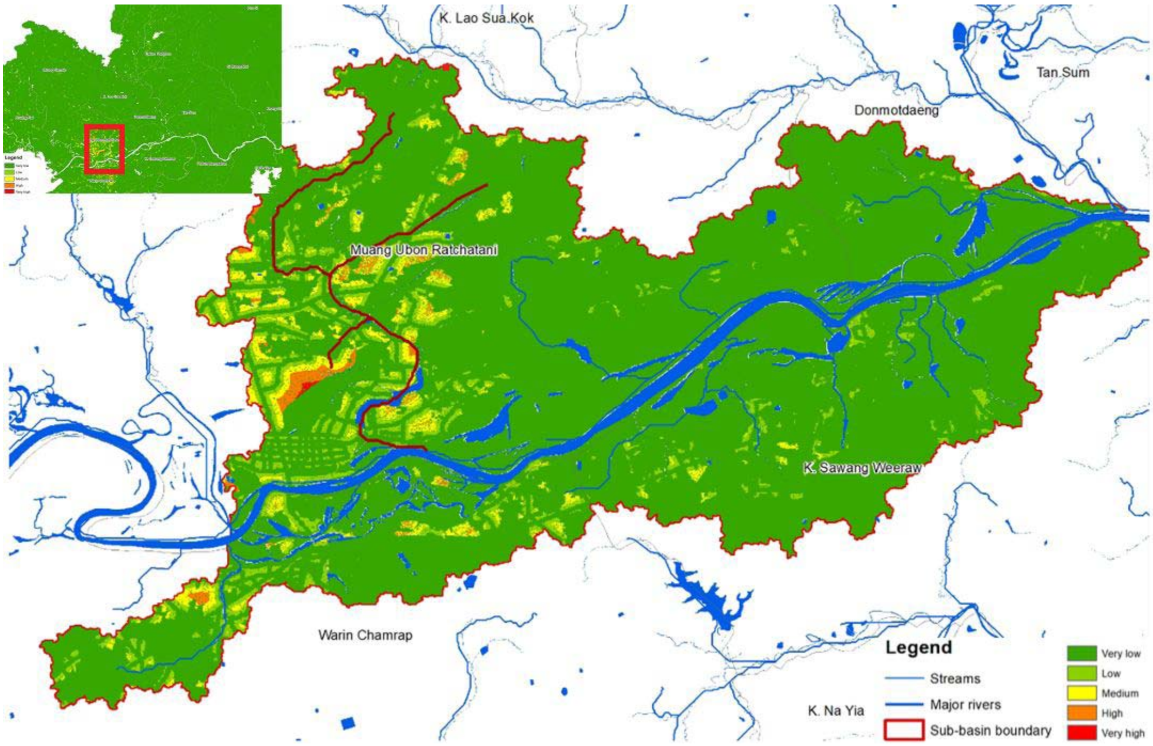


Figure 17

Figure 18

Or inconsistent segment areas. Watershed is an area of surface whose major runoff is conveyed to the single outlet and is the appropriate unit to study several processes of the land surface. For example, watershed is considered a fundamental erosional landscape element, wherein conspicuous interaction of land and water resources takes place. Being fundamental units of fluvial terrain, considerable research focal point has been done on watershed geometric characterization such as stream network topology and quantitative narration of shape, pattern, and drainage texture.

Hydrologic and geomorphic processes occur within the watershed, and morphometric characterization at the watershed scale reveals information regarding formation and development of land surface processes and thus provides a holistic insight into the hydrologic behavior of a watershed. Basin travel time, time to hydrograph peak (basin lag time), and intensity of erosional processes operating at watershed scale can be predicted with better insight and accuracy from morphometric evaluation of a watershed. For unguaged watersheds wherein, in addition to hydrology, information regarding soil, geology, geomorphology, and so forth is also scarce, morphometric analysis provides a very good alternative to understand the underlying factors controlling the hydrological behavior. However, in the urban area where the elevation is relatively flat this method will not be able to conduct due the digital elevation model problem.

With the advancement in geospatial and computer technology, assessment of the drainage basin morphometry has been more accurate and precise. Nowadays, using Geographical Information System (GIS) technique, various terrain and morphometric parameters of the drainage basins are evaluated with more ease and better accuracy. Satellite data and GIS tools have been successfully employed to generate data on the spatial deviations in drainage characteristics thus providing an insight into hydrologic conditions necessary for developing watershed management strategies.

2. Methodology

2.1 Terrain Preprocessing

Terrain Preprocessing uses DEM (digital elevation model) to identify the surface drainage pattern. Once preprocessed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation. The steps in the Terrain Preprocessing menu should be performed in sequential order, from top to bottom. The processes to use depend on the type and quality of the initial DEM. Processing must be completed before Watershed Processing functions can be used.

The terrain data is processed and analyzed using the 8-pour point approach to determine flow paths. Terrain analysis is computer intensive and some steps may require several hours, depending on the amount of data and computer resources. After terrain preprocessing is completed, the resulting datasets serves as a spatial database for the study. With the information centralized in the spatial database, pertinent datasets can be extracted for the subsequent work to build the hydrologic models. Preliminary watershed and stream delineation provided results that can be verified with published information to detect possible errors in the terrain data. If errors are detected, the DEM should be edited.

Terrain Reconditioning (Burn In)

This function modifies a DEM by imposing linear features onto it (burning/fencing). It is an implementation of the AGREE method developed at the University of Texas at Austin in 1997. This technique basically abrupt lower only the stream cell elevation by a fixed amount, also eliminate the undesirable side effect of fictitious islands near the stream centerline that parallel the stream as shown in **Figure 2-1**.

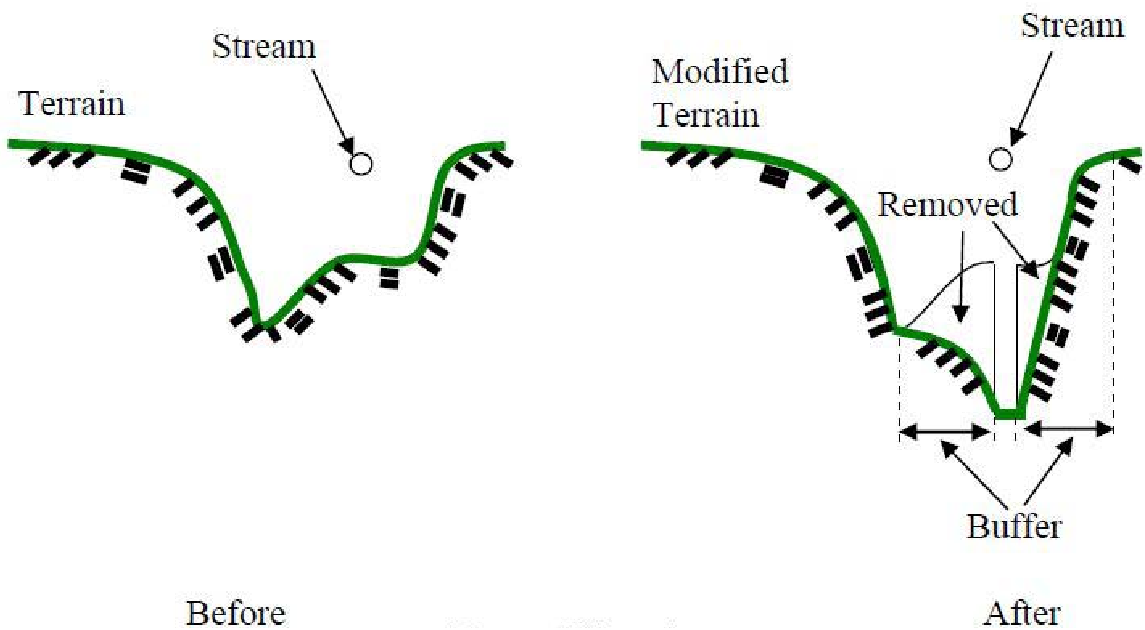
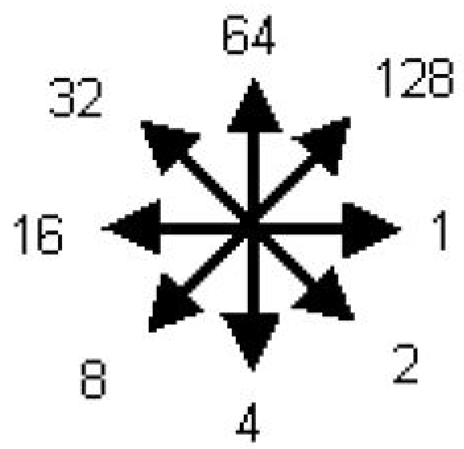


Figure 2-1



4 = south, 8 = southwest,
16 = west, 32 = northwest,
64 = north, 128 = northeast

Flow Accumulation

This step determines the number of upstream cells draining to a given cell. Upstream drainage area at given cell can be calculated by multiplying the flow accumulation value by the grid cell area.

Stream Definition

All cells with a flow accumulation greater than a specific threshold are classified as cells belonging to the stream network. Typically, cells with high flow accumulation, greater than a specific threshold value, are considered part of stream network. The flow accumulation for a particular cell must exceed the threshold value for a stream to be initiated. The smaller the threshold value chosen; the greater number of sub-basins delineated.

Stream Segmentation and Catchment delineation

The stream is divided into segments, or link which are the sections of a stream that connect two successive junctions, a junction and an outlet, or a junction and the drainage divide. Catchment Grid Delineation and Catchment Polygon Processing is the next step to delineates a sub-basin for every stream segment and create vector layer of sub-basin.

2.2 Extraction of drainage streams and delineating watersheds

A SRTM (Shuttle Radar Topographic Mission) digital elevation model (DEM) with a spatial resolution of 30 m was obtained from EarthExplorer (https://earthexplorer.usgs.gov/). The River network which are used for burning in into DEM is obtain from HydroSHEDS (https://www.hydrosheds.org/downloads). During subsequent processing to delineate watersheds, the digital elevation model (DEM) was hydrologically corrected and the sinks (errors) were removed and the drainage network was derived followed the above methods described in the Terrain Preprosseing by using Arc Hydro approach.

To create the drainage systems, a minimum thresholds flow accumulation value was used, and a stream order was assigned by applying a stream ordering method (Strahler, 1952). Strahler's ordering system assigns first order to streams without tributaries, second order to streams with at least two first-order tributaries, third order with at least two second-order tributaries and so on. The creation of a stream network was followed by the use of user-supplied pour points to delineate those points containing the highest watershed flow accumulation. Pour points were identified on the basis that the calculated watersheds cover the whole river basins. According to Horton (1945), a well-drained basin contains fifth-order stream channels; following this principle, pour points were selected in order to create watersheds of at least fifth-order stream channels.

2.3 Quantitative Morphometry relationship with runoff

In the literature, it is evident that different combinations of morphometric parameters have been used for various hydrological analysis. For instance, Bajabaa et al. (2014) evaluated 26 morphometric parameters related to linear, areal, and relief characteristics. Similarly, Abdel-Fattah et al. (2017) analysed 38 parameters grouped under four classes as scale, topographic, shape, and drainage network parameters. In this work, 29 morphometric parameters were selected under the four broad classes proposed by Abdel-Fattah et al. (2017) that provided a comprehensive picture of each drainage basin. The values of selected parameters were obtained using the corresponding equations, calculated using a GIS. Table 2-1 shows selected morphometric parameters along with the associated equations.

Basin area is a common parameter used to estimate stream discharge. This normally demonstrates a strong positive correlation with peak discharge as a bigger basin will receive a higher amount of precipitation, and therefore will generate a larger pulse of runoff (Abdel-Fattah et al. 2017). Time of concentration indicates the time that water needs to reach the outlet (Bhatt and Ahmed 2014). An inverse correlation exists between the time of concentration and runoff generation. A longer time of concentration of a basin means a higher probability of ground water recharge, hence less runoff (Bajabaa et al. 2014).

Various topographic parameters, including slope, elevation, relief, and ruggedness number, can influence flash flood occurrence. For instance, a steep slope increases the speed of runoff, therefore increasing the probability of inundation of areas with relatively gentle slope and elevation (Kabenge et al. 2017). On the other hand, a low surface slope reduces runoff velocity, providing a greater degree of surface infiltration and water recharge, and lowering peak flow (Bajabaa et al. 2014). A ruggedness number is the product of drainage density and relief divided by 1000. A ruggedness < 1 means smooth topography; a value of 1–2 indicates sharper topography, and extreme values (> 2) indicate 'badland' (areas where the bedrock is poorly cemented) topography. Watersheds with a high ruggedness number therefore receive a higher discharge, leading to a greater probability of flash flooding
occurring (Farhan et al. 2017).

Table 2-1

Parameters	Formula	Reference
Basin Area, A (km^2)	Area of each watershed	
Basin Perimeter, P	Perimeter of each watershed	
Time of concentration, Tc	$T_c = 0.542(L_{ms} / S_{ms})$	Abdel-Fattah et al. (2017)
Mean elevation, H	Mean elevation of each watershed	
Max. height of basin, H	Max. elevation of each	

	watershed	
Height of Basin Outlet, H	Elevation at pour points	
Total Basin Relief, R (m)	$R = H_{max} - H_{min}$	Schumm (1956)
Relief Ratio, R	$R_{hl} = R/L_b$	
Ruggedness number, R	$R_n = D_d \times (R/1000)$	Melton (1957)
Mean Basin Slope, S b	Avr. slope of each watershed	
Mainstream Slope, S	Avr. mainstream slope of each watershed	
Slope ratio, S	$S_r = S_{ms} / S_b$	Horton (1945)
Longest stream slope, S	Average slope of longest stream in each watershed	
Form Factor, F	$F = A/L_b^2$	Horton (1932)
Compactness Ratio, C	$C = P / 2\sqrt{\pi A}$	
Elongation Ratio, R	$R\,e = \sqrt{(A/\pi/L_b)}$	Schumm (1956)
Circularity Ratio, R	$R\,c = 4\pi A/P^2$	
Stream Order, U	Number of stream orders in each watershed	Strahler (1952)
Stream Number, N	Total stream number in each watershed	
Stream Length, L	Total stream length in each watershed	
Mainstream Length, L	Mainstream length in each watershed	
Stream Frequency, F	$F_s = N_u / A$	Horton (1945)
Drainage Density, D	$D_d = L_u / A$	
Drainage Texture, T	$T = D_d / F_s$	Smith (1950)
Bifurcation ratio, R	$R_{bu} = N_u / N_{u+1}$	Horton (1945)

The values of different shape parameters can also explain the volume and intensity of runoff in watersheds. One such parameter is the form factor which characterizes the runoff intensity in a basin. The higher the form factor value, the less the elongation of a basin, meaning that flow peaks over a shorter time period. The form factor value of a perfectly circular basin should be less than 0.79 (Farhan et al. 2017). The elongation ratio is 'the ratio between the diameter of a circle with the same area as the basin and the maximum length of the basin as measured for the relief ratio' (Schumm 1956). It maintains an inverse relationship with higher runoff as, for a given rainfall event, the basin with the smaller elongation ratio will generate a higher peak discharge. The elongation ratio can vary from 0.6 to 1.0, with a value close to 1.0 indicating low basin relief (Stralher 1964). Another shape parameter is the circularity ratio, which denotes the ratio of a circumference of a circle having the same area as the catchment to its perimeter (Schumm 1956). This ratio carries a positive correlation with runoff generation as watersheds with a higher circularity ratio are characterized by high relief, are less elongated, and less permeable, and hence have a
higher probability of generating a greater quantity of runoff (Farhan et al. 2017).

The runoff generation potential of a basin also varies with the different properties of stream systems. For instance, stream numbers are positively correlated with volume of runoff (Youssef et al. 2011). The total stream length of different watersheds is a major hydrological property that positively influences generation of runoff (Farhan et al. 2017). Longer stream length is responsible for a higher volume of runoff, leading to a flash flood occurrence (Bajabaa et al. 2014; Youssef et al. 2011). Stream frequency is defined as the number of streams per unit of basin area, and drainage density is the ratio of total streams length to a basin area (Horton 1945).

These two parameters are positively correlated with generation of runoff (Farhan et al. 2017). Generally, watersheds with low drainage density create suitable conditions for infiltration. Conversely, high stream frequency refers to areas of impermeable sub-surface material and reduced infiltration capacity (Youssef et al. 2011).

Table 2-2

Parameters	Correlation with peak runoff	Reference\
Basin area (A)	(+)	Abdel-Fattah et al. (2017) and Youssef et al. (2011)
Basin length (L_b)	(+)	Abdel-Fattah et al. (2017) and Bajabaa et al. (2014)
Time of concentration (T_c)	(-)	Youssef et al. (2011)
Mean elevation (H_m)	(+)	Abdel-Fattah et al. (2017) and Bajabaa et al. (2014)
Total Basin Relief (R)	(+)	Abdel-Fattah et al. (2017), Bajabaa et al. (2014) and Youssef et al. (2011)
Relief ratio (R_{hl})	(+)	Abdel-Fattah et al. (2017) and Youssef et al. (2011)
Ruggedness number (R_n)	(+)	Farhan et al. (2017)
Mean basin slope (S_b)	(+)	Abdel-Fattah et al. (2017), Bajabaa et al. (2014) and Schmidt et al. (2000)
Mainstream slope (S_{ms})	(+)	Abdel-Fattah et al. (2017)
Slope ratio (S_r)	(-)	Abdel-Fattah et al. (2017)
Longest stream slope (S_{ls})	(+)	Schmidt et al. (2000)
Form factor (F)	(+)	Abdelkareem (2017), Farhan et al. (2017) and Youssef et al. (2011)
Compactness ratio (C)	(-)	Youssef et al. (2011)
Circularity ratio (R_c)	(+)	Abdel-Fattah et al. (2017), Farhan et al. (2017) and Youssef et al. (2011)
Elongation ratio (R_e)	(-)	Bajabaa et al. (2014) and Youssef et al. (2011)
Total stream number (N_u)	(+)	Abdel-Fattah et al. (2017) and Youssef et al. (2011)
Total stream length (L_u)	(+)	Youssef et al. (2011)
Mainstream length (L_{ms})	(+)	Abdel-Fattah et al. (2017)
Stream frequency (F_s)	(+)	Youssef et al. (2011)
Drainage density (D_d)	(+)	Youssef et al. (2011)
Mean bifurcation ratio (B_w)	(-)	Bajabaa et al. (2014)

2.4 Dominant factor normalization

A rank (y) was assigned to each watershed according to the level of contribution to the stream runoff using a relative ranking method in which 1 denotes a very low and 5 a very high susceptibility in relation to the value of each morphometric parameter (x). Ranks were estimated by applying a linear interpolation technique. If the value of a morphometric parameter is positively correlated with the occurrence of a flash flood event, then Eq. 1 is used. Otherwise, Eq. 2 is applied.

$$y = \frac{(y_2 - y_1)(x_n - x_{min})}{(x_{max} - x_{min})} + y_1 \qquad (1)$$

$$y = \frac{(y_2 - y_1)(x_n - x_{min})}{(x_{min} - x_{max})} + y_1 \qquad (2)$$

y is the susceptibility rank of a parameter for the n th watershed (n = 1, 2, 3, …., n); the maximum rank $y_2 = 5$; minimum rank $y_1 = 1$; x_n is the value of a parameter for the nth watershed; x_{max} is the maximum value of a parameter among all watersheds, and x_{min} is the minimum value of a parameter among all watersheds. Then, the maps of each morphometric parameter were used to estimate the rank of each of the sub basins. The aggregate map was categorized using Eq. (1) into five susceptibility classes, "Very Low", "Low", "Moderate", "High", "Very High".

Appendix 5.1: California Integrated Waste Management Board's List of Materials Condensed List of Material Types

The list below was used to track composition data throughout this report. It is a condensed version of the 98 material types (shown in bold type) that were used for sorting.

	Paper		
		Uncoated Corrugated Cardboard and Paper Bags	
1			Uncoated Corrugated Cardboard
2			Paper Bags
3		Newspaper	
		Office Paper	
4			White Ledger
5			Colored Ledger
6			Computer Paper
7			Other Office Paper
		Miscellaneous Paper	
8			Magazines and Catalogs
9			Phone Books and Directories
10			Other Miscellaneous Paper
11		Remainder/Composite Paper	
	Glass		
12		Clear Glass Bottles and Containers	
13		Green Glass Bottles and Containers	
14		Brown Glass Bottles and Containers	
15		Other Colored Bottles and Containers	
16		Flat Glass	
17		Remainder/Composite Glass	
	Metal		
		Ferrous Metals	
18			Tin/Steel Cans
19			Major Appliances
20			Used Oil Filters*
21			Other Ferrous
		Non-Ferrous Metals	
22			Aluminum Cans
23			Other Non-Ferrous
24		Remainder/Composite Metal	
	*NOTE: This type was previously classified under "Other Ferrous."		
	Electronics*		
25			Brown Goods
26			Computer-related Electronics
27			Other Small Consumer Electronics
28			Television and Other Items with CRTs
	*NOTE: These types were previously classified under "Remainder/Composite Metal."		
	Plastic		
29		PET Containers	
30		HDPE Containers	
31		Miscellaneous Plastic Containers	
		Film Plastic*	
32			Trash Bags
33			Grocery and Other Merchandise Bags
			Non-Bag Commercial and Industrial Packaging Film

34			
35		Fi	lm Products
36		O	ther Film
37		Durable Plastic Items	
38		Remainder/Composite Plastic	
		*NOTE: These types were previously classified under the more general type "Film Plastic."	
	Other Organic Materials		
39		Food	
		Landscape and Agricultural	
40			Leaves and Grass
41			Prunings and Trimmings
42			Branches and Stumps
43			Agricultural Crop Residues
		Miscellaneous Organic	
44			Manures
45			Textiles
46			Carpet*
47			Remainder/Composite Organic
	*NOTE: Previously classified under "Remainder/Composite Organic."		
	Construction & Demolition		
48		Concrete	
49		Asphalt Paving	
50		Asphalt Roofing	
51		Lumber	
52		Gypsum Board	
53		Rock, Soil and Fines	
54		Remainder/Composite Construction & Demolition	
	Household Hazardous Waste		
55		Paint	
56		Vehicle and Equipment Fluids	
57		Used Oil	
58		Batteries	
59		Remainder/Composite Household Hazardous	
	Special Waste		
60		Ash	
61		Sewage Solids	
62		Industrial Sludge	
63		Treated Medical Waste	
64		Bulky Items	
65		Tires	
66		Remainder/Composite Special Waste	
67	Mixed Residue		

Expanded List of Material Types

The list below shows a hierarchy of material classes and sub-classes. As part of the Statewide Waste Characterization Study, solid waste was sorted into the 98 specific material types shown in bold type, and composition percentages were calculated for those material types.

	Paper		
		Uncoated Corrugated Cardboard and Paper Bags	
1			Uncoated Corrugated Cardboard

2			Paper Bags
3		Newspaper	
		Office Paper	
4			White Ledger
5			Colored Ledger
6			Computer Paper
7			Other Office Paper
		Miscellaneous Paper	
8			Magazines and Catalogs
9			Phone Books and Directories
10			Other Miscellaneous Paper
11		Remainder/Composite Paper	
	Glass		
		Clear Glass Bottles and Containers	
12			Clear Glass Small CRV
13			Clear Glass Large CRV
14			Clear Glass Non-CRV
		Green Glass Bottles and Containers	
15			Green Glass Small CRV
16			Green Glass Large CRV
17			Green Glass Non-CRV
		Brown Glass Bottles and Containers	
18			Brown Glass Small CRV
19			Brown Glass Large CRV
20			Brown Glass Non-CRV
		Other Colored Glass Bottles and Containers	
21			Other Colored Glass Small CRV
22			Other Colored Glass Large CRV
23			Other Colored Glass Non-CRV
24		Flat Glass	
25		Remainder/Composite Glass	
	Metal		
		Ferrous Metals	
26			Tin/Steel Cans
27			Small CRV Bimetal Cans
28			Large CRV Bimetal Cans
29			Major Appliances
30			Used Oil Filters*
31			Other Ferrous
		Non-Ferrous Metals	
32			Small CRV Aluminum Cans
33			Large CRV Aluminum Cans
34			Non-CRV Aluminum Cans
35			Other Non-Ferrous
36		Remainder/Composite Metal	
	*NOTE: This type was previously classified under “Other Ferrous.”		
	Electronics*		
37			Brown Goods
38			Computer-Related Electronics
39			Other Small Consumer Electronics
40			Television and Other Items with CRTs
	*NOTE: These types were previously classified under “Remainder/Composite Metal.”		
	Plastic		
		PET Containers	

41			RPPC Small CRV PET Bottles
42			RPPC Large CRV PET Bottles
43			RPPC Non-CRV PET Bottles
44			Other RPPC PET Containers
45			Non-RPPC Non-CRV PET Containers
		HDPE Containers	
46			RPPC CRV Small HDPE Natural Bottles
47			RPPC CRV Large HDPE Natural Bottles
48			RPPC Non-CRV HDPE Natural Bottles
49			RPPC CRV Small HDPE Colored Bottles
50			RPPC CRV Large HDPE Colored Bottles
51			RPPC Non-CRV HDPE Colored Bottles
52			Other RPPC HDPE Containers
53			Non-RPPC Small CRV HDPE Containers
54			Non-RPPC Non-CRV HDPE Containers
		Miscellaneous Plastic Containers	
55			RPPC Small CRV Bottles not HDPE or PET
56			RPPC Large CRV Bottles not HDPE or PET
57			RPPC Non-CRV Bottles not HDPE or PET
58			RPPC Clamshells not HDPE or PET
59			Other RPPC Containers not HDPE or PET
60			Non-RPPC Small CRV Miscellaneous Plastic Containers
61			Non-RPPC Non-CRV Miscellaneous Plastic Containers
		Film Plastic*	
62			Trash Bags
63			Grocery and Other Merchandise Bags
64			Non-Bag Commercial and Industrial Packaging Film
65		Fi	lm Products
66		O	ther Film
		Durable Plastic Items	
67			RPPC HDPE Buckets
68			Other Durable Plastic Items
69		Remainder/Composite Plastic	
		*NOTE: These types were previously classified under the more general type "Film Plastic."	
	Other Organic Materials		
70		Food	
		Landscape and Agricultural	
71			Leaves and Grass
72			Prunings and Trimmings
73			Branches and Stumps
74			Agricultural Crop Residues
		Miscellaneous Organic	
75			Manures
76			Textiles
77			Carpet*
78			Remainder/Composite Organic
	*NOTE: Previously classified under "Remainder/Composite Organic."		
	Construction & Demolition		
79		Concrete	
80		Asphalt Paving	
81		Asphalt Roofing	
82		Lumber	
83		Gypsum Board	

84		Rock, Soil and Fines
85		Remainder/Composite Construction & Demolition
	Household Hazardous Waste	
86		Paint
87		Vehicle and Equipment Fluids
88		Used Oil
89		Batteries
90		Remainder/Composite Household Hazardous
	Special Waste	
91		Ash
92		Sewage Solids
93		Industrial Sludge
94		Treated Medical Waste
95		Bulky Items
96		Tires
97		Remainder/Composite Special Waste
98	Mixed Residue	

PAPER

Definitions of Material Types

“Uncoated Corrugated Cardboard and Paper Bags” includes the two subtypes described below. The subtypes are “uncoated corrugated cardboard” and “paper bags.”

1. **Uncoated Corrugated Cardboard** usually has three layers. The center wavy layer is sandwiched between the two outer layers. It does not have any wax coating on the inside or outside. Examples include entire cardboard containers, such as shipping and moving boxes, computer packaging cartons, and sheets and pieces of boxes and cartons. This type does not include chipboard.

2. **Paper Bags** means bags and sheets made from Kraft paper. Examples include paper grocery bags, fast food bags, department store bags, and heavyweight sheets of Kraft packing paper.

3. **Newspaper** means paper used in newspapers. Examples include newspaper and glossy inserts, and all items made from newsprint, such as free advertising guides, election guides, plain news packing paper, stapled college schedules of classes, and tax instruction booklets.

“Office Paper” includes the four subtypes described below. The subtypes are “white ledger,” “colored ledger,” “computer paper,” and “other office paper.”

4. **White Ledger** means uncolored bond, rag, or stationary grade paper. It may have colored ink on it. When the paper is torn, the fibers are white. Examples include white photocopy, white laser print, and letter paper.

5. **Colored Ledger** means colored bond, rag, or stationery grade paper. When the paper is torn, the fibers are colored throughout. Examples include colored photocopy and letter paper. This subtype does not include fluorescent dyed paper or deep-tone dyed paper such as goldenrod colored paper.

6. **Computer Paper** means paper used for computer printouts. This subtype usually has a strip of form feed holes along two edges. If there are no holes, then the edges show tear marks. This subtype can be white or striped. Examples include computer paper and printouts from continuous feed printers. This subtype does not include “white ledger” used in laser or impact printers, nor computer paper containing groundwood.

7. **Other Office Paper** means other kinds of paper used in offices. Examples include manila folders, manila envelopes, index cards, white envelopes,

white window envelopes, white or colored notebook paper, carbonless forms, and junk mail. This subtype does not include "white ledger," "colored ledger," or "computer paper."

"Miscellaneous Paper" includes the three subtypes described below. The subtypes are "magazines and catalogs," "phone books and directories," and "other miscellaneous paper."

8. **Magazines and Catalogs** means items made of glossy coated paper. This paper is usually slick, smooth to the touch, and reflects light. Examples include glossy magazines, catalogs, brochures, and pamphlets.

9. **Phone Books and Directories** means thin paper between coated covers. These items are bound along the spine with glue. Examples include whole or damaged telephone books, "yellow pages," real estate listings, and some non-glossy mail order catalogs.

10. **Other Miscellaneous Paper** means items made mostly of paper that do not fit into any of the above subtypes. Paper may be combined with minor amounts of other materials such as wax or glues. This subtype includes items made of chipboard, groundwood paper, and deep-toned or fluorescent dyed paper. Examples include cereal and cracker boxes, unused paper plates and cups, goldenrod colored paper, school construction paper/butter paper, milk and ice-cream cartons and other frozen food boxes, unopened junk mail, colored envelopes for greeting cards, pulp paper egg cartons, unused pulp paper plant pots, and hardcover and soft cover books.

11. **Remainder/Composite Paper** means items made mostly of paper but combined with large amounts of other materials such as wax, plastic, glues, foil, food, and moisture. Examples include waxed corrugated cardboard, aseptic packages, waxed paper, tissue, paper towels, blueprints, sepia, onion skin, fast food wrappers, carbon paper, self-adhesive notes, and photographs.

GLASS

"Clear Glass Bottles and Containers" means clear glass beverage and food containers with or without a CRV label.

12. **Clear Glass Small CRV Bottles and Containers** means clear glass containers that meet the criteria for CRV containers designed to contain less than 24 ounces of material. Examples include whole or broken clear soda and fruit juice bottles, and whole or broken clear wine cooler bottles.

13. **Clear Glass Large CRV Bottles and Containers** means clear glass containers that meet the criteria for CRV containers designed to contain 24 ounces or

more of material.

14. **Clear Glass Non-CRV Bottles and Containers** means clear glass containers that do not meet the criteria for CRV containers. Examples include clear wine bottles, mayonnaise jars, and jam jars.

"Colored Glass Bottles and Containers" includes food and beverage containers of the three subtypes described below. The subtypes are "green glass bottles and containers," "brown glass bottles," and "other colored containers."

15. **Green Glass Small CRV Bottles and Containers** means green-colored glass containers that meet the criteria for CRV containers designed to contain less than 24 ounces of material. Examples include whole or broken green soda and beer bottles.

16. **Green Glass Large CRV Bottles and Containers** means green-colored glass containers that meet the criteria for CRV containers designed to contain 24 ounces or more of material.

17. **Green Glass Non-CRV Bottles and Containers** means green-colored glass containers that do not meet the criteria for CRV containers. Examples include green wine bottles.

18. **Brown Glass Small CRV Bottles and Containers** means brown-colored glass containers that meet the criteria for CRV containers designed to contain less than 24 ounces of material. Examples include whole or broken brown soda and beer bottles.

19. **Brown Glass Large CRV Bottles and Containers** means brown-colored glass containers that meet the criteria for CRV containers designed to contain 24 ounces or more of material.

20. **Brown Glass Non-CRV Bottles and Containers** means brown-colored glass containers that do not meet the criteria for CRV containers. Examples include brown wine bottles.

21. **Other Colored Glass S mall CRV Bottles and Containers** means colored glass containers bottles and containers other than green or brown that meets the criteria for CRV containers designed to contain less than 24 ounces of material. Examples include whole or broken soda bottles.

22. **Other Colored Glass Larg e CRV Bottles and Containers** means colored glass bottles and containers other than green or brown that meets the criteria for CRV containers designed to contain 24 ounces or more of material.

23. **Other Colored Glass No n-CRV Bott les and Containers** means colored glass

bottles and containers other than green or brown that does not meet the criteria for CRV containers.

24. **Flat Glass** means clear or tinted glass that is flat. Examples include glass windowpanes, doors, and tabletops, flat automotive window glass (side windows), safety glass, and architectural glass. This type does not include windshields, laminated glass, or any curved glass.

25. **Remainder/Composite Glass** means glass that cannot be put in any other type or subtype. It includes items made mostly of glass but combined with other materials. Examples include Pyrex, Corningware, crystal and other glass tableware, mirrors, non-fluorescent light bulbs, and auto windshields.

METAL

The type "ferrous metals" includes three subtypes described below. The subtypes are "tin/steel cans," "major appliances," and "other ferrous."

26. **Tin/Steel Cans** means rigid containers made mainly of steel. These items will stick to a magnet and may be tin-coated. This subtype is used to store food, beverages, paint and a variety of other household and consumer products. Examples include canned food and beverage containers, empty metal paint cans, empty spray paint and other aerosol containers, and non-CRV bimetal containers with steel sides and aluminum ends.

27. **Small CRV Bimetal Cans** means rigid container that have steel sides and aluminum ends and that meet the CRV criteria for containers designed to hold less than 24 ounces of material. These cans are often used to store beverages.

28. **Large CRV Bimetal Cans** means rigid containers that have steel sides and aluminum ends and that meet the CRV criteria for containers designed to hold 24 ounces or more of material.

29. **Major Appliances** means discarded major appliances of any color. These items are often enamel-coated. Examples include washing machines, clothes dryers, hot water heaters, stoves, and refrigerators. This subtype does not include electronics, such as televisions and stereos.

30. **Used Oil Filters** means metal oil filters used in motor vehicles and other engines, which contain a residue of used oil. NOTE: This type was previously classified under "Other Ferrous."

31. **Other Ferrous** means any iron or steel that is magnetic or any stainless steel item. This subtype does not include "tin/steel cans." Examples include structural steel beams, metal clothes hangers, metal pipes, stainless steel cookware, security bars, and scrap ferrous items.

"Non-Ferrous Metals" includes the two subtypes described below. The subtypes are "Aluminum Cans" and "Other Non-Ferrous."

32. **Small CRV Aluminum Cans** means any food or beverage container that is made mainly of aluminum and that meets the CRV criteria for containers designed to hold less than 24 ounces of material. Examples include most aluminum soda or beer cans. This subtype does not include bimetal containers with steel sides and aluminum ends.

33. **Large CRV Aluminum Cans** means any food or beverage container that is made mainly of aluminum and that meets the CRV criteria for containers designed to hold 24 ounces or more of material.

34. **Non-CRV Aluminum Cans** means any food or beverage container that is made mainly of aluminum and that does not meet the CRV criteria. Examples include some cat food and meat cans.

35. **Other Non- Ferrous** means any metal item, other than aluminum cans, that is not stainless steel and that is not magnetic. These items may be made of aluminum, copper, brass, bronze, lead, zinc, or other metals. Examples include aluminum window frames, aluminum siding, copper wire, shell casings, brass pipe, and aluminum foil.

36. **Remainder/Composite Metal** means metal that cannot be put in any other type or subtype. This type includes items made mostly of metal but combined with other materials and items made of both ferrous and non-ferrous metal combined. Examples include small non-electronic appliances such as toasters and hair dryers, motors, insulated wire, and finished products that contain a mixture of metals, or metals and other materials, whose weight is derived significantly from the metal portion of its construction.

ELECTRONICS

"Electronics" includes four subtypes described below. The subtypes are "Brown Goods," "Computer-related Electronics," "Other Small Consumer Electronics," and "Televisions and Other Items with CRTs." NOTE: These types were previously classified under "Remainder/Composite Metal."

37. **Brown Goods** means generally larger, non-portable electronic goods that have some circuitry. Examples include microwaves, stereos, VCRs, DVD players, radios, audio/visual equipment, and non-CRT televisions (such as LCD televisions).

38. **Computer-related Electronics** means electronics with large circuitry that is computer-related. Examples include processors, mice, keyboards, laptops,

disk drives, printers, modems, and fax machines.

39. **Other Small Consumer Electronics** means portable non-computer-related electronics with large circuitry. Examples include personal digital assistants (PDAs), cell phones, phone systems, phone answering machines, computer games and other electronic toys, portable CD players, camcorders, and digital cameras.

40. **Televisions and Other Items with CRTs**. Examples include televisions, computer monitors, and other items containing a cathode ray tube (CRT).

PLASTIC

NOTE: Many of the plastic types have been designed to collect information on Rigid Plastic Packaging Containers (RPPCs), a category that is subject to specific regulation. Please see the subsequent section for definitions and examples of RPPCs.

"PET Containers" means clear or colored PET containers. When marked for identification, it bears the number "1" in the center of the triangular recycling symbol and may also bear the letters "PETE" or "PET." The color is usually transparent green or clear. A PET container usually has a small dot left from the manufacturing process, not a seam. It does not turn white when bent. This includes subtypes 41–45 below.

41. **RPPC Small CRV PET Bottles** means clear or colored PET bottles designed to contain less than 24 ounces of material and meet the RPPC and CRV criteria.

42. **RPPC Large CRV PET Bottles** means clear or colored PET bottles designed to contain 24 ounces or more of material and meet the RPPC and CRV criteria.

43. **RPPC Non-CRV PET Bottles** means clear or colored PET bottles that meet the RPPC criteria but do not meet the CRV criteria.

44. **Other RPPC PET Containers** means non-bottle PET containers that meet the RPPC criteria. Includes clamshell containers.

45. **Non-RPPC Non-CRV PET Containers** means PET bottles and containers that do not meet the criteria for being either CRVs or RPPCs.

"HDPE Containers" means natural and colored HDPE containers. This plastic is usually either cloudy white, allowing light to pass through it (natural) or a solid color, preventing light from passing through it (colored). When marked for identification, it bears the number "2" in the triangular recycling symbol and may also bear the letters "HDPE." This includes types 46–54 below.

46. **RPPC CRV Small HDPE Natural Bottles** means clear/translucent HDPE bottles designed to contain less than 24 ounces of material and meet the RPPC and CRV criteria.

47. **RPPC CRV Large HDPE Natural Bottles** means clear/translucent HDPE bottles designed to contain 24 ounces or more of material and meet the RPPC and CRV criteria.

48. **RPPC Non-CRV HDPE Natural Bottles** means clear/translucent HDPE bottles that meet the RPPC criteria but do not meet the CRV criteria.

49. **RPPC CRV Small HDPE Colored Bottles** means colored, non-translucent HDPE bottles designed to contain less than 24 ounces of material and meet the RPPC and CRV criteria.

50. **RPPC CRV Large HDPE Colored Bottles** means colored, non-translucent HDPE bottles designed to contain 24 ounces or more of material and meet the RPPC and CRV criteria.

51. **RPPC Non- CRV HDPE Colored Bottles** means colored, non-translucent HDPE bottles that meet the RPPC criteria but do not meet the CRV criteria.

52. **Other RPPC HDPE Containers** means non-bottle HDPE containers that meet the RPPC criteria.

53. **Non-RPPC Small CRV HDPE Containers** means HDPE bottles and containers that do not meet the RPPC criteria but that meet the criteria for CRV containers designed to contain less than 24 ounces of material.

54. **Non-RPPC Non-CRV HDPE Containers** means HDPE bottles and containers that do not meet the criteria for being either CRVs or RPPCs.

"Miscellaneous Plastic Containers" means plastic containers made of types of plastic other than HDPE or PET. Items may be made of PVC, PP, or PS. When marked for identification, these items may bear the number "3," "4," "5," "6," or "7" in the triangular recycling symbol. This subtype also includes unmarked plastic containers. This includes types 55–61 below.

55. **RPPC Small CRV Bottles not HDPE or PET** means bottles made of types of plastic other than HDPE or PET (that is, made of types #3–7, or unmarked) that meet the RPPC and the CRV criteria for plastic items that contain less than 24 ounces of material.

56. **RPPC Large CRV Bottle s not HDPE or PET** means bottles made of types of plastic other than HDPE or PET (that is, made of types #3–7, or unmarked) that meet the RPPC and the CRV criteria for plastic items that contain 24

ounces or more of material.

57. **RPPC non-CRV Bottles not HDPE or PET** means bottles made of types of plastic other than HDPE or PET (that is, made of types #3–7, or unmarked) that meet the RPPC criteria but do not meet the CRV criteria.

58. **RPPC Clamshells not HDPE or PET** means clamshell packaging that meets the RPPC criteria, made out of plastic types #3-7 or unmarked. This category includes polystyrene egg cartons.

59. **Other RPPC Containers not HDPE or PET** means other plastic containers of types #3-7, or unmarked, that meet the RPPC criteria.

60. **Non-RPPC Small CRV Miscellaneous Plastic Containers** means other containers made of types #3-7 that do not meet the RPPC criteria but do meet the CRV criteria for plastic items that contain less than 24 ounces of material.

61. **Non-RPPC non-CRV Miscellaneous Plastic Containers** means other containers made of types #3-7 that do not meet the RPPC criteria or the CRV criteria. This includes single-serving drink cups from take-away food stores and restaurants.

"Film Plastic" means flexible plastic sheeting. It is made from a variety of plastic resins including HDPE and LDPE. It can be easily contoured around an object by hand pressure. This includes types 62–66 below. NOTE: These types were previously classified under the more general type "Film Plastic."

62. **Trash Bags** means plastic bags sold for use as trash bags, for both residential and commercial use. Does not include other plastic bags like shopping bags that might have been used to contain trash.

63. **Grocery and Other Merchandise** Bags means plastic shopping bags used to contain merchandise to transport from the place of purchase, given out by the store with the purchase. Includes dry-cleaning plastic bags intended for one-time use.

64. **Non-Bag Commercial and Industrial Packaging Film** means film plastic used for large- scale packaging or transport packaging. Examples include shrink-wrap, mattress bags, furniture wrap, and film bubble wrap.

65. **Film Products** means plastic film used for purposes other than packaging. Examples include agricultural film (films used in various farming and growing applications, such as silage greenhouse films, mulch films, and wrap for hay bales), plastic sheeting used as drop cloths, and building wrap.

66. **Other Film** means all other plastic film that does not fit into any other type. Examples include other types of plastic bags (sandwich bags, zipper-recloseable bags, newspaper bags, produce bags, frozen vegetable bags, bread bags), food wrappers such as candy-bar wrappers, mailing pouches, bank bags, X-ray film, metallized film (wine containers and balloons), and plastic food wrap.

"Durable Plastic Items" means plastic objects other than disposable package items. These items are usually made to last for a few months up to many years. These include the plastics used in construction, communication, electrical and electronics, furniture, transportation, and recreation industries. This includes types 67–68 below.

67. **RPPC HDPE Buckets** means colored and natural buckets and pails made of HDPE and designed to hold 5 gallons or less of material. This category includes buckets regardless of whether they are attached to metal handles. Examples include large paint buckets and commercial buckets used to contain food for commercial use (restaurants, etc.). These objects are packages containing material for sale, and are not sold as buckets themselves (such as mop buckets).

68. **Other Durable Plastic Items** means all other plastic objects other than containers, film plastic, or HDPE buckets. Examples include mop buckets, plastic outdoor furniture, plastic toys, CD's, plastic stay straps, and sporting goods, and plastic house wares such as dishes, cups and cutlery. This type also includes building materials such as house siding, window sashes and frames, housings for electronics (such as computers, televisions and stereos), fan blades, impact-resistance cases (for example, tool boxes, first aid boxes, tackle boxes, sewing kits, etc.), and plastic pipes and fittings.

69. **Remainder/Composite Plastic** means plastic that cannot be put in any other type or subtype. They are usually recognized by their optical opacity. This type includes items made mostly of plastic but combined with other materials. Examples include auto parts made of plastic attached to metal, plastic drinking straws, foam drinking cups, produce trays, foam meat and pastry trays, foam packing blocks, packing peanuts, foam plates and bowls, plastic strapping, plastic lids, some kitchen ware, toys, new plastic laminate (for example, Formica), vinyl, linoleum, plastic lumber, insulating foams, imitation ceramics, handles and knobs, plastic string (such as is used for hay bales), and plastic rigid bubble/foil packaging (as for medications).

ORGANIC

70. **Food** means food material resulting from the processing, storage, preparation, cooking, handling or consumption of food. This type includes

material from industrial, commercial or residential sources. Examples include discarded meat scraps, dairy products, egg shells, fruit or vegetable peels, and other food items from homes, stores and restaurants. This type includes grape pomace and other processed residues or material from canneries, wineries or other industrial sources.

"Landscape and Agricultural" includes the four subtypes described below. The subtypes are "Leaves and Grass," "Prunings and Trimmings," "Branches and Stumps," and "Agricultural Crop Residues."

71. **Leaves and Grass** means plant material, except woody material, from any public or private landscapes. Examples include leaves, grass clippings, sea-weeds and plants. This subtype does not include woody material or material from agricultural sources.

72. **Prunings and Trimmings** means woody plant material up to 4 inches in diameter from any public or private landscape. Examples include prunings, shrubs and small branches with branch diameters that do not exceed 4 inches. This subtype does not include stumps, tree trunks, or branches exceeding 4 inches in diameter. This subtype does not include material from agricultural sources.

73. **Branches and Stumps** means woody plant material, branches and stumps that exceed four inches in diameter from any public or private landscape.

74. **Agricultural Crop Residues** means plant material from agricultural sources. Examples include orchard and vineyard prunings, vegetable by-products from farming, residual fruits, vegetables, and other crop remains after usable crop is harvested. This subtype does not include processed residues from canneries, wineries, or other industrial sources.

"Miscellaneous Organic" includes three subtypes described below. The subtypes are "Manures," "Textiles," and "Carpet."

75. **Manures** means manure and soiled bedding materials from domestic, farm, or ranch animals. Examples include manure and soiled bedding from animal production operations, racetracks, riding stables, animal hospitals and other sources.

76. **Textiles** means items made of thread, yarn, fabric, or cloth. Examples include clothes, fabric trimmings, draperies, and all natural and synthetic cloth fibers. This subtype does not include cloth-covered furniture, mattresses, leather shoes, leather bags or leather belts.

77. **Carpet** means flooring applications consisting of various natural or synthetic fibers bonded to some type of backing material. Does not include carpet padding. *NOTE: Previously classified under "Remainder/Composite

Organic."

78. **Remainder/Composite Organic** means organic material that cannot be put in any other type or subtype. This type includes items made mostly of organic materials but combined with other materials. Examples include leather items, cork, hemp rope, garden hoses, rubber items, hair, carpet padding, cigarette butts, diapers, feminine hygiene products, wood products (popsicle sticks and toothpicks), sawdust, and animal feces.

CONSTRUCTION & DEMOLITION

79. **Concrete** means a hard material made from sand, gravel, aggregate, cement mix, and water. Examples include pieces of building foundations, concrete paving, and cinder blocks.

80. **Asphalt Paving** means a black or brown, tar-like material mixed with aggregate used as a paving material.

81. **Asphalt Roofing** means composite shingles and other roofing material made with asphalt. Examples include asphalt shingles and attached roofing tar and tar paper.

82. **Lumber** means processed wood for building, manufacturing, landscaping, packaging, and processed wood from demolition. Examples include dimensional lumber, lumber cutoffs, engineered wood such as plywood and particleboard, wood scraps, pallets, wood fencing, wood shake roofing, and wood siding.

83. **Gypsum Board** means interior wall covering made of a sheet of gypsum sandwiched between paper layers. Examples include used or unused, broken or whole sheets of sheetrock, drywall, gypsum board, plasterboard, gypboard, gyproc, and wallboard.

84. **Rock, Soil and Fines** means rock pieces of any size and soil, dirt, and other matter. Examples include rock, stones, and sand, clay, soil, and other fines. This type also includes non- hazardous contaminated soil.

85. **Remainder/Composite Construction & Demolition** means construction and demolition material that cannot be put in any other type or subtype. This type may include items from different types combined, which would be very hard to separate. Examples include brick, ceramics, tiles, toilets, sinks, dried paint not attached to other materials, and fiberglass insulation. This type may also include demolition debris that is a mixture of items such as plate glass, wood, tiles, gypsum board, and aluminum scrap.

HOUSEHOLD HAZARDOUS WASTE

86. **Paint** means containers with paint in them. Examples include latex paint, oil based paint, and tubes of pigment or fine art paint. This type does not include dried paint, empty paint cans, or empty aerosol containers.

87. **Vehicle and Equipment Fluids** means containers with fluids used in vehicles or engines, except used oil. Examples include used antifreeze and brake fluid. This type does not include empty vehicle and equipment fluid containers.

88. **Used Oil** means the same as defined in Health and Safety Code section 25250.1(a). Examples include spent lubricating oil such as crankcase and transmission oil, gear oil, and hydraulic oil.

89. **Batteries** mean any type of battery including both dry cell and lead acid. Examples include car, flashlight, small appliance, watch, and hearing aid batteries.

90. **Remainder/Composite Household Hazardous** means household hazardous material that cannot be put in any other type or subtype. This type also includes household hazardous material that is mixed. Examples include household hazardous waste which if improperly put in the solid waste stream may present handling problems or other hazards, such as pesticides, caustic cleaners, and fluorescent light bulbs.

SPECIAL WASTE

91. **Ash** means a residue from the combustion of any solid or liquid material. Examples include ash from structure fires, fireplaces, incinerators, biomass facilities, waste-to-energy facilities, and barbecues.

92. **Sewage Solids** means residual solids and semi-solids from the treatment of domestic waste water or sewage. Examples include biosolids, sludge, grit, screenings, and septage. This category does not include sewage or waste water discharged from the sewage treatment process.

93. **Industrial Sludge** means sludge from factories, manufacturing facilities, and refineries. Examples include paper pulp sludge, and water treatment filter cake sludge.

94. **Treated Medical Waste** means medical waste that has been processed in order to change its physical, chemical, or biological character or composition, or to remove or reduce its harmful properties or characteristics, as defined in section 25123.5 of the California Health and Safety Code.

95. **Bulky Items** means large hard-to-handle items that are not defined separately, including furniture, mattresses, and other large items.

Examples include all sizes and types of furniture, mattresses, box springs, and base components.

96. **Tires** mean vehicle tires. Examples include tires from trucks, automobiles, motorcycles, heavy equipment, and bicycles.

97. **Remainder/Composite Special Waste** means special waste that cannot be put in any other type. Examples include asbestos-containing materials, such as certain types of pipe insulation and floor tiles, auto fluff, auto-bodies, trucks, trailers, truck cabs, untreated medical waste/pills/ hypodermic needles, and artificial fireplace logs.

MIXED RESIDUE

98. Mixed Resid ue means material that cannot be put in any other type or subtype in the other types. This category includes mixed residue that cannot be further sorted. Examples include clumping kitty litter and residual material from a materials recovery facility or other sorting process that cannot be put in any of the previous remainder/composite types.

Definitions of RPPCs and CRV Containers

In coordination with classifying all materials according to the 98 material types, certain plastic materials were classified as RPPC (Rigid Plastic Packaging Containers) from each sample into the nine types listed below:

Table B-1: Definitions of RPPC and CRV Containers

	RPPC Material	Description and Examples
1	RPPC PET (#1) Bottles	PET bottles containing beverages or other liquids. Examples include bottles for soda pop, some sports drinks, sparkling waters, cooking oil, shampoo, and some liquors.
2	RPPC PET (#1) Other Containers	PET containers and packages, other than bottles, that are recloseable. Examples include packages containing small toys or hardware items.
3	RPPC HDPE (#2) Natural Bottles	Primarily milk jugs and some juice bottles.
4	RPPC HDPE (#2) Colored Bottles	Any HDPE bottle that is not clear/translucent. Examples include some orange juice bottles, many laundry detergent bottles, and some shampoo bottles.
5	RPPC HDPE (#2) Other Containers	Examples include some margarine containers, some food jars, and some yogurt containers.
6	RPPC #3–#7 Bottles	All plastic bottles that are not PET or HDPE. Examples include some sports drink bottles, many shampoo bottles, and some detergent bottles.
7	RPPC #3–#7 Clamshells	Food clamshell containers such as those often used by restaurants, delicatessens and fast food restaurants; and non-food clamshells used for packaging such as for hardware, electronics, automotive parts, sports gear,

	RPPC Material	Description and Examples
		safety equipment, and personal care products.
8	RPPC #3–#7 Other Containers	Includes containers for some prepared foods, such as chip dip. Also includes some yogurt and margarine containers.
9	RPPC HDPE (#2) Buckets	HDPE buckets, often used as containers for paint and other household chemicals and building materials. These buckets are sometimes used for shipment of bulk foods.

A container must meet all of the following criteria to be considered an RPPC:

- It is made entirely of plastic, except that lids, caps, or labels may be made of some other material.
- It is capable of maintaining its shape while holding a product.
- It has an attached or unattached lid or cap.
- Contains at least 8 fluid ounces but no more than 5 gallons, or the equivalent volumes.

Also, certain glass, plastic, and metal containers were classified as CRV (California Redemption Value) containers. CRV containers were defined for sorting as beverage containers that display the CRV notification. Generally, CRV containers include carbonated soft drinks, beer, bottled water, and juice and sports drinks. For more details, see the Department of Conservation, Division of Recycling websites at www.bottlesandcans.com/what_main.html and www.consrv.ca.gov/dor/crcp/recyclers/Images/Act-2004.pdf.

Appendix 5.2: Volume-to-Weight Conversion Factors

(Guidelines for Waste Characterization Studies in the State of Washington)

The following table provides material density estimates for use in visual waste characterization methods. It is important to note that the density figures presented here are estimates intended for use as "rules of thumb." Situations often exist where the actual density of each material differs from the figure presented here.

1 pounds per (cubic yard) = 0.593276421 kg per (cubic meter)

Material	Density (lbs per cubic yard)	Source
Paper		
Newspaper	400	EPA Business Guide
Cardboard	50	Tellus
Other Groundwood	250	EPA Government Guide
High-Grade Paper	364	Tellus
Magazines	400	EPA Government Guide
Mixed / Low-Grade Paper	364	EPA Government Guide
Compostable Paper	903	Cascadia
Remainder/Composite Paper		
Process Sludge / Other Industrial Sludge		
Plastic		
PET Bottles	35	EPA Government Guide
HDPE Bottles, CLEAR	24	EPA Government Guide
HDPE Bottles, COLORED	24	EPA Government Guide
Film and Bags	23	Tellus
Bottles Types 3 - 7		
Expanded Polystyrene	22	Tellus
Other Rigid Plastic Packaging	50	EPA Government Guide
Other Plastic Products		
Remainder/Composite Plastic	50	EPA Government Guide
Organics		
Yard, Garden and Prunings	108	EPA Business Guide
Food Waste	1,443	Tellus
Manures	1,628	Tellus
Disposable Diapers		
Carcasses, Offal		
Crop Residues	910	Cascadia
Septage		
Remainder/Composite Organics		

Material	Density (lbs per cubic yard)	Source
Wood Wastes		
Natural Wood	330	CIWMB
Treated Wood	330	CIWMB
Painted Wood	330	CIWMB
Dimensional Lumber	330	Tellus
Engineered	425	Tellus
Packaging		
Other Untreated Wood	330	CIWMB
Wood Byproducts	375	Tellus
Remainder/Composite Wood		
Construction, Demolition & Landclearing Wastes		
Insulation	17	CIWMB
Asphalt	1,215	FEECO
Concrete	2,700	FEECO
Drywall	394	Tellus
Soil, Rocks & Sand	2,200	Average of CIWMB figures
Roofing Waste	600	Average of figures from San Diego, CIWMB, Cascadia
Ceramics	320	Cascadia measurement
Remainder/Composite C&D		
Glass		
Clear Beverage Glass	600	EPA Government Guide
Green Beverage Glass	600	EPA Government Guide
Brown Beverage Glass	600	EPA Government Guide
Clear Container Glass	600	EPA Government Guide
Green Container Glass	600	EPA Government Guide
Brown Container Glass	600	EPA Government Guide
Plate Glass	1,000	EPA Government Guide
Remainder/Composite Glass	1,000	EPA Government Guide
Non-glass Ceramics		
Metal		
Aluminum Cans	91	Tellus
Aluminum Foil / Containers		
Other Aluminum	175	Tellus
Copper	1,094	Tellus
Other Non-Ferrous Metals		
Tin Cans	850	EPA Business Guide
White Goods	180	EPA Government Guide
Other Ferrous	906	EPA Business Guide
Remainder/Composite Metals		

Material	Density (lbs per cubic yard)	Source
Consumer Products		
Computers	440	Cascadia
Other Electronics	440	Cascadia
Textiles, SYNTHETIC		
Textiles, ORGANIC		
Textiles, MIXED/Unknown		
Shoes		
Tires & Other Rubber	380	Cascadia
Furniture & Mattresses		
Carpet	305	San Diego
Carpet Padding		
Rejected Products	340	FEECO
Returned Products		
Other Composite		
Residuals		
Ash	1,000	FEECO
Dust		
Fines / Sorting Residues	2,700	Tellus
Sludge & Other Indust.		
Hazardous and Special Wastes		
Used Oil		
Oil Filters	200	Minnesota
Antifreeze		
Auto Batteries		
Household Batteries		
Pesticides & Herbicides		
Latex Paint	1,600	Cascadia
Oil Paint	1,200	Cascadia
Medical Waste		
Fluorescent Tubes	300	Cascadia
Asbestos		
Other Hazardous Waste		
Other Non-hazardous Waste		

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