Project No. PJ1819/1/443

Assessment and Characterization of Plastic Waste in NCT of Delhi

(July-2020)

Submitted To

Department of Environment,
Govt. of NCT of Delhi
Level 6th C-Wing, Delhi Secretariat
I.P.Estate, New Delhi-110 002

Submitted By

Shriram Institute for Industrial Research
(A Unit of Shriram Scientific & Industrial Research Foundation)
19, University Road, Delhi-110 007 (India)

Information Format

Project Title	**Assessment and Characterization of Plastic Waste in NCT of Delhi**
Project Authority	Department of Environment Govt. of NCT of Delhi IP Estate, New Delhi
Contract No.	F.12 (579)/Env/Plastic Study/2018/1430-1446
Project No.	PJ1819/1/443
No. of Pages	133

Project Incharge

Authorised Signatory

SHRIRAM

Shriram Institute for Industrial Research

(A Unit of Shriram Scientific & Industrial Research Foundation)

19, University Road, Delhi-110 007

Table of Content

List of Figures

List of Tables

List of Abbreviations

ABS	:	Acrylonitrile butadiene styrene
AFR	:	Alternative Fuels or Raw material
ASTM	:	American Society for Testing and Materials
BIS	:	Bureau of Indian Standards
BMP	:	Bulk Moulding Products
CAGR	:	Compounded Annual Growth Rate
CGWB	:	Central Ground Water Board
CIPET	:	Central Institute of Plastic Engineering and Technology
CPCB	:	Central Pollution Control Board
DCB	:	Delhi Cantonment Board
DOE	:	Department of Environment, Govt. of NCT of Delhi
DU	:	University of Delhi
EDMC	:	East Delhi Municipal Corporation
EPR	:	Extended Producer Responsibility
EPS	:	Expanded polystyrene
FCTS	:	Fixed Compactor Transfer Station
FP	:	Food Product
FRP	:	Fibre Reinforced Plastics
GAIA	:	Global Alliance for Incinerator Alternatives
GNCTD	:	Government of National Capital Territory of Delhi
GPS	:	Global Positioning System
HDPE	:	High Density Polyethylene
HP	:	Hard Plastic
HP	:	Household Care Products
IEC	:	Information, Education and Communication
IRC: SP	:	Indian Road Congress Specification
ITS	:	Indirect Tensile Strength
Kg	:	Kilogram
KII	:	Key Informant Interview
LDPE	:	Low Density Polyethylene
LLDPE	:	Linear low-density polyethylene
LNG	:	Liquefied Natural Gas

LPG	:	Liquefied Petroleum Gas
ML	:	Multi-layered
MLP	:	Multi Layered Plastic
MMT	:	Million Metric Tonnes
MoEF&CC	:	Ministry of Environment, Forests & Climate Change
MSMEs	:	Micro, Small and Medium Enterprises
MSW	:	Municipal Solid Waste
MT	:	Metric Tonne
NCT	:	National Capital Territory
NDMC	:	North Delhi Municipal Corporation
NDMC	:	New Delhi Municipal Council
PBS	:	Poly (butylene succinate)
PBT	:	Polybutylene terephthalate
PC	:	Polycarbonate
PC	:	Personal Care Products
PCL	:	Polycaprolactone
PE	:	Polyethylene
PEF	:	Process Engineered Fuel
PET	:	Polyethylene terephthalate
PETE	:	Polyethylene terephthalate
PHA	:	Polyhydroxyalkanoates
PLA	:	Polylactic acid
PMMA	:	Polymethyl methacrylate
PP	:	Polypropylene
PPO	:	Poly(p-phenylene oxide)
PS	:	Polystyrene
PUF	:	Polyurethane Foam
PVA	:	Polyvinyl alcohol
PVC	:	Polyvinyl Chloride
PVDC	:	Polyvinylidene chloride
PW	:	Plastic Waste
PWM	:	Plastic Waste Management
QA	:	Quality Assurance
QC	:	Quality Control

RDF	:	Refuse Derived Fuel
RPF	:	Refuse-derived Paper and Plastic densified fuel
SL	:	Single-layer
SDMC	:	South Delhi Municipal Corporation
SMC	:	Sheet Moulding Compound
SOP	:	Standard Operating Procedure
SPI	:	Society of Plastic Industry
SRF	:	Solid Recovered Fuel
SRI	:	Shriram Institute for Industrial Research
SW	:	Solid Waste
TGA	:	Thermo Gravimetric Analysis
TPD	:	Tonnes per Day
TPS	:	Thermoplastic starch
ULB	:	Urban Local Body
UNEP	:	United Nations Environment Programme
UT	:	Union Territory
VFB	:	Voids Filled with Bitumen
VMA	:	Voids in the Mineral Aggregate
WTE	:	Waste to Energy

Executive Summary

As consumption of plastic has increased exponentially in recent years, the indiscriminate dumping and littering of plastic waste is exerting wide spectrum of detrimental impacts on environment the magnitude of which varies from place to place. The effective implementation/ enforcement of Plastic Waste Management Rules 2016, amended 2018, in totality is always a challenge for local authorities.

The assessment and characterization plastic wastes helps to understand the magnitude of Plastic Wastes to envisage strategies for its management in efficient ways. The Department of Environment, Government of NCT of Delhi, assigned Shriram Institute for Industrial Research (SRI), a project to undertake ".Assessment and Characterization of Plastic Waste in the NCT of Delhi. The study involved assessment and characterization of plastic waste in different areas of Delhi. Altogether study has been undertaken at 59 locations in Delhi.

The protocol of ASTM as well as methodology involving quartering and coning process as given in the CPCB report (January 2015) has been followed for sampling for quantification of plastic waste from the total solid waste.

The average quantity of plastic waste at residential areas has been estimated as 8.30% (or 83.0 Kg/MT) of total solid waste, whereas at tourist areas, market places & commercial areas, public places, institutional areas and educational institutions, it is found 7.49% (or 74.9 Kg/MT), 13.12% (or 131.2 Kg/MT), 16.76% (or 167.6 Kg/MT), 10.22% (or 102.2 Kg/MT) and 15.3% (or 153.0 Kg/MT) respectively. The average plastic waste of all 59 locations has been estimated as 10.10% (or 101.0 Kg/MT) of solid waste. The total plastic waste in Delhi is estimated as 1060 Tonnes per Day (TPD), whereas the per capita per day plastic waste generation in Delhi is calculated to 53.6 gram.

The single-use plastics (SUP) with respect to total solid waste (SW) at residential areas is found 5.5% (or 54.8 Kg/MT), whereas at tourist areas, market places & commercial areas, public places, institutional areas and educational institutions, the SUP is assessed as 4.6% (or 45.9 Kg/MT), 6.2% (or 61.5 Kg/MT), 2.3% (or 22.5 Kg/MT), 5.6% (or 56.0 Kg/MT), 9.6% (or 96.4 Kg/MT respectively of total SW. On average, the SUP in NCT of Delhi is assessed as 5.6% (or 56.0 Kg/MT) of total SW.

The plastic waste reduction pathways including reuse and disposal options are illustrated in the report in addition to the alternatives to plastic. In order to devise efficient ways of Plastic Waste Management, the policy recommendations are also incorporated in this report, which includes development of Standard Operating Procedures for Plastic Waste Management by local authorities; setting-up of material recovery facilities at ward level; formulation of Extended Producers Responsibility (EPR) plan and its implementation; formulation of BIS specifications for recycled products; up-scaling and commercialization of bio-based compostable plastics; and creation of enabling environment for plastic waste management through capacity building of stakeholders.

1. Introduction

1.1 Background

The Indian market in the field of plastics products has now grown to become one of the leading sectors in the country's economy, consisting of over 30,000 processing units and employing more than 4 million people. The production of plastics comprising of LLDPE, HDPE, LDPE, PS, PP, PVC, EX-PS etc. during the FY 2014-15 was 7.557 MMT, which has grown to 10.040 MMT during FY 2018-19 at compounded annual growth rate (CAGR) of 7.36. The production of performance plastic during the FY 2018-19 was amounted to 1.589 MMT. The ever increasing consumption of plastic products because of their applications in several end uses, has increased the demand for plastic products in India.[1-4]

Also the expanding sectors such as health, pharmaceuticals and others, are significant contributor towards propelling the plastic market, which is classified on the basis of type, class, source and applications. In terms of number of application and products, polyethylene (PE) is dominating the Indian market followed by that polyvinyl chloride (PVC) and polypropylene (PP). The plastics industry in India provides material to several prominent sectors of economy like automotive, consumer packaging, and electronics. Such developments over the last few decades, resulted into the tremendous increase in the demand and usage of plastics in multifaceted areas.[1-5]

Though, the average per capita consumption of plastic in India is about 11 kg, which is spectacularly low as compared to the global average of 28 kg and per capita consumption by US (109 kg), Europe (65 kg) and China (38 kg), the CPCB/ CIPET study of Assessment and Characterization of plastic wastes in 60 cities indicated 15,342 tonnes of plastic waste generation per day. In accordance with the Plastic Waste Management Rules, 2016, as amended 2018, the information provided by 35 SPCBs/ PCCs to CPCB in context to Plastic Waste Management in respective states during the year 2018-19, indicates the estimated quantum of plastic waste amounting to 33,60,043 tonnes per annum. The statewide contribution to this estimate included maximum 12.2% from Maharashtra followed by 11.9% from Tamilnadu, 10.6% from Gujarat, 8.9% from West Bengal, 8.1% from Karnataka, 7.6% from Uttar Pradesh, 6.7% from Delhi, 5.4% from Telengana, 4.0% from Kerala, 3.1% from Rajasthan and 18.7% from other states/ UTs.[6-9]

Disposal of plastic waste is a serious environmental problem. Plastic wastes, specifically carry bags are the major environmental and public health threat, particularly in urban areas of India. The plastic bags of all sizes and thickness are often found occupying the landscape of cities due to indiscriminate use and littering. Plastic bags and disposables tend to clog drains, gutters, and rainwater vents, thereby not only causing unaesthetic visual impacts but also creating a flood-like scenario even during sparse rains. In addition, littering poses a danger to stray animals, who engulf plastic bags along with food waste. Being a non-biodegradable material, it does not decay for several years even if dumped on the landfills, ultimately finds its way back to the environment thereby causing varying magnitude of detrimental impacts. Depending upon the physical properties, the plastic can be classified as thermoplastic and thermosetting materials. Thermoplastic materials can be moulded into desired shapes on heating. When subjected to the same conditions of heat and pressure,

these can be remolded. Thermosetting materials once formulated cannot be softened/ remolded by the application of heat. Thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total post-consumer plastics waste generated in India.[6,11-13]

The examples of some typical Thermoplastic and Thermosetting materials are given below:

Thermoplastic Material (Recyclable)	Thermoset Material (Non-recyclable)
♦ Polyethylene Terephthalate (PET)	♦ Bakelite
♦ Polypropylene (PP)	♦ Epoxy
♦ Polyvinyl Acetate (PVA)	♦ Melamine
♦ Polyvinyl Chloride (PVC)	♦ Polyester
♦ Polystyrene (PS)	♦ Urea-formaldehyde
♦ Low Density Polyethylene (LDPE)	♦ Alkyd
♦ High Density Polyethylene (HDPE)	♦ Multilayered & Laminated plastic
	♦ Nylon
	♦ Polyurethane Foam (PUF)

Plastic litter, both at the macro and micro scale, is widespread and has tendency to accumulate into varying environment medium. Due to ultraviolet radiation, oxidation and mechanical forces, it is reported in various studies that plastic items breakdown into increasingly smaller microplastic fragments, below 5 mm in diameter. The distribution of microplastics in the environment is strongly dependent upon their density. The microplastic find their ways into the wide spectrum of environmental medium such as fresh water bodies, wastewater stream, sewage & effluent treatment plants, sludge, sediments, river bodies and the ultimate sink as marine environment. The problem of ocean plastic litter is on the rise due to the overflowing effect of plastic waste into the sea. The seas near Mumbai, Kerala, and the Andaman and Nicobar Islands are amongst the worst polluted in the world.[6, 14-15]

1.2 Legal Framework[6, 9,16]

In order to address the ever increasing detrimental impacts of plastic waste generation and its indiscriminant disposal, the union government promulgated the Plastic Waste Management Rules in 2011 under the Environment Protection Act of 1986 to ensure the scientific management of plastic wastes. These rules replaced the earlier Recycled Plastics Manufacture and Usage Rules, 1999 that were amended in 2003.

The rules 2011 were superseded by the Plastic Waste Management Rules, 2016. These rules seek to effectively address the concerns of plastic waste with far more comprehensive outlook.

The Plastic Waste Management 2016 rules were revised to be known as the Plastic Waste Management (Amendment) Rules 2018.

Table-1 Plastic Waste Management Rules (2011 vis-à-vis 2016 amended to 2018)

Attributes	The Plastic Waste (Management and Handling) Rules, 2011	The Plastic Waste Management Rules, 2016
Applicability	These rules are applicable to every waste generator, local body, gram panchyat, manufacturer, producer and brand owner	These rules are applicable to every waste generator, local body, gram panchyat, manufacturer, importer, producer and brand owner.
Salient features	♦ These rules addressed the issue of carry bags by setting minimum standards for the thickness and a mandate for retailers to charge a fee for each plastic bag made available. ♦ These rules included ban on plastics to be used as sachets for storing, packing or selling tobacco, *pan masala* and *gutkha*, in addition to prohibition on packaging food in packets of recycled plastics or compostable plastics. ♦ Provision for specific BIS standards for recycled carry bags and colour as per BIS specification together with uniform thickness of plastic carry bags to 40 microns and above, were also mandated. ♦ The framework created through these rules proposed assignment of responsibilities for management of plastic waste on the urban local bodies (ULBs) together with the provision to set-up a monitoring committee known as "State Level Advisory Body" at state level to oversee the functioning of ULBs in context to Plastic Waste Management. ♦ The rules mandated that "No carry bags be made available free of cost to consumers. The municipal authority may determine the minimum price for plastic carry bags.	♦ The rules extend the focus of waste management to rural areas by imposing responsibility on *gram panchayats* to create awareness and to ensure that no open burning of plastic takes place and also to make sure that segregation and channelization of such waste takes place in their jurisdiction. ♦ The minimum thickness of plastic carry bags has been increased from 40 micron to 50 micron. The rationale for doing this has dual purpose, not only will the recyclability quotient increases, the enhancement in the manufacturing cost will deter retailers from supplying bags free of cost. ♦ The rules also mandated the producers and brand owners to formulate a plan in consultation with the local bodies to introduce a collect back system, known as the Extended Producers Responsibility (EPR), which would facilitate the municipalities tackling the plastic waste management issues with regulatory support. As a part of the EPR, it also provides for collection of a fee from the producers, importers of plastic carry bags/ multilayered packaging in order to strengthen the financial status of local authorities and, therefore, the plastic waste management systems.

	♦ As per the rules the municipal authority may also direct the manufacturers to establish plastic waste collection centres, either collectively or individually, in line with the principle of 'Extended Producers Responsibility'. ♦ The rules have stipulated provisions for marking or labeling to indicate name, registration number of the manufacturer, thickness and also to indicate whether they are recycled or compostable.	
Amendment	None	The Plastic Waste Management 2016 rules were revised to be known as the Plastic Waste Management (Amendment) Rules 2018 by incorporating three major changes inter alia others, in the later. ♦ The rules notify that under Section 9 (3), the term 'non-recyclable multilayered plastic' to be substituted by 'multilayered plastic which is non-recyclable or non-energy recoverable or with no alternate use'. ♦ Section 15 dealing with the pricing of carry bags has to be omitted. This rule earlier had the provision that shopkeepers and vendors, who make plastic bags available to dispense any commodity, are to register with the respective urban local body on payment of a fee of Rs. 48,000 annually @ rupees four thousands per month. ♦ The rules stipulate a centralized registration system by mandating brand owners and producers operating in more than two states to register with the Central Pollution Control Board (CPCB).

1.3 Award of work on Assessment and Characterization of Plastic Waste in NCT of Delhi

The Department of Environment, Government of NCT of Delhi, assigned Shriram Institute for Industrial Research (A Unit of Shriram Scientific and Industrial Research Foundation) also known as "SRI", a project to undertake ".Assessment and Characterization of Plastic Waste in the NCT of Delhi**"** vide reference number F.12 (579)/ Env/ Plastic Study/ 2018/ 1430-1446 dated 25 February 2019**.** The SRI has undertaken the project through execution of various tasks as per the defined "Scope of Work" as described in the "Terms of Reference". The various project activities have been undertaken after the approval of Inception Report, which gives the details about Technical Approach and Methodology for execution of the project. Prior to the start of study detailed checklists, questionnaire, survey instruments etc. have been developed by SRI, which were duly approved by the Department of Environment.

Duration : 6 Months

Scope of Work

The Scope of Work include following activities:

Task-1	:	Assessment of total quantum of Plastic Waste generated in Delhi (Estimation of total volume of input plastic in Delhi and how much of it is converted to waste plastic with characterization and suggestion w.r.t. disposal measures).
Task-2	:	Characterization of Plastic waste (Recyclable, non-recyclable, soft plastic, hard plastic multilayered / tetra packs, PET, packaging plastics from online shopping or otherwise, etc.)
Task-3	:	Questionnaire Survey w.r.t. plastic usage and waste disposal practices at various levels, i.e.in commercial areas (eatery and non-eatery units/ shops), residential areas (households of different income groups), public and social events (exhibitions, fairs, wedding functions etc.)
Task-4	:	Per capita generation of plastic waste
Task-5	:	Plastic waste due to tourism in Delhi
Task-6	:	Brand Audit of plastic waste in Delhi
Task-7	:	Alternative to plastic and waste reduction pathways
Task-8	:	Recycling of plastics in Delhi
Task-9	:	Reuse and disposal
Task-10	:	Conclusions and Policy Recommendations

1.4 Description about study areas: NCT of Delhi

(a) Location and Geography[17-21]

The National Capital Territory of Delhi is situated between the Himalayas and Aravalli ranges and is surrounded by Haryana state on all sides except east where it borders with Uttar Pradesh. It lies between latitudes 28°24'15" & 28°53'00" N and longitudes 76°50'24" & 77°20'30" E. The area is covered under the Survey of India Toposheet Nos. 53D and 53H. The NCT of Delhi covers an area of 1,483 km^2, of which 1,114 km^2 is designated as urban, while 369 km^2 as rural. It has a length of 51.9 km and a width of 48.48 km. In context to administrative purposes, the NCT Delhi is divided into 9 districts. As per the census of India (2011), the NCT Delhi has three Statutory Towns, 110 Census Towns and 112 Villages. The NCT of Delhi, has five local municipal corporations; North Delhi Municipal Corporation, South Delhi Municipal Corporation, East Delhi Municipal Corporation, New Delhi Municipal Council and Delhi Cantonment Board (DCB). The Municipal corporations handle civic administration for the city.

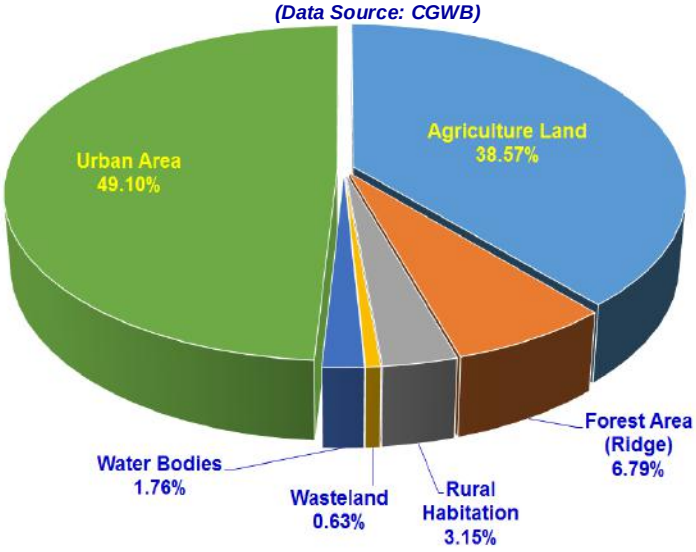
(b) The Climate [17,18,22]

The climate of NCT Delhi is mainly influenced by its inland position and the prevalence of air of the continental type during the major part of the year. Delhi has a humid sub-tropical climate with long and hot summers and cold winters. Only during the three monsoon months i.e., July, August and September, the air of oceanic origin penetrates to this region and causes increased humidity, cloudiness and precipitation. The normal annual rainfall in the State is 611.8 mm. About 81% of the annual rainfall is received during the monsoon months July, August and September.

(c) Physiography and Landuse[17,18,22]

Physiographical features of the area represent a mature topography with vast gently undulatory plains, low linear ridges and isolated hillocks. Physiography of Delhi is dominated by the river Yamuna, the Aravalli range, and the plains in between, formed by alluvium deposits of recent age. The land use distribution of Delhi is graphically presented in figure-1. The map of landuse/ land cover of NCT of Delhi is shown in figure-2. Out of the total geographical area of 1483.716 sq km, urban area constitutes 728.478 sq km thereby covering 49% of the NCT. About 38% of the total land area covering most parts of Southwest and Northwest districts falls under the agricultural landuse. Land

Figure-1: Landuse Distribution of NCT of Delhi[22]
(Data Source: CGWB)



utilization has changed drastically over the years. The most distinguishing land cover of Delhi is its ridge which constitutes 6.79% of the total land cover. The agricultural land use is repeatedly modified and more and more areas are shifted from cultivation and being utilized for other uses.

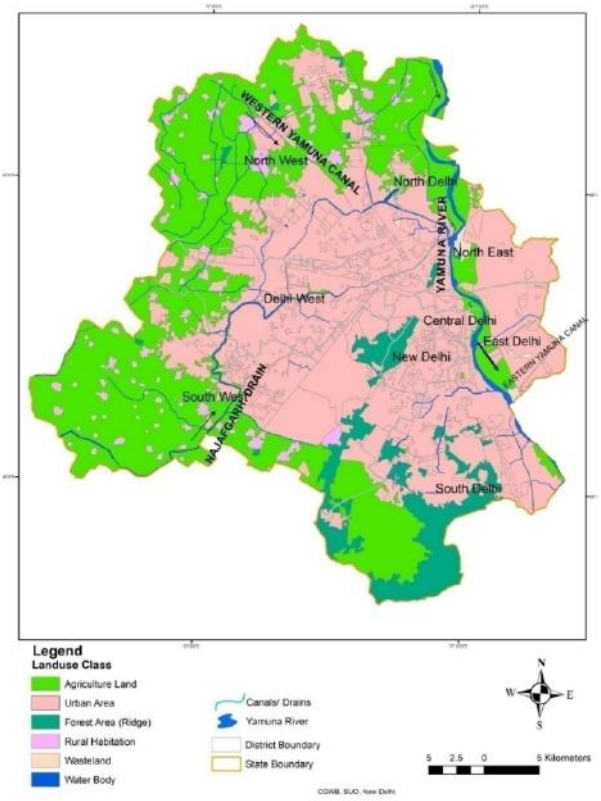
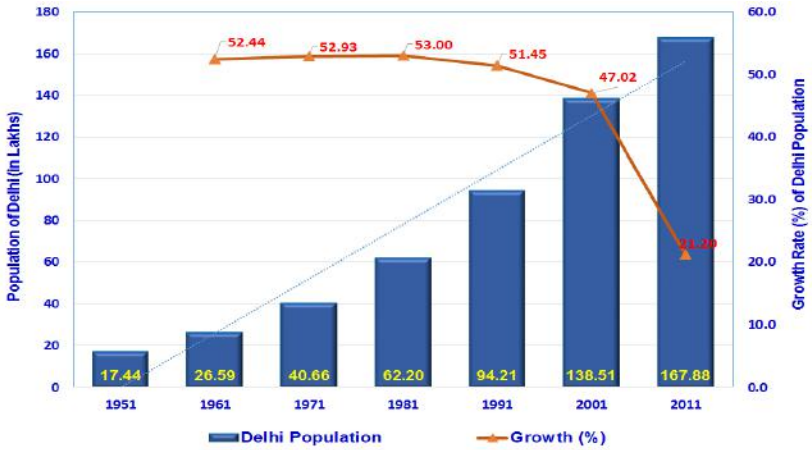


Figure-2: Landuse Distribution Map of NCT of Delhi[22]
(Source: CGWB)

(d) The Demography [17-21]

The decadal growth rate of population during 2001-2011 was recorded at 21.2 per cent from 138.51 lakh to 167.88 lakh. The rate of growth of population in Delhi was highest during 1971-81 at 53.00 per cent. The annual rate of growth of population in Delhi during the last decade was 2.12 per cent per annum which was higher than the national level of 0.35 per cent per annum. The population in Delhi during 1951-2011 is depicted in figure-3.

Figure-3: The Trend of the population & its growth rate of NCT of Delhi (1951-2011)
(Data Source: Economic Survey of Delhi, 2016-17)



District-wise Population

At the time of 1991 census Delhi was a single district Territory. In 1996, Government of NCT of Delhi, through a Gazette notification, created 9 districts and 27 sub-divisions. Population Census 2001 was conducted in each of 9 districts and 27 Sub-divisions. The district-wise population of NCT Delhi during the census 2001 and 2011 is presented in Table-2. More than 53 per cent of the population of Delhi in 2011 lived in three districts viz. North-west, South and West districts of Delhi. At present, the NCT of Delhi has 11 number of districts.

Table-2 District wise Population of Delhi

Sl.	District	2001			2011		
		Number	Percent	Rank	Number	Percent	Rank
1.	North West	2860869	20.65	1	3656539	21.78	1
2.	South	2267023	16.37	2	2731929	16.27	2
3.	West	2128908	15.37	3	2543243	15.15	3
4.	North East	1768061	12.77	4	2241624	13.35	5
5.	South East	1755041	12.67	5	2292958	13.66	4
6.	East	1463583	10.57	6	1709345	10.18	6
7.	North	781525	5.64	7	887978	5.29	7
8.	Central	646385	4.67	8	582320	3.47	8
9.	New Delhi	179112	1.29	9	142004	0.85	9
Total		**13850507**	**100.00**		**16787941**	**100.00**	

Household Size

Number of persons living together in one house commonly called as household size. As per 2011 census, there were 3,340,538 households in Delhi. The average size of household in Delhi was found of 5.02. It indicates that in one house there had been more than five persons. More than one half of the households had more than five members during the year 2011. The distribution of households by size in Delhi in 2001 and 2011 are presented in Table-3.

Table-3 Household Pattern in Delhi

Sl.	Size of Household	No. of Households		Percent of total number of Households	
		2001	2011	2001	2011
1.	One member	99,786	123,106	3.90	3.70
2.	Two members	206,925	252,370	8.10	7.60
3.	Three members	295,216	428,403	11.56	12.80
4.	Four members	544,289	803,065	21.31	24.00
5.	Five members	506,711	681,142	19.84	20.40
6.	Six to eight members	680,065	853,773	26.63	25.60
7.	Nine or more members	221,157	198,679	8.66	5.90
Total Households		**2,554,149**	**3,340,538**	**100.00**	**100.00**

2. Approach and Methodology

2.1 Preliminary Plan

The preliminary plan of work including survey formats to undertake the field work, has been prepared and submitted to the Department of Environment (DOE), the Government of NCT of Delhi (GNCTD). In order to start survey for the Assessment and Characterization of Plastic Waste, a meeting was convened on 13 June 2019 by the DOE-GNCTD with SRI team, to discuss modalities and to finalize the methodologies to execute the project. Details about study area and survey, assessment and characterization methodology, as discussed and finalized, are illustrated hereinafter.

2.2 Study Scope/ Area

I. Survey of various areas for Assessment and Characterization of Plastic Waste

Various areas taken for study to include

(A) Residential Areas:

Areas like High Income, Middle Income, low income and Slum area, unauthorized/ regularized colony & unauthorized colony etc. would be studies in each of the 11 zones of NCT of Delhi.

(B) Tourist Areas:

- Akshardham Temple
- Jama Masjid
- Gurudwara Bangla Sahib
- Red Fort
- National Museam
- Millennium Park

(C) Market Places/ commercial areas:

- Khan Market, Ghazipur Sabji Mandi, Azadpur Mandi, Okhla Mandi, Krishna Nagar, Ajmal Khan Road, Lajpat Nagar Central Market, Kamla Nagar Market.
- Connaught Place
- Select City Mall

(D) Public Places:

- Bus Terminal (Kashmere Gate/ Anand Vihar)
- New Delhi Railway Station/ Sarai Kale Khan
- IGI Airport

(E) Institutional Areas:

- CGO Complex
- Tis Hazari Court
- Civic Centre

(F) Academic Institution:

- Delhi University, North Campus
- One College DU outside campus
- DAV School Sreshtha Vihar; Ryan International Scholl, Mayur Vihar Ph-III

(G) Hospital:

Cafetaria/ Canteen of LNGP Hospital/ Swami Dayanand Hospital/ Ram Manohar Lohia Hospital/ AIIMS

(H) Miscellaneous Areas:

- Ridge (Kamla Nehru Ridge).
- CBD Karkardooma during functions

(I) Vacant lands/ drain

Shahdara drain

(J) Recycling Facilities

Survey of registered recycling facilities and storage facilities.

II. Brand Audit

Based on the volume of input plastic in Delhi, retailers/ distributers of various prominent brands be surveyed on sample size basis and data thus collected to be collated and extrapolated to estimate/ quantify plastic, which can be converted into waste.

III. Photographs and Geocodes

The site photographs to be taken during survey along with the recording of geocode of the locations.

2.3 Assessment and Characterization Methodology

(a) Sampling Procedure[8,23]

The protocol of ASTM D 5231-92 (Reapproved 2003) and methodology given in the CPCB report (January 2015) has been followed for sampling for quantification of plastic waste from the total solid waste. In this context, following process has been adopted.

(i) Nature of Waste at *Dhalao*

Approximately 800-1000 kg Municipal Solid Waste (MSW), as received at Dhalao (as shown in figure-4), from different areas, was be equally divided into four section (quadrats) followed by discarding of two sections and taking up remaining two sections for next quartering and finally taking up about 100-125 kg of solid waste for further sorting/ segregation to estimate the quantity of plastic waste. Quartering and coning process is explained in figure-5. Wherever, waste quantity per day is less than 100 kg, total waste collected per day has been processed for segregation.

Figure-4: Waste received at *Dhalao*

Figure-5: Quartering process followed at *Dhalao*

(ii) Direct transfer of Waste from Auto-tipper to the tipper-Trucks

The mixed waste is directly transferred to tipper-trucks from the auto-tippers at some of the locations instead of depositing the same at dhalao. In such cases, mixed waste of auto-tippers has been processed for assessment and characterization.

Figure-6: Direct transfer of mixed waste from auto-tippers to tipper-trucks

The auto-tippers have two compartments i.e one for keeping wet waste and other for dry waste. The wet waste, as collected separately at the source, is being sent to compost plant. The dry waste is segregated to separate plastics and recyclables for sending these to scrap dealers. The remnant mixed waste is being transferred to compacted tipper truck for dispatching it to waste to energy plant.

(b) Assessment and Characterization Method[8,23,24]

The methodology given in the CPCB report (January 2015), has been followed for quantification and characterization of plastic waste from the total solid waste. The plastics constitute two major categories: (i) Thermoplastics and (ii) Thermoset plastics. The plastics materials are categorized in seven types based on properties & applications. In order to make the recycling easier, the universally accepted standards has been developed to help consumers to identify and sort out the main types of plastics with marking code. The symbols defined by Society of the Plastic Industry (SPI) USA are adopted as also defined in IS 14534:2016 of BIS as follows:

The segregated plastic waste is being further sorted into following categories. The total and sorted waste would be weighed at site itself.

Table-4 Various categories of Plastic Waste and their origin

Code No. of Plastic	Category	Origin of Plastic Waste
1	(1) Polyethylene Terephthalate (PET)	Drinking water bottles; PET Bottles
2 + 4	(2) High Density Polyethylene (HDPE)	Carry bags, bottle caps, household articles, milk/detergents bags, containers etc.
	(4) Low Density Polyethylene (LDPE)	Carry bags, films
3	(3) Polyvinyl Chloride (PVC)	Credit cards, pipes and gutters, electrical fittings, furniture, folders, pens, medical disposables, floorings etc.
5	(5) Polypropylene (PP)	Medicine bottles, cereal liners, packaging films etc.
6	(6) Polystyrene (PS)	Foam packing, Tea cups, Ice cream cups etc.
7	(7) Other inclusive of ABS, PPO, PC, PBT etc.	Insulators in electric & electronic devices, thermoplastic material, and other engineered plastic.

3. Plastic Waste Generation in Different Study Areas

(A) Residential Areas

(I) District/ Zone wise Coverage of Residential Areas

District/ zone wise residential areas for different income groups, covered for Assessment and Characterization of PW, are illustrated in table-5

Table-5 District wise coverage of Residential Areas

District/ Zone	Category/ Income Groups	Location	Date of Survey
North Delhi	High	Model Town-II	22.08.2019
	Middle		
	Low	Burari Sant Nagar	04.10.2019
	Slum	Jahangirpuri JJ cluster	26.08.2019
South Delhi	High	GK Part-II	28.11.2019
	Middle	Vasant Kunj	29.11.2019
	Low	Chhattarpur	29.11.2019
West Delhi	High	Punjabi Bagh	30.11.2019
	Middle	Vikaspuri	04.12.2019
	Low	Uttam Nagar	03.01.2020
East Delhi	High	Mayur Vihar Phase-III	15.10.2019
	Middle	Shakarpur	15.10.2019
	Low	Trilokpuri	16.10.2019
Shahdara	High	Anand Vihar	14.10.2019
	Middle		
	Middle	Shahdara	14.10.2019
	Low	Kardampuri	09.10.2019
	Slum	Sunder Nagri	09.10.2019
NE Delhi	Low	Sonia Vihar	04.10.2019
SE Delhi	High	Sunder Nagar	20.11.2019
	Middle	Hauz Khas	29.09.2019
	Low	Madanpur Khadar	17.01.2020
Central Delhi	High	Civil Lines	22.08.2019
	Middle	Jama Masjid C/M	19.08.2019
	Low	G.T.B.Nagar	11.02.2020
New Delhi	High	Chanakyapuri	30.11.2019
	Middle	R.K.Puram	28.11.2019
	Slum	Rangpuri, Mahipalpur	14.01.2020
NW Delhi	High	Peeragarhi	04.02.2020
	Middle	Rohini Sector-3	04.02.2020
	Low	Madhipur	04.02.2020
	Slum	Nangloi JJ Colony	27.09.2019
SW Delhi	High	Dwarka	13.01.2020
	Middle	Palam	08.01.2020
	Low	Rosanpura	13.01.2020

(II) Plastic Waste (PW) at North Delhi Residential Areas

The survey was undertaken in Model Town-II (representing high & medium income group), Burari Sant Nagar (representing low income group) and Jahangirpuri JJ cluster (representing slum area). The assessment and characterization data can be summed-up as follows:

(a) Model Town-II

The data is summarized in table-6. The total plastic waste at this location is quantified to 79.43 Kg/MT of total SW (7.95%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 91.65% of the total plastic waste, followed by PVC material and PET material, which amounted to 2.56% and 2.48% respectively. While PS material constituted 1.64% of total plastic waste, PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 1.67%.

(b) Burari Sant Nagar

The data is summarized in table-7. The total plastic waste at this location is quantified to 165.70 Kg/MT of total SW (16.57%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 79.18% of the total plastic waste, followed by PS material, which amounted to 18.04%. While PVC and PS both the materials constituted 1.01% each of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 0.75%.

(c) Jahangirpuri JJ Cluster

The data is summarized in table-8. The total plastic waste at this location is quantified to 107.71 Kg/MT of total SW (10.77%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 71.33% of the total plastic waste, followed by PET material, which amounted to 25.06%. While PVC and PS materials constituted 1.47% and 1.16% respectively of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 1.00%.

Figure-7: Assessment & characterization of PW at North Delhi Residential Areas

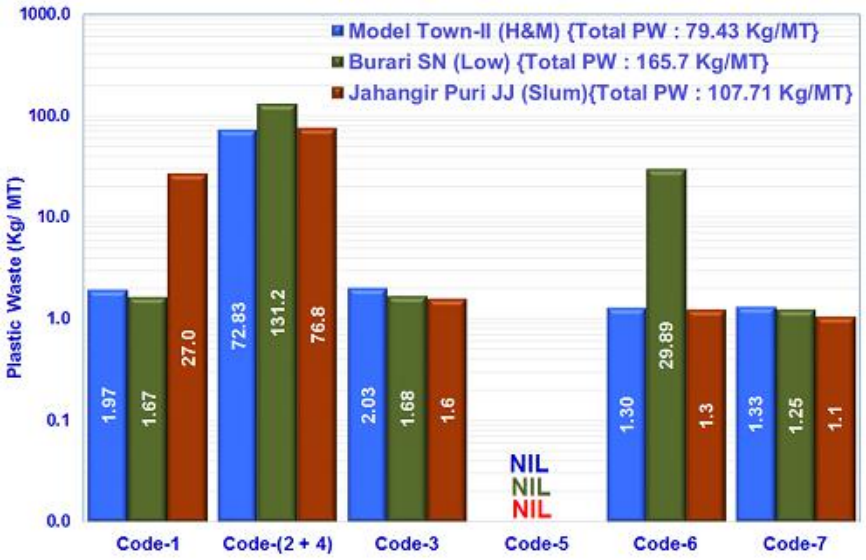


Table-6 Assessment and Characterization of Plastic Waste at Model Town-II

Zone				North
Location				Model Town-II
Date of Survey				22.08.2019
Site Geocodes	**Latitudes**			28°42'36.9"N
	Longitudes			77°11'31.4"E
Ward Number				77
Dhalao Number				03
Area Category				High & Medium Income
Quantity of waste received per day (Secondary Information)				3 to 4 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				99.96 Kg
Plastic Waste Quantification	Sorted Total Quantity			7.943 Kg
	Plastic Waste Kg/MT			79.43
	Plastic Waste (%)			7.95
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.197	1.97	2.48
2 and 4	HDPE & LDPE	7.280	72.83	91.65
3	PVC	0.203	2.03	2.56
5	PP	Nil	Nil	Nil
6	PS	0.130	1.30	1.64
7	Others	0.133	1.33	1.67

Table-7 Assessment and Characterization of Plastic Waste at Burari Sant Nagar

Zone				North
Location				Burari Santnagar
Date of Survey				04.10.2019
Site Geocodes	**Latitudes**			28°44'38.3"N
	Longitudes			77°11'51.6"E
Ward Number				7,8,9 & 10
Dhalao No.				No (Waste is dumped and spread on open land on Sant Nagar Road side)
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				70 to 80 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				112.40 Kg
Plastic Waste Quantification	Sorted Total Quantity			18.625 Kg
	Plastic Waste Kg/MT			165.70
	Plastic Waste (%)			16.57
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.188	1.67	1.01
2 and 4	HDPE & LDPE	14.75	131.21	79.18
3	PVC	0.189	1.68	1.01
5	PP	Nil	Nil	Nil
6	PS	3.360	29.89	18.04
7	Others	0.140	1.25	0.75

Table-8 Assessment and Characterization of Plastic Waste at Jahangirpuri JJ cluster

Zone			North
Location			Jahangirpuri JJ Cluster
Date of Survey			26.08.2019
Site Geocodes		**Latitudes**	28°43'39.2"N
		Longitudes	77°10'36.2"E
Ward Number			22
Dhalao Number			04
Area Category			Slum
Quantity of waste received per day (Secondary Information)			6 to 7 TPD
Quantity of Waste Processed for Segregation of Plastic Waste			105.20 Kg
Plastic Waste Quantification		Sorted Total Quantity	11.331 Kg
		Plastic Waste Kg/MT	107.71
		Plastic Waste (%)	10.77

Plastic Waste Categorization

Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.840	27.00	25.06
2 and 4	HDPE & LDPE	8.080	76.81	71.31
3	PVC	0.167	1.59	1.47
5	PP	Nil	Nil	Nil
6	PS	0.131	1.25	1.16
7	Others	0.113	1.07	1.00

Figure-8: Plastic Waste at Model Town-II

Figure-9: Plastic Waste at Burari Sant Nagar

Figure-10: Plastic Waste at Jahangirpuri

(III) Plastic Waste (PW) at South Delhi Residential Areas

The survey was undertaken in Greater Kailash Part-II (representing high income group), Vasant Kunj (representing middle income group) and Chhattarpur (representing low income group). The assessment and characterization data can be summed-up as follows:

(a) Greater Kailash Part-II (GK-II)

The data is summarized in table-9. The total plastic waste at this location is quantified to 32.10 Kg/MT of total SW (3.21%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 57.94% of the total plastic waste, followed by PS material and PP material, which amounted to 9.35% and 6.85% respectively. While PET material constituted 3.43% of total plastic waste, the PVC material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 22.43%.

(b) Vasant Kunj

The data is summarized in table-10. The total plastic waste at this location is quantified to 45.47 Kg/MT of total SW (4.55%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 65.53% of the total plastic waste, followed by PS material and PET material, which amounted to 9.90% and 9.35% respectively. While PP material constituted 4.95% of total plastic waste, the PVC material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 10.28%.

(c) Chhattarpur

The data is summarized in table-11. The total plastic waste at this location is quantified to 110.84 Kg/MT of total SW (11.08%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 39.95% of the total plastic waste, followed by PET material, which amounted to 33.31%. While PP material and PVC material constituted 6.22% and 3.88% respectively of total plastic waste, the PS material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 16.64%.

Figure-11: Assessment & characterization of PW at South Delhi Residential Areas

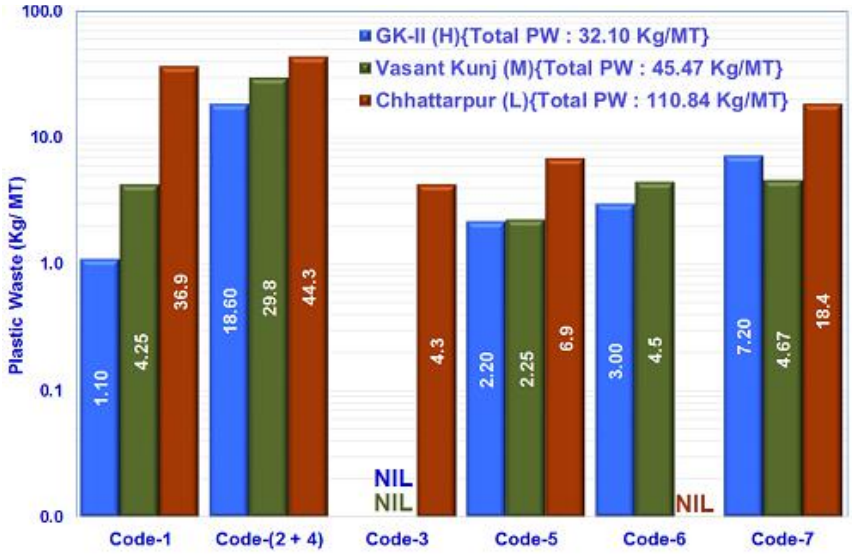


Table-9 Assessment and Characterization of Plastic Waste at GK-II

Zone				South Delhi
Location				Greater Kailash-II (GK-II)
Date of Survey				28.11.2019
Site Geocodes		**Latitudes**		28°32'7.0"N
		Longitudes		77°14'11.7"E
Ward Number				87-S
FCTS Location				Ward 87-S, GK-II
Area Category				High Income
Quantity of waste received per day (Secondary Information)				15 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				500 Kg
Plastic Waste Quantification		Sorted Total Quantity		16.05 Kg
		Plastic Waste Kg/MT		32.10
		Plastic Waste (%)		3.21
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.550	1.10	3.43
2 and 4	HDPE & LDPE	9.300	18.60	57.94
3	PVC	Nil	Nil	Nil
5	PP	1.100	2.20	6.85
6	PS	1.500	3.00	9.35
7	Others	3.600	7.20	22.43

Table-10 Assessment and Characterization of Plastic Waste at Vasant Kunj

Zone				South Delhi
Location				Vasant Kunj
Date of Survey				29.11.2019
Site Geocodes		**Latitudes**		28°31'35.4"N
		Longitudes		77°08'48.9"E
Ward Number				69-S
FCTS Location				Ward 69-C, Vasant Kunj
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				15-16 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification		Sorted Total Quantity		18.189 Kg
		Plastic Waste Kg/MT		45.47
		Plastic Waste (%)		4.547
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	1.700	4.25	9.35
2 and 4	HDPE & LDPE	11.920	29.80	65.53
3	PVC	Nil	Nil	Nil
5	PP	0.900	2.25	4.95
6	PS	1.800	4.50	9.90
7	Others	1.869	4.67	10.28

Table-11 Assessment and Characterization of Plastic Waste at Chhattarpur

Zone				South Delhi
Location				Chhattarpur
Date of Survey				29.11.2019
Site Geocodes		**Latitudes**		28°29'39.4"N
		Longitudes		77°08'59.9"E
Ward Number				70-S
FCTS Location				Ward 70-S, Chhattarpur
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				25 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				500 Kg
Plastic Waste Quantification		Sorted Total Quantity		55.420 Kg
		Plastic Waste Kg/MT		110.84
		Plastic Waste (%)		11.08
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	18.460	36.92	33.31
2 and 4	HDPE & LDPE	22.140	44.28	39.95
3	PVC	2.153	4.31	3.88
5	PP	3.445	6.89	6.22
6	PS	Nil	Nil	Nil
7	Others	9.222	18.44	16.64

Figure-12: Plastic Waste at GK Part-II

Figure-13: Plastic Waste at Vasant Kunj

Figure-14: Plastic Waste at Chhattarpur

(IV) Plastic Waste (PW) at West Delhi Residential Areas

The survey was undertaken in Punjabi Bagh (representing high income group), Vikaspuri (representing middle income group) and Uttam Nagar (representing low income group). The assessment and characterization data can be summed-up as follows:

(a) Punjabi Bagh

The data is summarized in table-12. The total plastic waste at this location is quantified to 60.17 Kg/MT of total SW (6.02%). The characterization of plastic waste indicates that it constituted 42.19% PET material followed by HDPE and LDPE materials together, which constituted 27.96% of the total plastic waste. While PS, PP and PS material constituted 5.69%, 1.02% and 0.54% respectively of total plastic waste, other plastic components apart from above materials constituted 22.61% of total plastic waste.

(b) Vikaspuri

The data is summarized in table-13. The total plastic waste at this location is quantified to 38.45 Kg/MT of total SW (3.84%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 20.22% of the total plastic waste, followed by PET material and PP material, which amounted to 15.34% and 10.71% respectively. While PS material constituted 10.57% of total plastic waste, the PVC material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 43.16% of total plastic waste.

(c) Uttam Nagar

The data is summarized in table-14. The total plastic waste at this location is quantified to 28.99 Kg/MT of total SW (2.90%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 50.90% of the total plastic waste, followed by PET material, which amounted to 41.67%. While PVC material and PS material constituted 1.76% and 0.56% respectively of total plastic waste, the PP material was found Nil (practically not seen). Other plastic components apart from above materials constituted 5.11% of total plastic waste.

Figure-15: Assessment & characterization of PW at West Delhi Residential Areas

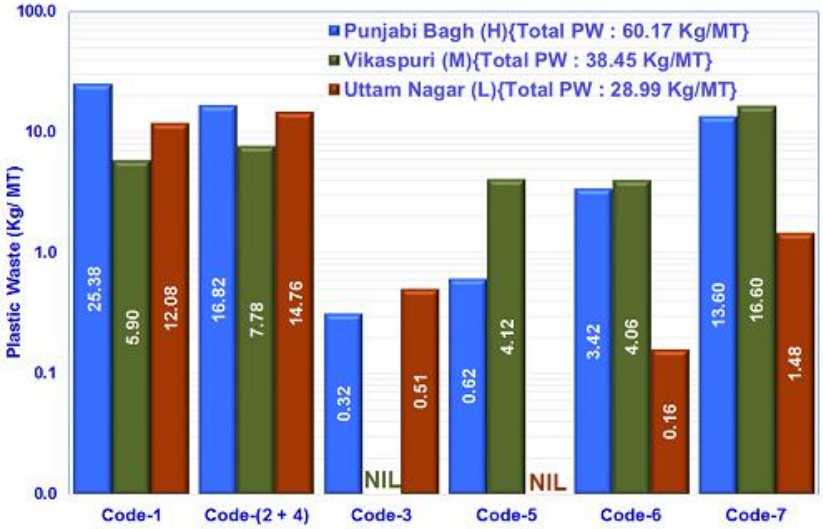


Table-12 Assessment and Characterization of Plastic Waste at Punjabi Bagh

Zone				West Delhi
Location				Punjabi Bagh
Date of Survey				30.11.2019
Site Geocodes		**Latitudes**		28°59'52.36"N
		Longitudes		77°07'50.06"E
Ward Number				2-S
FCTS Location				Ward No. 2-S; Punjabi Bagh
Area Category				High Income
Quantity of waste received per day (Secondary Information)				15-16 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification		Sorted Total Quantity		24.066 Kg
		Plastic Waste Kg/MT		60.17
		Plastic Waste (%)		6.02
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	10.153	25.38	42.19
2 and 4	HDPE & LDPE	6.728	16.82	27.96
3	PVC	0.129	0.32	0.54
5	PP	0.246	0.62	1.02
6	PS	1.369	3.42	5.69
7	Others	5.441	13.60	22.61

Table-13 Assessment and Characterization of Plastic Waste at Vikaspuri

Zone				West Delhi
Location				Vikaspuri
Date of Survey				04.12.2019
Site Geocodes		**Latitudes**		28°37'56.4"N
		Longitudes		77°04'39.3"E
Ward Number				20-S
FCTS Location				Ward No. 20-S, Vikaspuri
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				6-8 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification		Sorted Total Quantity		15.38 Kg
		Plastic Waste Kg/MT		38.45
		Plastic Waste (%)		3.84
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.360	5.90	15.34
2 and 4	HDPE & LDPE	3.110	7.78	20.22
3	PVC	Nil	Nil	Nil
5	PP	1.647	4.12	10.71
6	PS	1.625	4.06	10.57
7	Others	6.638	16.60	43.16

Table-14 Assessment and Characterization of Plastic Waste at Uttam Nagar

Zone				West
Location				Uttam Nagar
Date of Survey				03.01.2020
Site Geocodes	**Latitudes**			28°37'07.6"N
	Longitudes			77°04'28.4"E
Ward Number				15-S
Dhalao Number				211
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				700 Kg
Plastic Waste Quantification	Sorted Total Quantity			20.295 Kg
	Plastic Waste Kg/MT			28.99
	Plastic Waste (%)			2.90
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	8.456	12.08	41.67
2 and 4	HDPE & LDPE	10.330	14.76	50.90
3	PVC	0.358	0.51	1.76
5	PP	Nil	Nil	Nil
6	PS	0.114	0.16	0.56
7	Others	1.037	1.48	5.11

Figure-16: Plastic Waste at Punjabi Bagh

Figure-17: Plastic Waste at Vikaspuri

Figure-18: Plastic Waste at Uttam Nagar

(V) Plastic Waste at East Delhi Residential Areas

The survey was undertaken at Mayur Vihar Phase-III (representing high and middle income group), Shakarpur (representing middle income group) and Trilokpuri (representing low income group). The assessment and characterization data can be summed-up as follows:

(a) Mayur Vihar Phase-III

The data is summarized in table-15. The total plastic waste at this location is quantified to 46.83 Kg/MT of total SW (4.68%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 61.38% of the total plastic waste, followed by PET material and PVC material, which amounted to 10.23% and 3.67% respectively. While PS material constituted 2.96% of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 21.76% of total plastic waste.

(b) Shakarpur

The data is summarized in table-16. The total plastic waste at this location is quantified to 171.02 Kg/MT of total SW (17.10%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 95.28% of the total plastic waste, followed by PS material, which amounted to 2.17%. While PET material and PVC material constituted 0.95% and 0.80% respectively, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 0.80% of total plastic waste.

(c) Trilokpuri

The data is summarized in table-17. The total plastic waste at this location is quantified to 56.28 Kg/MT of total SW (5.63%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 89.87% of the total plastic waste, followed by PVC material, which amounted to 3.30%. While PET material and PS material constituted 2.35% and 2.33% respectively, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 2.14% of total plastic waste.

Figure-19: Assessment & characterization of PW at East Delhi Residential Areas

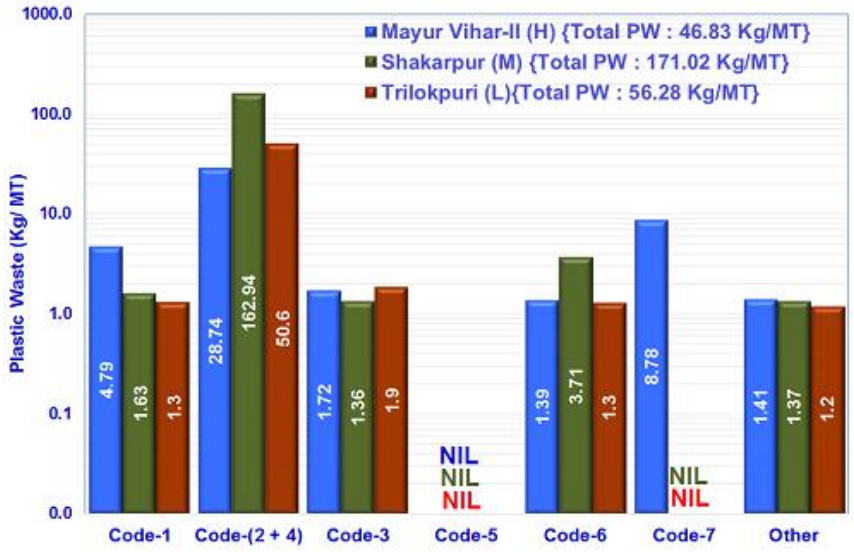


Table-15 Assessment and Characterization of Plastic Waste at Mayur Vihar Phase-III

Zone				East
Location				Mayur Vihar Phase-III
Date of Survey				15.10.2019
Site Geocodes	**Latitudes**			28°36'54.85"N
	Longitudes			77°20'16.74"E
Ward Number				216
Dhalao Number				72
Area Category				High & Middle Income
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				100.20 Kg
Plastic Waste Quantification	Sorted Total Quantity			4.692 Kg
	Plastic Waste Kg/MT			46.83
	Plastic Waste (%)			4.68
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.480	4.79	10.23
2 and 4	HDPE & LDPE	2.880	28.74	61.38
3	PVC	0.172	1.72	3.67
5	PP	Nil	Nil	Nil
6	PS	0.139	1.39	2.96
7	Others	1.021	10.19	21.76

Table-16 Assessment and Characterization of Plastic Waste at Shakarpur

Zone				East Delhi
Location				Shakarpur
Date of Survey				15.10.2019
Site Geocodes	**Latitudes**			28°37'3.3"N
	Longitudes			77°16'58.8"E
Ward Number				222
Dhalao Number				99
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				120 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				105.00 Kg
Plastic Waste Quantification	Sorted Total Quantity			17.957 Kg
	Plastic Waste Kg/MT			171.02
	Plastic Waste (%)			17.10
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.171	1.63	0.95
2 and 4	HDPE & LDPE	17.11	162.95	95.28
3	PVC	0.143	1.36	0.80
5	PP	Nil	Nil	Nil
6	PS	0.39	3.71	2.17
7	Others	0.144	1.37	0.80

Table-17 Assessment and Characterization of Plastic Waste at Trilokpuri

Zone				East Delhi
Location				Trilokpuri
Date of Survey				16.10.2019
Site Geocodes		**Latitudes**		28°36'07.3"N
		Longitudes		77°18'29.9"E
Ward Number				211/3E
Dhalao Number				22
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				102.80 Kg
Plastic Waste Quantification		Sorted Total Quantity		5.786 Kg
		Plastic Waste Kg/MT		56.28
		Plastic Waste (%)		5.63
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.136	1.32	2.35
2 and 4	HDPE & LDPE	5.200	50.58	89.87
3	PVC	0.191	1.86	3.30
5	PP	Nil	Nil	NA
6	PS	0.135	1.31	2.33
7	Others	0.124	1.21	2.14

Figure-20: Plastic Waste at Mayur Vihar

Figure-21: Plastic Waste at Shakarpur

Figure-22: Plastic Waste at Tirlokpuri

(VI) Plastic Waste (PW) at Shahdara Residential Areas

The survey was undertaken at Anand Vihar (representing high and medium income group), Shahdara (representing middle income group), Kardampuri (representing Low income group) and Sunder Nagri (representing slum area). The assessment and characterization data can be summed-up as follows:

(a) Anand Vihar

The data is summarized in table-18. The total plastic waste at this location is quantified to 49.29 Kg/MT of total SW (4.93%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 86.97% of the total plastic waste, followed by PET material and PVC material, which amounted to 3.96% and 3.67% respectively. While PS material constituted 2.76% of total plastic waste, other plastic waste apart from above materials constituted 2.64% of total plastic waste.

(b) Shahdara

The data is summarized in table-19. The total plastic waste at this location is quantified to 84.73 Kg/MT of total SW (8.47%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 57.03% of the total plastic waste, followed by PP material and PET material, which amounted to 31.96% and 5.90% respectively. While PS material and PVC material constituted 1.70% and 1.73% respectively, other plastic waste apart from above materials constituted 1.68% of total plastic waste.

(c) Kardampuri

The data is summarized in table-20. The total plastic waste at this location is quantified to 92.81 Kg/MT of total SW (9.28%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 92.40% of the total plastic waste, followed by PS material and PET material, which amounted to 2.09% and 2.08% respectively. While PVC material constituted 1.99% of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 1.43% of total plastic waste.

(d) Sunder Nagri

The data is summarized in table-21. The total plastic waste at this location is quantified to 42.96 Kg/MT of total SW (4.30%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 83.94% of the total plastic waste, followed by PET material and PVC material, which amounted to 5.00% and 4.10% respectively. While PS material constituted 3.44% of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 3.51% of total plastic waste.

Figure-23: Assessment & characterization of PW at Shahdara Residential Areas

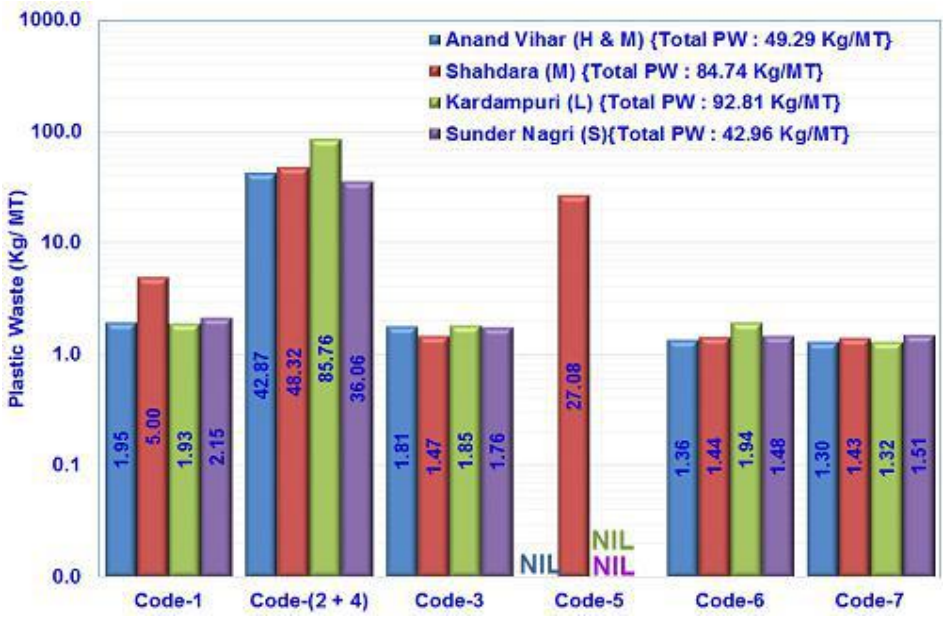


Table-18 Assessment and Characterization of Plastic Waste at Anand Vihar

Zone				Shahdara
Location				Anand Vihar
Date of Survey				14.10.2019
Site Geocodes	**Latitudes**			28°39'02.5"N
	Longitudes			77°18'16.4"E
Ward Number				225/18E
Dhalao Number				110
Area Category				Middle & High Income
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				104.50 Kg
Plastic Waste Quantification	Sorted Total Quantity			5.151 Kg
	Plastic Waste Kg/MT			49.29
	Plastic Waste (%)			4.93
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.204	1.95	3.96
2 and 4	HDPE & LDPE	4.480	42.87	86.97
3	PVC	0.189	1.81	3.67
5	PP	Nil	Nil	Nil
6	PS	0.142	1.36	2.76
7	Others	0.136	1.30	2.64

Table-19 Assessment and Characterization of Plastic Waste at Shahdara

Zone				Shahdara
Location				Shahdara
Date of Survey				14.10.2019
Site Geocodes	**Latitudes**			28°40'53.3"N
	Longitudes			77°17'30.5"E
Ward Number				38 E
Dhalao Number				73
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				96.02 Kg
Plastic Waste Quantification	Sorted Total Quantity			8.136 Kg
	Plastic Waste Kg/MT			84.73
	Plastic Waste (%)			8.47
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.480	5.00	5.90
2 and 4	HDPE & LDPE	4.640	48.32	57.03
3	PVC	0.141	1.47	1.73
5	PP	2.600	27.08	31.96
6	PS	0.138	1.44	1.70
7	Others	0.137	1.43	1.68

Table-20 Assessment and Characterization of Plastic Waste at Kardampuri

Zone				Shahdara
Location				Kardampuri
Date of Survey				09.10.2019
Site Geocodes	**Latitudes**			28°41'56.3"N
	Longitudes			77°17'05.5"E
Ward Number				49 E
Dhalao Number				98
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				80-90 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				98.88 Kg
Plastic Waste Quantification	Sorted Total Quantity			9.177 Kg
	Plastic Waste Kg/MT			92.81
	Plastic Waste (%)			9.28
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.191	1.93	2.08
2 and 4	HDPE & LDPE	8.480	85.76	92.40
3	PVC	0.183	1.85	1.99
5	PP	Nil	Nil	Nil
6	PS	0.192	1.94	2.09
7	Others	0.131	1.32	1.43

Table-21 Assessment and Characterization of Plastic Waste at Sunder Nagri

Zone				Shahdara
Location				Sundar Nagri
Date of Survey				09.10.2019
Site Geocodes	**Latitudes**			28°41'45.1"N
	Longitudes			77°19'20.1"E
Ward Number				244/ 38E
Dhalao Number				52
Area Category				Slum & Low Income
Quantity of waste received per day (Secondary Information)				100-120 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				95.40 Kg
Plastic Waste Quantification	Sorted Total Quantity			4.098 Kg
	Plastic Waste Kg/MT			42.96
	Plastic Waste (%)			4.30
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.205	2.15	5.00
2 and 4	HDPE & LDPE	3.440	36.06	83.94
3	PVC	0.168	1.76	4.10
5	PP	Nil	Nil	Nil
6	PS	0.141	1.48	3.44
7	Others	0.144	1.51	3.51

Figure-24: Plastic Waste at Anand Vihar

Figure-25: Plastic Waste at Shahdara

Figure-26: Plastic Waste at Kardampuri

Figure-27: Plastic Waste at Sunder Nagri

(VII) Plastic Waste (PW) at North East Delhi Residential Areas

The survey was undertaken at Sonia Vihar (representing Low income group). The assessment and characterization data, is mentioned in table-21. The total plastic waste at this location is quantified to 105.86 Kg/MT of total SW (10.59%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 66.97% of the total plastic waste, followed by PET material and PVC material, which amounted to 28.38% and 2.00% respectively. While PS material constituted 1.31% of total plastic waste, other plastic waste apart from above materials constituted 1.34% of total plastic waste.

Table-22 Assessment and Characterization of Plastic Waste at Sonia Vihar

Zone				North East
Location				Sonia Vihar
Date of Survey				04.10.2019
Site Geocodes		**Latitudes**		28°42'52.7"N
		Longitudes		77°15'22.5"E
Ward Number				64 E & 60E
Dhalao Number	No (waste is dumped and spread on open land on Pushta Road)			
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				70-90 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				99.87 Kg
Plastic Waste Quantification		Sorted Total Quantity		10.572 Kg
		Plastic Waste Kg/MT		105.86
		Plastic Waste (%)		10.59
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	3.000	30.04	28.38
2 and 4	HDPE & LDPE	7.080	70.89	66.97
3	PVC	0.211	2.11	2.00
5	PP	Nil	Nil	Nil
6	PS	0.139	1.39	1.31
7	Others	0.142	1.42	1.34

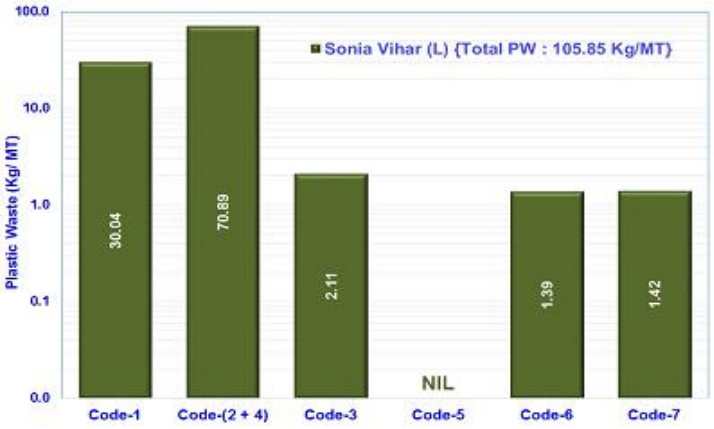


Figure-28: Assessment & characterization of PW at Sonia Vihar (NE Delhi Residential Area)

Figure-29: Plastic Waste at Sonia Vihar

(VIII) Plastic Waste at South East Delhi Residential Areas

The survey was undertaken at Sunder Nagar (representing high income group), Hauz Khas (representing middle income group) and Madanpur Khadar (representing Low income group). The assessment and characterization data can be summed-up as follows:

(a) Sunder Nagar

The data is summarized in table-23. The total plastic waste at this location is quantified to 101.79 Kg/MT of total SW (10.18%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 37.33% of the total plastic waste, followed by PET material and PS material, which amounted to 24.56% and 7.61% respectively. While PP material constituted 5.40% of total plastic waste, the PVC material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 25.09% of total plastic waste.

(b) Green Park, Hauz Khas

The data is summarized in table-24. The total plastic waste at this location is quantified to 85.89 Kg/MT of total SW (8.59%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 58.00% of the total plastic waste, followed by PET material and PP material, which amounted to 15.30% and 4.62% respectively. While PS material and PVC material constituted 3.84% and 1.45% respectively, the other plastic waste apart from above materials constituted 16.79% of total plastic waste.

(c) Madanpur Khadar

The data is summarized in table-25. The total plastic waste at this location is quantified to 53.01 Kg/MT of total SW (5.30%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 44.19% of the total plastic waste, followed by PET material, which amounted to 30.84. While PS material and PVC material constituted 3.10% and 0.53% respectively, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 23.33% of total plastic waste.

Figure-30: Assessment & characterization of PW at South East Delhi Residential Areas

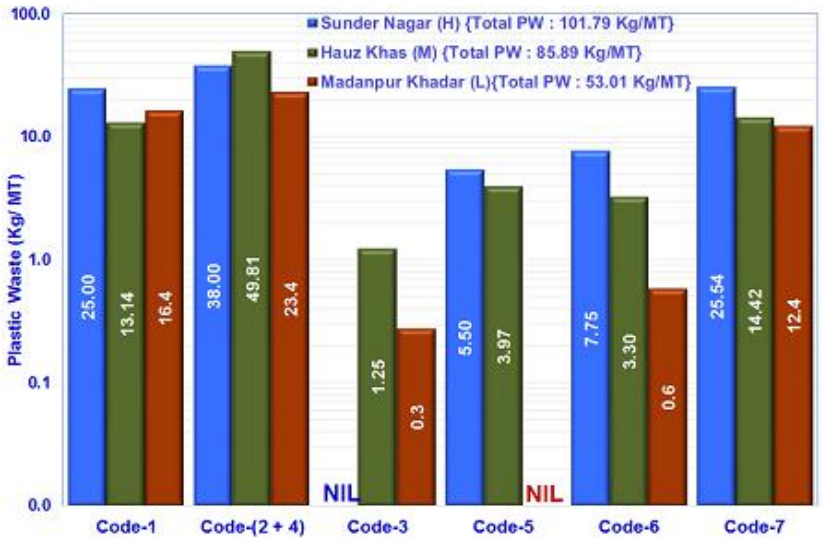


Table-23 Assessment and Characterization of Plastic Waste at Sunder Nagar

Zone				South East Delhi
Location				Sunder Nagar
Date of Survey				20.11.2019
Site Geocodes		**Latitudes**		28°36'04.7"N
		Longitudes		77°14'29.3"E
Ward Number				55-S
Dhalao Number				52
Area Category				High Income
Quantity of waste received per day (Secondary Information)				4-5 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification		Sorted Total Quantity		40.71 Kg
		Plastic Waste Kg/MT		101.79
		Plastic Waste (%)		10.18
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	10.000	25.00	24.56
2 and 4	HDPE & LDPE	15.200	38.00	37.33
3	PVC	Nil	Nil	Nil
5	PP	2.200	5.50	5.40
6	PS	3.100	7.75	7.61
7	Others	10.214	25.54	25.09

Table-24 Assessment and Characterization of Plastic Waste at Green Park; Hauz Khas

Zone				South East Delhi
Location				Green Park; Hauz Khas
Date of Survey				29.09.2019
Site Geocodes		**Latitudes**		28°33'09.4"N
		Longitudes		77°12'10.9"E
Ward Number				61-S
FCTS Location				Ward 61-S of Green Park
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				20-25 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				105.00 Kg
Plastic Waste Quantification		Sorted Total Quantity		9.018 Kg
		Plastic Waste Kg/MT		85.89
		Plastic Waste (%)		8.59
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	1.38	13.14	15.30
2 and 4	HDPE & LDPE	5.23	49.81	58.00
3	PVC	0.131	1.25	1.45
5	PP	0.417	3.97	4.62
6	PS	0.346	3.30	3.84
7	Others	1.514	14.42	16.79

Table-25 Assessment and Characterization of Plastic Waste at Madanpur Khadar

Zone				South East Delhi
Location				Madanpur Khadar
Date of Survey				17.01.2020
Site Geocodes		**Latitudes**		28°32'30.2"N
		Longitudes		77°18'24.8"E
Ward Number				101-S
FCTS Location				Near *Dhalao* No.195
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				20-25 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification		Sorted Total Quantity		21.204 Kg
		Plastic Waste Kg/MT		53.01
		Plastic Waste (%)		5.30
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	6.540	16.35	30.84
2 and 4	HDPE & LDPE	9.370	23.43	44.19
3	PVC	0.113	0.28	0.53
5	PP	Nil	Nil	Nil
6	PS	0.234	0.59	1.10
7	Others	4.947	12.37	23.33

Figure-31: Plastic Waste at Sunder Nagar

Figure-32: Plastic Waste at Green Park, Hauz Khas

Figure-33: Plastic Waste at Madanpur Khadar

(IX) Plastic Waste (PW) in Central Delhi Residential Areas

The survey was undertaken at Civil Lines (representing high income group), Jama Masjid Cycle Market cum Residential Area (representing middle income group) and G.T.B Nagar (representing Low income group). The assessment and characterization data can be summed-up as follows:

(a) Civil Lines

The data is summarized in table-26. The total plastic waste at this location is quantified to 67.52 Kg/MT (6.75%) of the total SW. The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 90.44% of the total plastic waste, followed by PET material and PVC material, which amounted to 2.88% and 2.85% respectively. While PS material constituted 1.82% of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 2.02% of total plastic waste.

(b) Jama Masjid Cycle Market cum Residential Area

The data is summarized in table-27. The total plastic waste at this location is quantified to 101.93 Kg/MT of total SW (10.19%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 71.76% of the total plastic waste, followed by PET material, which amounted to 23.92%. While PVC material and PS material constituted 1.79% and 1.27% respectively of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 1.26% of total plastic waste.

(c) G.T.B Nagar

The data is summarized in table-28. The total plastic waste at this location is quantified to 107.21 Kg/MT of total SW (10.72%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 54.19% of the total plastic waste, followed by PET material, which amounted to 23.97%. While PS material, PP material and PVC material constituted 3.65%, 2.74% and 1.21% respectively of total plastic waste, other plastic waste apart from above materials constituted 14.23% of total plastic waste.

Figure-34: Assessment & characterization of PW at Central Delhi Residential Areas

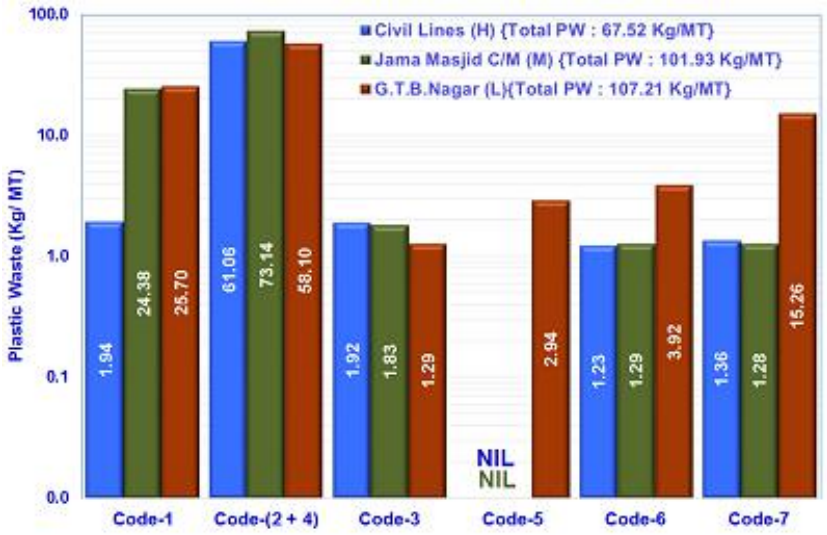


Table-26 Assessment and Characterization of Plastic Waste at Civil Lines

Zone				Central
Location				Civil Lines
Date of Survey				22.08.2019
Site Geocodes	**Latitudes**			28°40'20.7"N
	Longitudes			77°13'29.9"E
Ward Number				83
Dhalao Number				14
Area Category				High Income
Quantity of waste received per day (Secondary Information)				3-4 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				103.50 Kg
Plastic Waste Quantification	Sorted Total Quantity			6.988 Kg
	Plastic Waste Kg/MT			67.52
	Plastic Waste (%)			6.75
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.201	1.94	2.88
2 and 4	HDPE & LDPE	6.320	61.06	90.44
3	PVC	0.199	1.92	2.85
5	PP	Nil	Nil	Nil
6	PS	0.127	1.23	1.82
7	Others	0.141	1.36	2.02

Table-27 Assessment and Characterization of Plastic Waste at Jama Masjid Cycle Market

Zone				Central
Location				Jama Masjid Cycle Market
Date of Survey				19.08.2019
Site Geocodes	**Latitudes**			28°39'02.1"N
	Longitudes			77°14'10.4"E
Ward Number				84
Dhalao Number				05
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				35-45 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				108.28 Kg
Plastic Waste Quantification	Sorted Total Quantity			11.037 Kg
	Plastic Waste Kg/MT			101.93
	Plastic Waste (%)			10.19
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.640	24.38	23.92
2 and 4	HDPE & LDPE	7.920	73.14	71.76
3	PVC	0.198	1.83	1.79
5	PP	Nil	Nil	Nil
6	PS	0.140	1.29	1.27
7	Others	0.139	1.28	1.26

Table-28 Assessment and Characterization of Plastic Waste at G.T.B.Nagar

Zone				Central
Location				G.T.B.Nagar
Date of Survey				11.02.2020
Site Geocodes	**Latitudes**			28°41'43.2"N
	Longitudes			77°12'22.6"E
Ward Number				77
FCTS Location				Polo Road
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				30-35 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				110.50 Kg
Plastic Waste Quantification	Sorted Total Quantity			11.847 Kg
	Plastic Waste Kg/MT			107.21
	Plastic Waste (%)			10.72
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.840	25.70	23.97
2 and 4	HDPE & LDPE	6.420	58.10	54.19
3	PVC	0.143	1.29	1.21
5	PP	0.325	2.94	2.74
6	PS	0.433	3.92	3.65
7	Others	1.686	15.26	14.23

Figure-35: Plastic Waste at Civil Lines

Figure-36: Plastic Waste at Jama Masjid Cycle Market

Figure-37: Plastic Waste at GTB Nagar

(X) Plastic Waste (PW) at New Delhi Residential Areas

The survey was undertaken at Chanakyapuri (representing high income group), R.K.Puram Sector-7 (representing middle income group) and Rangpuri, Mahipalpur (representing low income group). The assessment and characterization data can be summarized as follows:

(a) Chanakyapuri

The data is summarized in table-29. The total plastic waste at this location is quantified to 133.28 Kg/MT (13.33%) of the total SW. The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 25.55% of the total plastic waste, followed by PET material and PP material, which amounted to 16.88% and 8.36% respectively. While PVC material constituted 3.58% of total plastic waste, the PS material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 45.63% of total plastic waste.

(b) R.K.Puram Sector-7

The data is summarized in table-30. The total plastic waste at this location is quantified to 32.42 Kg/MT of total solid waste, which amounts to 3.24% of the total SW. The characterization of plastic waste indicates that PET material constituted 53.35% of total plastic waste followed by HDPE and LDPE materials together, which constituted 32.77% of the total plastic waste. While PP material and PS material each amounted to 0.77% of total plastic waste, the PVC material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 12.34% of total plastic waste.

(c) Rangpuri, Mahipalpur

The data is summarized in table-31. The total plastic waste at this location is quantified to 80.92 Kg/MT of total SW (8.09%). The characterization of plastic waste indicated that HDPE and LDPE materials together constituted 57.92% of the total plastic waste, followed by PET material and PS material, which amounted to 14.72% and 4.42% respectively. While PVC material and PP material each amounted to 1.52% of total plastic waste, the other plastic waste apart from above materials constituted 19.91% of total plastic waste.

Figure-38: Assessment & characterization of PW in New Delhi Residential Areas

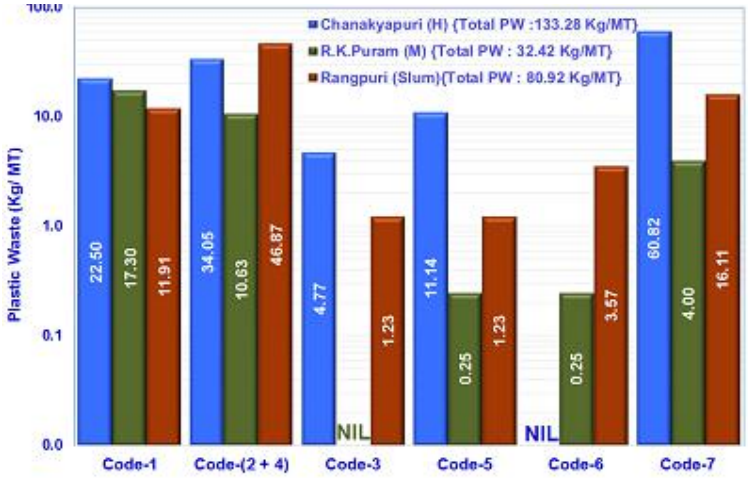


Table-29 Assessment and Characterization of Plastic Waste at Chanakyapuri

Zone				New Delhi
Location				Chanakyapuri
Date of survey				30.11.2019
Site Geocodes	**Latitudes**			28°36'8.02"N
	Longitudes			77°11'19.3"E
Ward Number				Circle No.10
FCTS Location				Circle No. 10, Chanakyapuri
Area Category				High Income
Quantity of waste received per day (Secondary Information)				12-15 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				450 Kg
Plastic Waste Quantification	Sorted Total Quantity			59.977 Kg
	Plastic Waste Kg/MT			133.28
	Plastic Waste (%)			13.33
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	10.124	22.50	16.88
2 and 4	HDPE & LDPE	15.324	34.05	25.55
3	PVC	2.146	4.77	3.58
5	PP	5.014	11.14	8.36
6	PS	Nil	Nil	Nil
7	Others	27.369	60.82	45.63

Table-30 Assessment and Characterization of Plastic Waste at R.K.Puram Sector-7

Zone				New Delhi
Location				R.K.Puram Sector-7
Date of Survey				28.11.2019
Site Geocodes	**Latitudes**			28°34'12.8"N
	Longitudes			77°10'04.8"E
Ward Number				65-S
FCTS Location				Ward No. 65-S, Sector-7
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				8-10 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification	Sorted Total Quantity			12.969 Kg
	Plastic Waste Kg/MT			32.42
	Plastic Waste (%)			3.24
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	6.919	17.30	53.35
2 and 4	HDPE & LDPE	4.250	10.63	32.77
3	PVC	Nil	Nil	Nil
5	PP	0.100	0.25	0.77
6	PS	0.100	0.25	0.77
7	Others	1.600	4.00	12.34

Table-31 Assessment and Characterization of Plastic Waste at Rangpuri, Mahipalpur

Zone				New Delhi
Location				Rangpuri, Mahipalpur
Date of Survey				14.01.2020
Site Geocodes	**Latitudes**			28°32'03.3"N
	Longitudes			77°07'12.0"E
Ward Number				50
Dhalao Number				6
Area Category				Slum
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				115 Kg
Plastic Waste Quantification	Sorted Total Quantity			9.306 Kg
	Plastic Waste Kg/MT			80.92
	Plastic Waste (%)			8.09
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	1.370	11.91	14.72
2 and 4	HDPE & LDPE	5.390	46.87	57.92
3	PVC	0.141	1.23	1.52
5	PP	0.141	1.23	1.52
6	PS	0.411	3.57	4.42
7	Others	1.853	16.11	19.91

Figure-39: Plastic Waste at Chanakyapuri

Figure-40: Plastic Waste at R.K.Puram Sector-7

Figure-41: Plastic Waste at Rangpuri, Mahipalpur

(XI) Plastic Waste (PW) at North West Delhi Residential Areas

The survey was undertaken at Peeragarhi (representing high income group), Rohini Sector-3 (representing middle income group), Madipur (representing low income area) and Nangloi JJ Colony (representing slum area). The assessment and characterization data can be summed-up as follows:

(a) Peeragarhi

The data is summarized in table-32. The total plastic waste at this location is quantified to 138.91 Kg/MT of total SW (13.89%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 43.26% of the total plastic waste, followed by PET material, which amounted to 29.27%. While PS material, PP material and PVC material constituted 2.82%, 2.56% and 0.89% respectively of total plastic waste, the other plastic waste apart from above materials constituted 21.20% of total plastic waste.

(b) Rohini Sector-3

The data is summarized in table-33. The total plastic waste at this location is quantified to 127.41 Kg/MT of total SW (12.74%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 39.54% of the total plastic waste, followed by PET material and PS material, which amounted to 26.19% and 3.89% respectively. While PS material, PP material and PVC material amounted to 3.89%, 1.86% and 0.93% respectively, the other plastic waste apart from above materials constituted 27.59% of total plastic waste.

(c) Madhipur

The data is summarized in table-34. The total plastic waste at this location is quantified to 87.65 Kg/MT of total SW (8.77%). The characterization of plastic waste indicates that HDPE and LDPE materials together constitutes 48.40% of the total plastic waste, followed by PET material, which amounted to 25.59%. While PS material, PP material and PVC material amounted to 2.39%, 1.97% and 1.40% respectively, the other plastic waste apart from above materials constituted 20.25% of total plastic waste.

(d) JJ Colony, Rajendra Park, Nangloi

The data is summarized in table-35. The total plastic waste at this location is quantified to 78.55 Kg/MT of total SW (7.86%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 91.31% of the total plastic waste, followed by PET material, which amounted to 2.72%. While PVC material and PS material constituted 2.52% and 1.71% respectively of total plastic waste, the PP material was Nil (practically not seen). Other plastic waste apart from above materials constituted 1.74% of total plastic waste.

Figure-42: Assessment & characterization of PW at NW Delhi Residential Areas

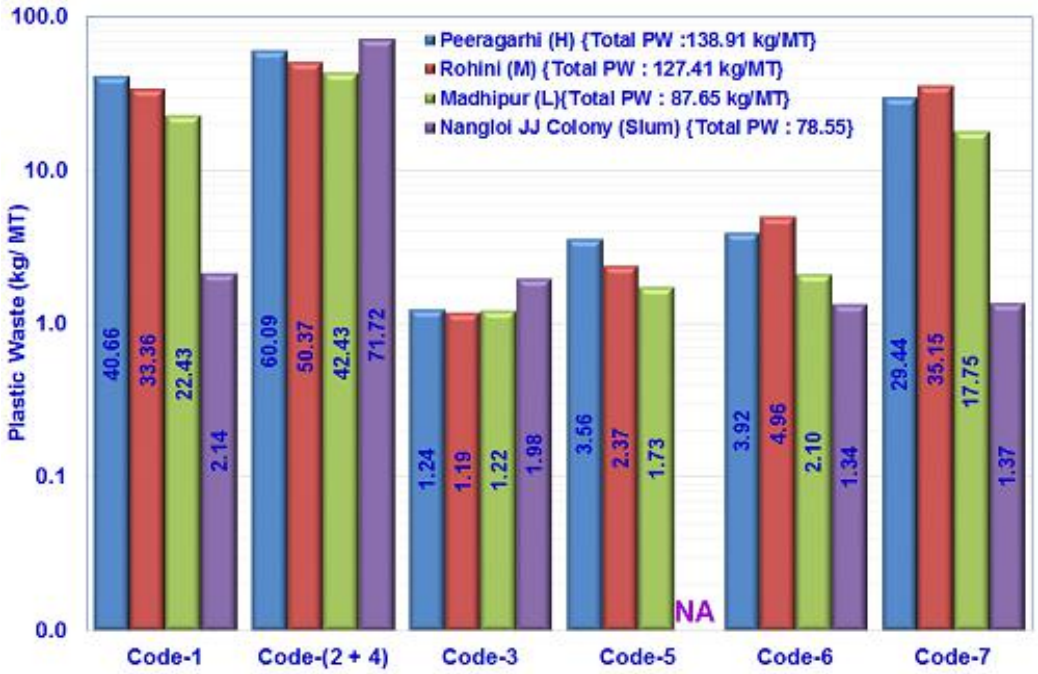


Table-32 Assessment and Characterization of Plastic Waste at Peeragarhi

Zone				North West
Location				Peeraghari
Date of Survey				04.02.2020
Site Geocodes	**Latitudes**			28°40'21.6"N
	Longitudes			77°06'21.0"E
Ward Number				67
Dhalao Number				K/7/67/D-3
Area Category				High Income
Quantity of waste received per day (Secondary Information)				8-10 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				106.00 Kg
Plastic Waste Quantification	Sorted Total Quantity			14.724 Kg
	Plastic Waste Kg/MT			138.91
	Plastic Waste (%)			13.89
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	4.310	40.66	29.27
2 and 4	HDPE & LDPE	6.370	60.09	43.26
3	PVC	0.131	1.24	0.89
5	PP	0.377	3.56	2.56
6	PS	0.415	3.92	2.82
7	Others	3.121	29.44	21.20

Table-33 Assessment and Characterization of Plastic Waste at Rohini Sector-3

Zone				North West
Location				Rohini Sector-3
Date of Survey				04.02.2020
Site Geocodes	**Latitudes**			28°42'7.8"N
	Longitudes			77°06'58.8"E
Ward Number				63
Dhalao Number				No (Waste being dumped outside the damaged *dhalao*; new one was under construction)
Area Category				Middle Income
Quantity of waste received per day (Secondary Information)				10-12 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				107.00 Kg
Plastic Waste Quantification	Sorted Total Quantity			13.633 Kg
	Plastic Waste Kg/MT			127.41
	Plastic Waste (%)			12.74
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	3.570	33.36	26.19
2 and 4	HDPE & LDPE	5.390	50.37	39.54
3	PVC	0.127	1.19	0.93
5	PP	0.254	2.37	1.86
6	PS	0.531	4.96	3.89
7	Others	3.761	35.15	27.59

Table-34 Assessment and Characterization of Plastic Waste at Madhipur

Zone				North West
Location				Madhipur, Peeragarhi
Date of Survey				04.02.2020
Site Geocodes	**Latitudes**			28°40'45.3"N
	Longitudes			77°0.5'58.7"E
Ward Number				67
Dhalao Number				3
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				4-5 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				103.00 Kg
Plastic Waste Quantification	Sorted Total Quantity			9.028 Kg
	Plastic Waste Kg/MT			87.65
	Plastic Waste (%)			8.77
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.310	22.43	25.59
2 and 4	HDPE & LDPE	4.370	42.43	48.40
3	PVC	0.126	1.22	1.40
5	PP	0.178	1.73	1.97
6	PS	0.216	2.10	2.39
7	Others	1.828	17.75	20.25

Table-35 Assessment and Characterization of Plastic Waste at JJ Colony, Rajendra Park, Nangloi

Location				JJ Colony, Rajendra Park, Nangloi
Date of Survey				27.09.2019
Site Geocodes	**Latitudes**			28°40'34.6"N
	Longitudes			77°03'55.0"E
Ward Number				37
Dhalao Number				No (Waste dumped near Rly.Station)
Area Category				Slum
Quantity of waste received per day (Secondary Information)				40-50 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				101.50 Kg
Plastic Waste Quantification	Sorted Total Quantity			7.973 Kg
	Plastic Waste Kg/MT			78.55
	Plastic Waste (%)			7.86
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/ MT of Total SW**	**Percentage of PW**
1	PET	0.217	2.14	2.72
2 and 4	HDPE & LDPE	7.280	71.72	91.31
3	PVC	0.201	1.98	2.52
5	PP	Nil	Nil	Nil
6	PS	0.136	1.34	1.71
7	Others	0.139	1.37	1.74

Figure-43: Plastic Waste at Peeragarhi

Figure-44: Plastic Waste at Rohini Sector-3

Figure-45: Plastic Waste at Madhipur

Figure-46: Plastic Waste at Nangloi JJ Colony

(XII) Plastic Waste (PW) at South West Delhi Residential Areas

The survey was undertaken at Dwarka Sector-12 (representing high income group), Palam (representing middle income group) and Roshanpura (representing low income group). The assessment and characterization data can be summed-up as follows.

(a) Dwarka Sector-12

The data is summarized in table-36. The total plastic waste at this location is quantified to 92.74 Kg/MT of total SW (9.27%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 49.91% of the total plastic waste, followed by PET material, which amounted to 24.54%. While PS material, PP material and PVC material constituted 2.65%, 1.52% and 1.17% respectively, the other plastic waste apart from above materials constituted 20.21% of total plastic waste.

(b) Palam

The data is summarized in table-37. The total plastic waste at this location is quantified to 81.18 Kg/MT of total SW (8.12%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 60.57% of the total plastic waste, followed by PET material, which amounted to 23.84%. While PS material, PP material and PVC material constituted 2.41%, 1.77% and 1.37% respectively, the other plastic waste apart from above materials constituted 10.04% of total plastic waste.

(c) Roshanpura

The data is summarized in table-38. The total plastic waste at this location is quantified to 49.83 Kg/MT of total SW (4.98%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 46.33% of the total plastic waste, followed by PET material, which amounted to 25.46%. While PS material, PP material and PVC material constituted 1.84%, 1.40% and 0.55% respectively, the other plastic waste apart from above materials constituted 24.42% of total plastic waste.

Figure-47: Assessment & characterization of PW at SW Delhi Residential Areas

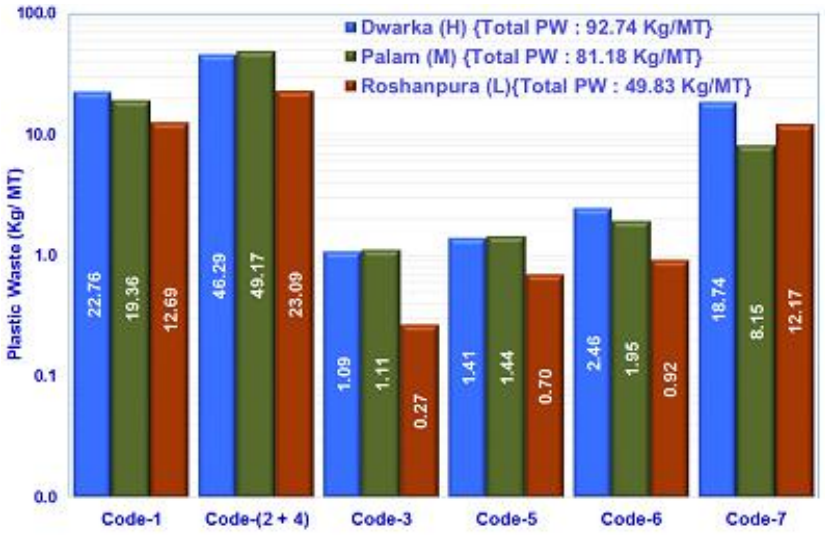


Table-36 Assessment and Characterization of Plastic Waste at Dwarka Sector-12

Zone				South West
Location				Dwarka, Sector-12
Date of Survey				13.01.2020
Site Geocodes		**Latitudes**		28°35'29.4"N
		Longitudes		77°02'42.9"E
Ward Number				36 & 38
Dhalao Number	Dhalao available without any number (FCTS is under construction)			
Area Category				High Income
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				105.00 Kg
Plastic Waste Quantification		Sorted Total Quantity		9.738 Kg
		Plastic Waste Kg/MT		92.74
		Plastic Waste (%)		9.27
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.390	22.76	24.54
2 and 4	HDPE & LDPE	4.860	46.29	49.91
3	PVC	0.114	1.09	1.17
5	PP	0.148	1.41	1.52
6	PS	0.258	2.46	2.65
7	Others	1.968	18.74	20.21

Table-37 Assessment and Characterization of Plastic Waste at Palam

Zone				South West
Location				Palam
Date of Survey				08.01.2020
Site Geocodes		**Latitudes**		28°35'16.9"N
		Longitudes		77°04'58.8"E
Ward Number				54 S
Dhalao Number	Dhalao available without any number (FCTS is under construction)			
Area Category				Middle
Quantity of waste received per day (Secondary Information)				5-6 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				109.00 Kg
Plastic Waste Quantification		Sorted Total Quantity		8.849 Kg
		Plastic Waste Kg/MT		81.18
		Plastic Waste (%)		8.12
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.110	19.36	23.84
2 and 4	HDPE & LDPE	5.360	49.17	60.57
3	PVC	0.121	1.11	1.37
5	PP	0.157	1.44	1.77
6	PS	0.213	1.95	2.41
7	Others	0.888	8.15	10.04

Table-38 Assessment and Characterization of Plastic Waste at Roshanpura

Zone				South West
Location				Roshanpura
Date of Survey				13.01.2020
Site Geocodes	**Latitudes**			28°36'05.9"N
	Longitudes			76°59'17.3"E
Ward Number				44 S
FCTS Location				Ward No.44 S
Area Category				Low Income
Quantity of waste received per day (Secondary Information)				15 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				450 Kg
Plastic Waste Quantification	Sorted Total Quantity			22.425 Kg
	Plastic Waste Kg/MT			49.83
	Plastic Waste (%)			4.98
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	5.710	12.69	25.46
2 and 4	HDPE & LDPE	10.390	23.09	46.33
3	PVC	0.123	0.27	0.55
5	PP	0.314	0.70	1.40
6	PS	0.412	0.92	1.84
7	Others	5.476	12.17	24.42

Figure-48: Plastic Waste at Dwarka

Figure-49: Plastic Waste at Palam

Figure-50: Plastic Waste at Rosanpura

(B) Tourist Areas

(I) Coverage of Tourist Areas

The Tourist Areas covered for Assessment and Characterization of Plastic Waste, are illustrated in table-39. The plastic waste assessment and characterization data of tourist areas, can be summed-up as follows:

Table-39 The coverage of Tourist Areas

District/ Zone	Tourist Spot	Category	Date of Survey
Central Delhi	Red Fort	Monument	12.07.2019
Central Delhi	Jama Masjid	Pilgrimage	20.08.2019
South East	Millennium Park	Picnic Spot/ Park	26.08.2019
East	Akshardham Temple	Pilgrimage	03.12.2019
New Delhi	Gurudwara Bangla Sahib	Pilgrimage	30.11.2019
New Delhi	National Museum	Museum	24.07.2019

(II) Red Fort

The data is summarized in table-40. The total plastic waste at this location is quantified to 64.13 Kg/MT of total SW (6.41%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 86.32% of the total plastic waste, followed by PET material and PS material, which amounted to 5.02% and 3.45% respectively. While PVC material constituted 2.97% of total plastic waste, PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 2.24% of total PW.

(III) Jama Masjid

The data is summarized in table-41. The total plastic waste at this location is quantified to 112.34 Kg/MT of total SW (11.23%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 93.89% of the total plastic waste. While PET material, PVC material and PS material, amounted to 1.87%, 1.79% and 1.21% respectively, the PS material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 1.24% of total plastic waste.

(IV) Akshardham Temple

The data is summarized in table-42. The total plastic waste at this location is quantified to 56.25 Kg/MT of total SW (5.62%). The characterization of plastic waste indicates that 100% presence of PET material. The other materials were found Nil (practically not seen).

(V) Gurudwara Bangla Sahib

The data is summarized in table-43. The plastic waste is not available, as it is not seen in the Gurudwara complex. The *Langar/ Bhandara/ Prasad* is now being served in plates/ bowls made of dry leaves, the waste of which is being sent for composting.

(VI) Millennium Park

The data is summarized in table-44. The total plastic waste at this location is quantified to 21.48 Kg/MT of total SW (2.15%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 81.48% of the total plastic waste. While PET material and PVC material, each amounted to 9.26% of total plastic waste, the materials (PP, PS and others) were found Nil (practically not seen).

(VII) National Museum

The data is summarized in table-45. The total plastic waste at this location is quantified to 195.08 Kg/MT of total SW (19.51%). The characterization of plastic waste indicates that PET material comprised of 52.10% of total plastic waste, whereas HDPE and LDPE materials together constituted 47.90% of the total plastic waste. The other material were found Nil (practically not seen).

Table-40 Assessment and Characterization of Plastic Waste at Red Fort

Zone				Central
Location				Red Fort
Date of Survey				12.07.2019
Site Geocodes	**Latitudes**			28°39'06.3"N
	Longitudes			77°14'22.2"E
Ward Number				84
Dhalao Number				02/84
Area Category				Tourist Area
Quantity of waste received per day (Secondary Information)				Average 2 TPD Maximum during event is 8TPD
Quantity of Waste Processed for Segregation of Plastic Waste				99.38 Kg
Plastic Waste Quantification	Sorted Total Quantity			6.373 Kg
	Plastic Waste Kg/MT			64.13
	Plastic Waste (%)			6.41
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.320	3.22	5.02
2 and 4	HDPE & LDPE	5.501	55.35	86.32
3	PVC	0.189	1.90	2.97
5	PP	Nil	Nil	Nil
6	PS	0.220	2.21	3.45
7	Others	0.143	1.44	2.24

Table-41 Assessment and Characterization of Plastic Waste at Jama Masjid

Zone				Central
Location				Jama Masjid
Date of Survey				20.08.2019
Site Geocodes	**Latitudes**			28°38'58.0"N
	Longitudes			77°14'00.3"E
Ward Number				85
Dhalao Number				17/85
Area Category				Tourist
Quantity of waste received per day (Secondary Information)				40-50 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				102.30 kg
Plastic Waste Quantification	Sorted Total Quantity			11.492 kg
	Plastic Waste Kg/MT			112.34
	Plastic Waste (%)			11.23
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.215	2.10	1.87
2 and 4	HDPE & LDPE	10.79	105.47	93.89
3	PVC	0.206	2.01	1.79
5	PP	Nil	Nil	Nil
6	PS	0.139	1.36	1.21
7	Others	0.142	1.39	1.24

Table-42 Assessment and Characterization of Plastic Waste at Akshardham Temple

Zone				East
Location				Akshardham Temple
Date of Survey				03.12.2019
Site Geocodes	**Latitudes**			28°36'47.4"N
	Longitudes			77°16'34.6"E
Ward Number				Temple complex
Dhalao Number				Within temple complex
Area Category				Tourist Area
Quantity of waste received per day (Secondary Information)				500-600 Kg per day
Quantity of Waste Processed for Segregation of Plastic Waste				520 Kg
Plastic Waste Quantification	Sorted Total Quantity			29.250 Kg
	Plastic Waste Kg/MT			56.25
	Plastic Waste (%)			5.62
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	29.25	56.25	100.00
2 and 4	HDPE & LDPE	Nil	Nil	Nil
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	Nil	Nil	Nil
7	Others	Nil	Nil	Nil

Table-43 Assessment and Characterization of Plastic Waste at Gurudwara Bangla Sahib

Zone				New Delhi
Location				Gurudwara Bangla Sahib
Date of Survey				30.11.2019
Site Geocodes	**Latitudes**			28°37'32.6"N
	Longitudes			77°12'39.0"E
Ward Number				Gurudwara Complex
Dhalao Number				Within Gurudwara complex
Area Category				Tourist Area
Quantity of waste received per day (Secondary Information)				400 to 500 Kg/d
Quantity of Waste Processed for Segregation of Plastic Waste				60 Kg
Plastic Waste Quantification	Sorted Total Quantity			Nil
	Plastic Waste Kg/MT			Nil
	Plastic Waste (%)			Nil
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	Nil	Nil	Nil
2 and 4	HDPE & LDPE	Nil	Nil	Nil
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	Nil	Nil	Nil
7	Others	Nil	Nil	Nil

- *Langar/ Bhandara/ Prasad* is now served in leaves plates, the waste of which is being sent for composting.
- Plastic Waste is found Nil, as it is not seen in the Gurudwara complex.

Table-44 Assessment and Characterization of Plastic Waste at Millennium Park

Zone				South East
Location				Millennium Park
Date of Survey				26.08.2019
Site Geocodes	**Latitudes**			28°35'49.8"N
	Longitudes			77°15'15.8"E
Ward Number				Near Sarai Kale Khan ISBT
Dhalao Number				Own Dhalao
Area Category				Miscellaneous LU
Quantity of waste received per day (Secondary Information)				25-30 Kg per day
Quantity of Waste Processed for Segregation of Plastic Waste				25.14 Kg
Plastic Waste Quantification	Sorted Total Quantity			0.540 Kg
	Plastic Waste Kg/MT			21.48
	Plastic Waste (%)			2.15
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.05	1.99	9.26
2 and 4	HDPE & LDPE	0.44	17.50	81.48
3	PVC	0.05	1.99	9.26
5	PP	Nil	Nil	Nil
6	PS	Nil	Nil	Nil
7	Others	Nil	Nil	Nil

Table-45 Assessment and Characterization of Plastic Waste at National Museum

Zone				New Delhi
Location				National Museum
Date of Survey				24.07.2019
Site Geocodes	**Latitudes**			28°36'42.42"N
	Longitudes			77°13'9.12"E
Ward Number				Within museum complex
Dhalao Number				Dust Bin
Area Category				Tourism
Quantity of waste received per day (Secondary Information)				20-30 Kg per day
Quantity of Waste Processed for Segregation of Plastic Waste				6.1
Plastic Waste Quantification	Sorted Total Quantity			1.190 Kg
	Plastic Waste Kg/MT			195.08
	Plastic Waste (%)			19.51
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.62	101.64	52.10
2 and 4	HDPE & LDPE	0.57	93.44	47.90
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	Nil	Nil	Nil
7	Others	Nil	Nil	Nil

Figure-51: Assessment & characterization of PW in Tourist Areas

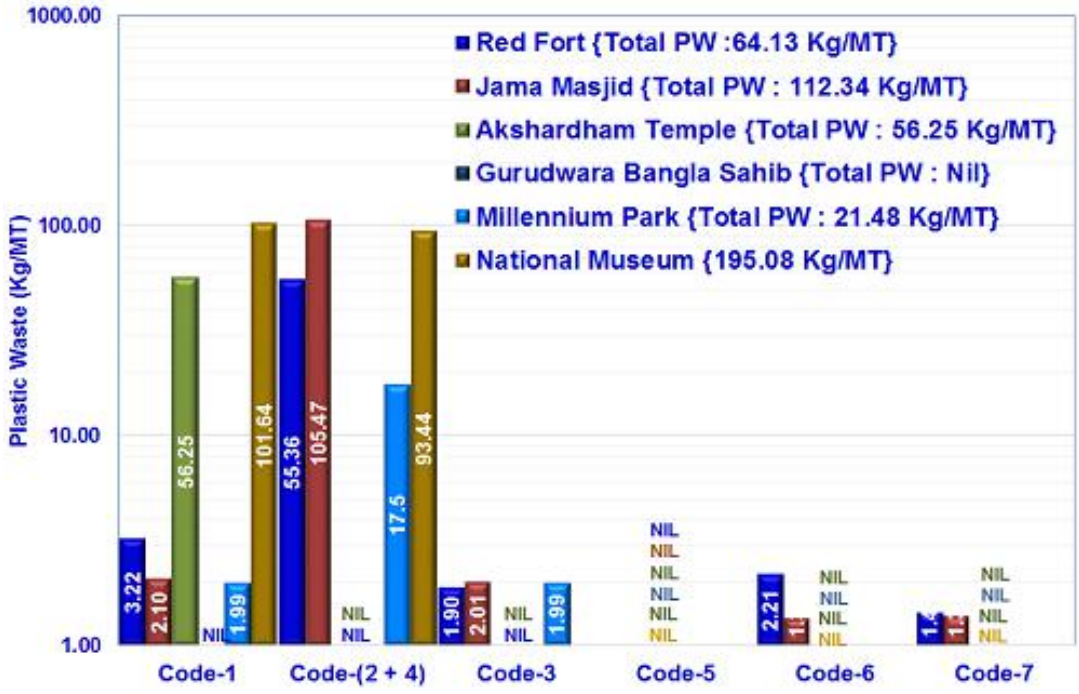


Figure-52: Plastic Waste at Red Fort

Figure-53: Plastic Waste at Jama Masjid

Figure-54: Plastic Waste at Millennium Park

Figure-55: Plastic Waste at Akshardham Temple

Figure-56: Plastic Waste at National Museaum

(C) Market Places and Commercial Areas

(I) Coverage of Market Places and Commercial areas

The market places and commercial areas covered for Assessment and Characterization of Plastic Waste, are illustrated in table-46, which are categorized into *Mandis* and Markets. The plastic waste assessment and characterization data of these areas, can be summed-up as follows:

Table-46 The coverage of Market Places and Commercial Areas

District/ Zone	Areas Description	Category	Date of Survey
East	Ghazipur Vegetable Market	Mandi	30.09.2019
South	Okhla Mandi	Mandi	02.01.2020
North	Azadpur Mandi	Mandi	11.02.2020
South East	Lajpat Nagar Central market	Commercial Area	20.11.2019
New Delhi	Khan Market	Commercial Area	01.10.2019
Central	Kamla Nagar Market	Commercial Area	04.02.2020
East	Krishna Nagar Market	Commercial Area	14.02.2020
Karol Bagh	Ajmal Khan Road Market	Commercial Area	14.02.2020
Karol Bagh	Videocon Cycle Market	Commercial Area	15.02.2020

(II) Plastic Waste Generation at Mandis

The survey was undertaken at Ghazipur Vegetable Market, Okhla Mandi and Azadpur Mandi. The assessment and characterization data can be summed-up as follows.

(a) Ghazipur Vegetable Market

The data is summarized in table-47. The total plastic waste at this location is quantified to 114.15 Kg/MT of total SW (11.41%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 94.61% of the total plastic waste. While PET material, PVC material and PS material respectively constituted 1.64%, 1.41% and 1.18% of total plastic waste, the PP material was found Nil (practically not seen). Other plastic waste apart from above materials constituted 1.16% of total plastic waste.

(b) Okhla Mandi

The data is summarized in table-48. The total plastic waste at this location is quantified to 19.82 kg/MT of total SW (1.98%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 51.85% of the total plastic waste followed by PET material, which constituted 44.53%. While PS material constituted 1.84% of total plastic waste, the PP and PVC materials were found Nil (practically not seen). Other plastic waste apart from above materials constituted 1.78% of total plastic waste.

(c) Azadpur Mandi

The data is summarized in table-49. The total plastic waste at this location is quantified to 98.07 Kg/MT of total SW (9.81%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 40.88% of the total plastic waste followed by PET material, which constituted 17.68%. While PS material constituted 20.30% of total plastic waste, the PP and PVC materials were found Nil (practically not seen). Other plastic waste apart from above materials constituted 21.14% of total plastic waste.

Figure-57: Assessment & characterization of PW at *Mandis* (Market & Commercial Areas)

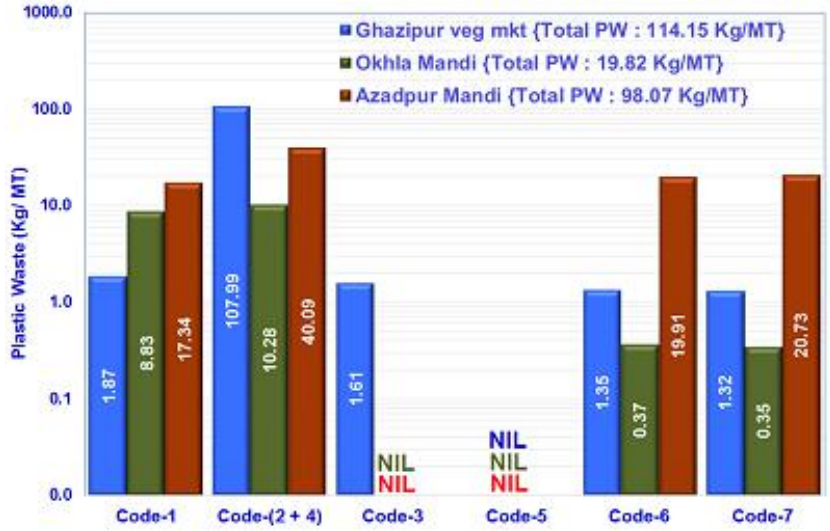


Table-47 Assessment and Characterization of Plastic Waste at Ghazipur Vegetable Market

Zone				East
Location				Ghazipur Vegetable Market
Date of Survey				30.09.2019
Site Geocodes	**Latitudes**			28°37'50.9"N
	Longitudes			77°19'21.8"E
Ward Number				39 E
Dhalao Number				Own *Dhalao*
Area Category				Market
Quantity of waste received per day (Secondary Information)				300 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				105.10 Kg
Plastic Waste Quantification	Sorted Total Quantity			11.997 Kg
	Plastic Waste Kg/ MT			114.15
	Plastic Waste (%)			11.41
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.197	1.87	1.64
2 and 4	HDPE & LDPE	11.35	107.99	94.61
3	PVC	0.169	1.61	1.41
5	PP	Nil	Nil	Nil
6	PS	0.142	1.35	1.18
7	Others	0.139	1.32	1.16

Table-48 Assessment and Characterization of Plastic Waste at Okhla Mandi

Zone				South
Location				Okhla Mandi
Date of Survey				02.01.2020
Site Geocodes	**Latitudes**			28°33'35.3"N
	Longitudes			77°15'41.1"E
Ward Number				89-S
Dhalao Number				123
Area Category				Market Area
Quantity of waste received per day (Secondary Information)				10 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification	Sorted Total Quantity			7.927 Kg
	Plastic Waste Kg /MT			19.82
	Plastic Waste (%)			1.98
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/ MT of Total SW**	**Percentage of PW**
1	PET	3.53	8.83	44.53
2 and 4	HDPE & LDPE	4.11	10.28	51.85
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	0.146	0.37	1.84
7	Others	0.141	0.35	1.78

Table-49 Assessment and Characterization of Plastic Waste at Azadpur Mandi

Zone				North
Location				Azadpur Mandi
Date of Survey				11.02.2020
Site Geocodes	**Latitudes**			28°42'42.86"N
	Longitudes			77°10'20.05"E
Ward Number				Mandi Complex
Dhalao Number				Not available (dumping area demarcated)
Area Category				Market
Quantity of waste received per day (Secondary Information)				(15-20 TPD) x 2
Quantity of Waste Processed for Segregation of Plastic Waste				109 Kg
Plastic Waste Quantification	Sorted Total Quantity			10.690 Kg
	Plastic Waste Kg/MT			98.07
	Plastic Waste (%)			9.81
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/ MT of Total SW**	**Percentage of PW**
1	PET	1.890	17.34	17.68
2 and 4	HDPE & LDPE	4.370	40.09	40.88
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	2.170	19.91	20.30
7	Others	2.260	20.73	21.14

Figure-58: Plastic Waste at Ghazipur Mandi

Figure-59: Plastic Waste at Okhla Mandi

Figure-60: Plastic Waste at Azadpur Mandi

(IV) Plastic Waste Generation at Commercial Areas

The survey was undertaken at Lajpat Nagar Central Market, Khan Market, Kamala Nagar Market, Krishna Nagar Market, Ajmal Khan Road Market and Videocon Cycle Market. The assessment and characterization data can be summed-up as follows:

(a) Lajpat Nagar Central Market

The data is summarized in table-50. The total plastic waste at this location is quantified to 177.24 Kg/MT of total SW (17.72%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 28.16% of the total plastic waste, followed by PET material, which amounted to 27.24%. While PVC material, PS material and PP material constituted 0.64%, 0.61% and 0.55% respectively of total plastic waste, other plastic waste apart from above materials constituted 42.80%.

(b) Khan Market

The data is summarized in table-51. The total plastic waste at this location is quantified to 139.96 Kg/MT of total SW (14.00%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 39.61% of the total plastic waste, followed by PET material, which amounted to 30.45%. While PS material, PP material and PVC material constituted 4.00%, 2.18% and 0.87% respectively, other plastic waste apart from above materials constituted 22.89% of total plastic waste.

(c) Kamla Nagar Market

The data is summarized in table-52. The total plastic waste at this location is quantified to 149.98 Kg/MT of total SW (15.00%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 43.59% of the total plastic waste, followed by PET material, which amounted to 32.52%. While PP material, PS material and PVC material constituted 2.62%, 2.30% and 0.89% respectively, other plastic waste apart from above materials constituted 18.08% of total plastic waste.

(d) Krishna Nagar Market

The data is summarized in table-53. The total plastic waste at this location is quantified to 148.45 Kg/MT of total SW (14.84%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 40.42% of the total plastic waste, followed by PET material, which amounted to 26.00%. While PS material, PVC material and PP material constituted 1.50%, 0.87% and 0.86% respectively, other plastic waste apart from above materials constituted 30.35% of total plastic waste.

(e) Ajmal Khan Road Market

The data is summarized in table-54. The total plastic waste at this location is quantified to 170.95 Kg/MT of total SW (17.10%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 31.89% of the total plastic waste, followed by PET material, which amounted to 28.01%. While PS material, PVC material and PP material constituted 0.92%, 0.73% and 0.68% respectively, other plastic waste apart from above materials constituted 37.77% of total plastic waste.

(f) Videocon Cycle Market

The data is summarized in table-55. The total plastic waste at this location is quantified to 162.10 Kg/MT of total SW (16.21%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 40.61% of the total plastic waste, followed by PET material, which amounted to 28.75%. While PS material, PP material and PVC material constituted 7.78%, 1.32% and 0.72% respectively, other plastic waste apart from above materials constituted 20.82% of total plastic waste.

Figure-61: Assessment & characterization of PW at Commercial Areas

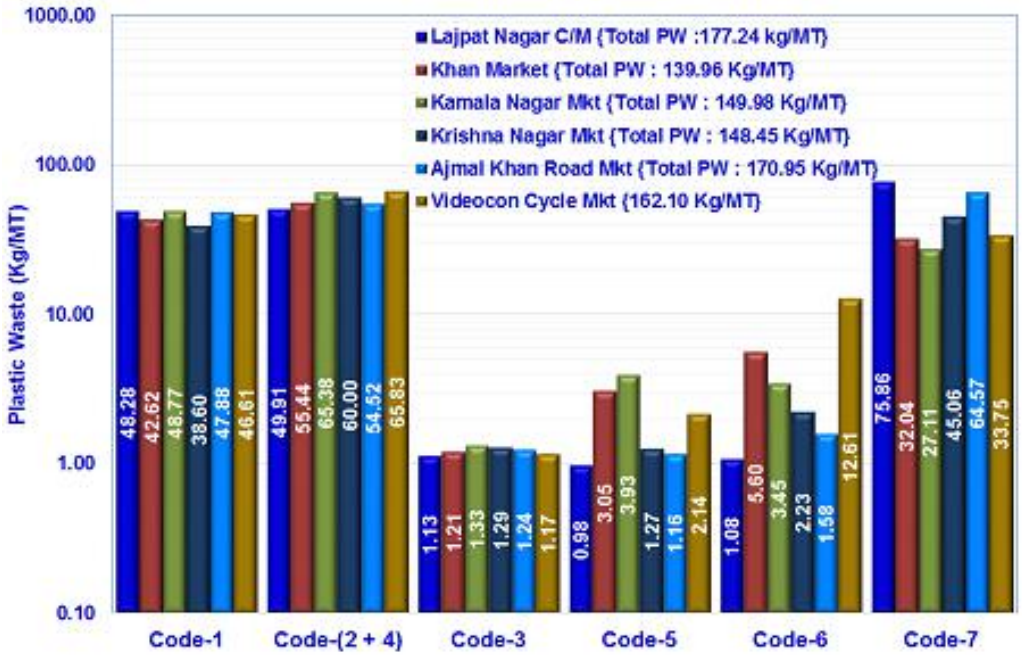


Table-50 Assessment and Characterization of Plastic Waste at Lajpat Nagar Central Market

Zone				South East
Location				Lajpat Nagar Central Market
Date of Survey				20.11.2019
Site Geocodes	**Latitudes**			28°34'05.6"N
	Longitudes			77°14'29.2"E
Ward Number				57 S
Dhalao Number				5/575
Area Category				Market
Quantity of waste received per day (Secondary Information)				2-3 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				116 Kg
Plastic Waste Quantification	Sorted Total Quantity			20.56 Kg
	Plastic Waste Kg/MT			177.24
	Plastic Waste (%)			17.72
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	5.600	48.28	27.24
2 and 4	HDPE & LDPE	5.790	49.91	28.16
3	PVC	0.131	1.13	0.64
5	PP	0.114	0.98	0.55
6	PS	0.125	1.08	0.61
7	Others	8.800	75.86	42.80

Table-51 Assessment and Characterization of Plastic Waste at Khan Market

Zone				New Delhi
Location				Khan Market
Date of Survey				01.10.2019
Site Geocodes	**Latitudes**			28°35'54.4"N
	Longitudes			77°13'20.0"E
Ward Number				NDMC 005
Dhalao Number				Mobile Bin
Area Category				Market
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				103.00 Kg
Plastic Waste Quantification	Sorted Total Quantity			14.416 Kg
	Plastic Waste Kg/MT			139.96
	Plastic Waste (%)			14.00
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	4.390	42.62	30.45
2 and 4	HDPE & LDPE	5.710	55.44	39.61
3	PVC	0.125	1.21	0.87
5	PP	0.314	3.05	2.18
6	PS	0.577	5.60	4.00
7	Others	3.300	32.04	22.89

Table-52 Assessment and Characterization of Plastic Waste at Kamla Nagar Market

Zone				Central
Location				Kamla Nagar Market
Date of Survey				04.02.2020
Site Geocodes	**Latitudes**			28°40'41.99"N
	Longitudes			77°12'4.38"E
Ward Number				69
Dhalao Number				FCTS
Area Category				Market
Quantity of waste received per day (Secondary Information)				40 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				106.00 Kg
Plastic Waste Quantification	Sorted Total Quantity			15.898 Kg
	Plastic Waste Kg/MT			149.98
	Plastic Waste (%)			15.00
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	5.170	48.77	32.52
2 and 4	HDPE & LDPE	6.930	65.38	43.59
3	PVC	0.141	1.33	0.89
5	PP	0.417	3.93	2.62
6	PS	0.366	3.45	2.30
7	Others	2.874	27.11	18.08

Table-53 Assessment and Characterization of Plastic Waste at Krishna Nagar Market

Zone				East
Location				Krishna Nagar Market
Date of Survey				14.02.2020
Site Geocodes	**Latitudes**			28°39'25.98"N
	Longitudes			77°17'25.62"E
Ward Number				229
Dhalao Number				135
Area Category				Market
Quantity of waste received per day (Secondary Information)				15-20 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				107 Kg
Plastic Waste Quantification	Sorted Total Quantity			15.884 Kg
	Plastic Waste Kg/MT			148.45
	Plastic Waste (%)			14.84
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	4.130	38.60	26.00
2 and 4	HDPE & LDPE	6.420	60.00	40.42
3	PVC	0.138	1.29	0.87
5	PP	0.136	1.27	0.86
6	PS	0.239	2.23	1.50
7	Others	4.821	45.06	30.35

Table-54 Assessment and Characterization of Plastic Waste at Ajmal Khan Road Market

Zone				Karol Bagh
Location				Ajmal Khan Road Market
Date of Survey				14.02.2020
Site Geocodes	**Latitudes**			28°39'12.58"N
	Longitudes			77°11'21.91"E
Ward Number				93
Dhalao Number				20
Area Category				Market
Quantity of waste received per day (Secondary Information)				30 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				104 Kg
Plastic Waste Quantification	Sorted Total Quantity			17.779 Kg
	Plastic Waste Kg/MT			170.95
	Plastic Waste (%)			17.10
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	4.980	47.88	28.01
2 and 4	HDPE & LDPE	5.670	54.52	31.89
3	PVC	0.129	1.24	0.73
5	PP	0.121	1.16	0.68
6	PS	0.164	1.58	0.92
7	Others	6.715	64.57	37.77

Table-55 Assessment and Characterization of Plastic Waste at Videocon Cycle Market

Zone				Karol Bagh
Location				Videocon Cycle Market
Date of Survey				15.02.2020
Site Geocodes	**Latitudes**			28°38'43.33"N
	Longitudes			77°12'12.53"E
Ward Number				93
Dhalao Number				18
Area Category				Market
Quantity of waste received per day (Secondary Information)				8-10 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				115 Kg
Plastic Waste Quantification	Sorted Total Quantity			18.641 Kg
	Plastic Waste Kg/MT			162.10
	Plastic Waste (%)			16.21
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	5.360	46.61	28.75
2 and 4	HDPE & LDPE	7.570	65.83	40.61
3	PVC	0.134	1.17	0.72
5	PP	0.246	2.14	1.32
6	PS	1.450	12.61	7.78
7	Others	3.881	33.75	20.82

Figure-62: Plastic Waste at Lajpat Nagar Market

Figure-63: Plastic Waste at Khan Market

Figure-64: Plastic Waste at Kamla Nagar Market

Figure-65: Plastic Waste at Krishna Nagar Market

Figure-66: Plastic Waste at Ajmal Khan Road Market

Figure-67: Plastic Waste at Videocon Cycle Market

(D) Plastic Waste Generation at Public Places

(I) Coverage of Public Places

The public places covered for the Assessment and Characterization of Plastic Waste, are illustrated in table-56. The plastic waste assessment and characterization data of these areas, are summarized as follows:

Table-56 The coverage of Public Places

District/ Zone	Areas Description	Category	Date of Survey
Central	Kashmere Gate ISBT	Bus Terminal	30.10.2019
New Delhi	New Delhi Railway Station	Railway Station	03.12.2020
South	Nizamuddin Railway Station	Railway station	18.12.2019
IGI Airport	IGI Airport	Airport	11.09.2020*

*Secondary data receiving date

(II) Plastic Waste at Kashmere Gate ISBT

The data is summarized in table-57. The total plastic waste at this location is quantified to 302.51 kg/MT of total SW (30.25%). The characterization of plastic waste indicates that PET material constitute 83.68% of total plastic waste followed by HDPE and LDPE materials together, which constituted 9.30%. While PS material, PP material and PVC material were found Nil (practically not seen), the other plastic waste apart from above materials constituted 7.02% of total plastic waste.

(III) Plastic Waste at New Delhi Railway Station

The data is summarized in table-58. The total plastic waste at this location is quantified to 132.34 Kg/MT of total SW (13.23%). The characterization of plastic waste indicates that PET material constituted 62.07% of total plastic waste followed by PS material, which constituted 16.19%. The HDPE and LDPE materials together, constituted 13.64% of the total plastic waste. While PP material and PVC material were found Nil (practically not seen), the other plastic waste apart from above materials constituted 8.10% of total plastic waste.

(IV) Plastic Waste at Nizamuddin Railway Station

The data is summarized in table-59. The total plastic waste at this location is quantified to 111.25 kg/MT of total SW (11.13%). The characterization of plastic waste indicates that PET material constituted 63.30% of total plastic waste, while HDPE & LDPE materials, PVC material, PP material and PS material were found Nil (practically not seen), the other plastic waste apart from above materials constituted 40.83% of total plastic waste.

(V) Plastic Waste at IGI Airport

The data is summarized in table-60. The total plastic waste at this location is quantified to 124.4 kg/MT of total SW (12.44%). The plastic waste characterization indicates that PET material constituted 50.00% of total plastic waste. HDPE & LDPE materials constitutes 20% of total plastic waste and PS constitute 14.02%. While PVC material and PP material are reported Nil, the other plastic waste apart from above materials constituted 15.98% of total plastic waste.

Figure-68: Assessment & characterization of PW at Public Places

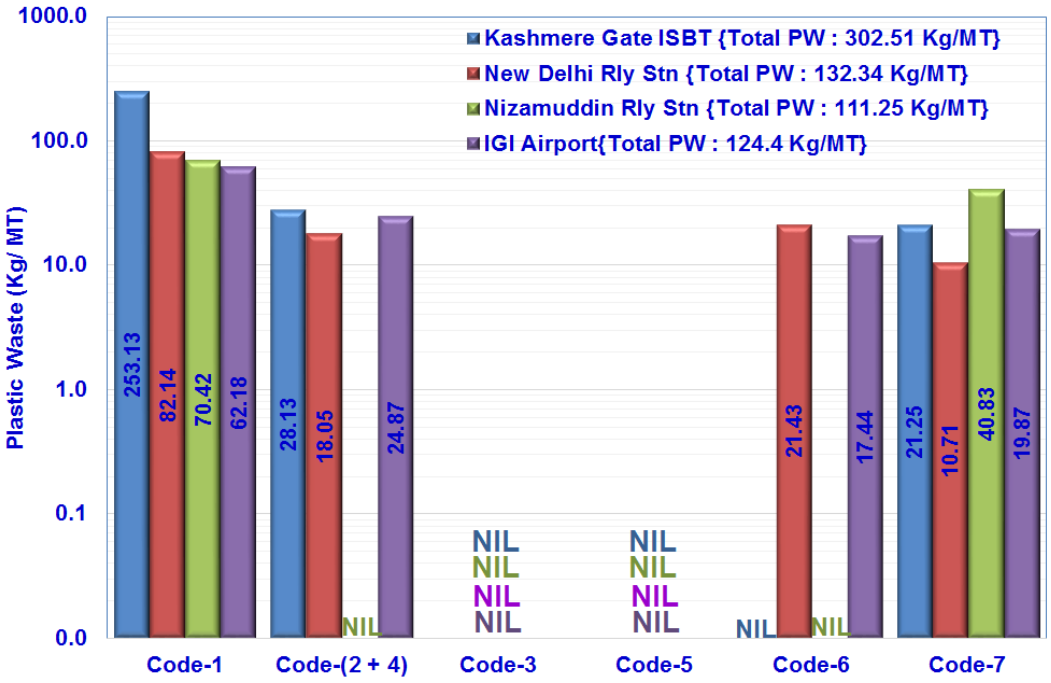


Table-57 Assessment and Characterization of Plastic Waste at Kashmere Gate ISBT

Zone				Central
Location				Kashmere Gate ISBT
Date of Survey				30.10.2019
Site Geocodes	**Latitudes**			28°40'09.2"N
	Longitudes			77°13'50.2"E
Ward Number				-
Dhalao Number				Area demarcated for waste disposal
Area Category				Public Places
Quantity of waste received per day (Secondary Information)				1 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				160 Kg
Plastic Waste Quantification	Sorted Total Quantity			48.40 Kg
	Plastic Waste Kg/MT			302.45
	Plastic Waste (%)			30.25
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	40.5	253.13	83.68
2 and 4	HDPE & LDPE	4.5	28.13	9.30
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	Nil	Nil	Nil
7	Others	3.4	21.25	7.02

Table-58 Assessment and Characterization of Plastic Waste at New Delhi Railway Station

Zone				New Delhi
Location				New Delhi Railway Station
Date of Survey				03.12.2019
Site Geocodes	**Latitudes**			28°38'16.9"N
	Longitudes			77°13'22.9"E
Ward Number				-
Dhalao Number				Area demarcated for waste disposal
Area Category				Public Places
Quantity of waste received per day (Secondary Information)				14 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				1400 Kg
Plastic Waste Quantification	Sorted Total Quantity			185 Kg
	Plastic Waste Kg/MT			132.34
	Plastic Waste (%)			13.23
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	115.00	82.14	62.07
2 and 4	HDPE & LDPE	25.27	18.05	13.64
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	30.00	21.43	16.19
7	Others	15.00	10.71	8.10

Table-59 Assessment and Characterization of Plastic Waste at Nizamuddin Railway Station

Zone				South
Location				Nizamuddin Railway Station
Date of Survey				18.12.2019
Site Geocodes	**Latitudes**			28°35'28.0"N
	Longitudes			77°15'16.9"E
Ward Number				-
Dhalao Number				Area demarcated for waste disposal
Area Category				Public Places
Quantity of waste received per day (Secondary Information)				4 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				400 Kg
Plastic Waste Quantification	Sorted Total Quantity			44.500 Kg
	Plastic Waste Kg/MT			111.25
	Plastic Waste (%)			11.13
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	28.167	70.42	63.30
2 and 4	HDPE & LDPE	Nil	Nil	Nil
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	Nil	Nil	Nil
7	Others	16.333	40.83	36.70

Table-60 Assessment and Characterization of Plastic Waste at IGI Airport

Location				IGI Airport
Area Category				Public Places
Quantity of waste received per day (Secondary Information)				15.6 TPD
Quantity of Plastic Waste (Average value for year 2019-20)				1.94 TPD
%age of plastic waste of total solid waste				12.44%
				124.4 Kg/MT
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	970	62.18	50.00
2 and 4	HDPE & LDPE	388	24.87	20.00
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	272	17.44	14.02
7	Others	310	19.87	15.98

(Data Source: Secondary information obtained from DIAL)

Figure-69: Plastic Waste at New Delhi Railway Station

Figure-70: Plastic Waste at Nizamuddin Railway Station

Figure-71: Plastic Waste at ISBT Kashmere Gate

(E) Plastic Waste Generation at Institutional Areas and Office Complexes

(I) Coverage of Institutional Areas and Office Complexes

The institutional areas and office complexes covered for the Assessment and Characterization of Plastic Waste are illustrated in table-61. The plastic waste assessment and characterization data of these areas are summarized hereinafter.

Table-61 The coverage of institutional areas and office complexes

District/ Zone	Areas Description	Category	Date of Survey
New Delhi	CGO Complex	Institutional Area	20.12.2019
Central	Tis Hazari Court	Office Complex	18.12.2019
Central	Civic Centre	Office Complex	06.01.2020

(II) Plastic Waste at CGO Complex

The data is summarized in table-62. The total plastic waste at this location is quantified to 103.72 Kg/MT of total SW (10.37%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 52.28% of the total plastic waste, followed by PET material, which amounted to 18.53%. While PS material, PVC material and PP material constituted 4.68%, 2.58% and 2.42% respectively, other plastic waste apart from above materials constituted 19.51% of total plastic waste.

(III) Plastic Waste at Tis Hazari Court

The data is summarized in table-63. The total plastic waste at this location is quantified to 115.34 Kg/MT of total SW (11.53%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 44.78% of the total plastic waste, followed by PET material, which amounted to 21.13%. While PS material, PP material and PVC material constituted 5.55%, 1.86% and 1.13% respectively, other plastic waste apart from above materials constituted 25.56% of total plastic waste.

(IV) Plastic Waste at Civic Centre

The data is summarized in table-64. The total plastic waste at this location is quantified to 87.40 Kg/MT of total SW (8.74%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 54.00% of the total plastic waste, followed by PET material, which amounted to 7.14%. While PS material, PP material and PVC material constituted 4.10%, 3.36% and 2.77% respectively, other plastic waste apart from above materials constituted 28.63% of total plastic waste.

Figure-72: Assessment & characterization of PW at Institutional Areas and Office Complexes

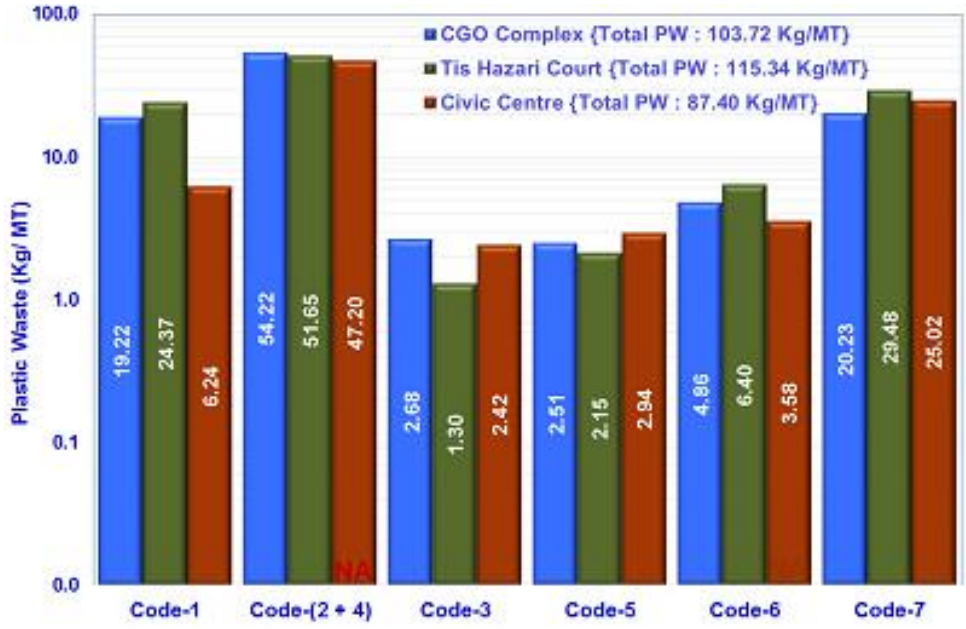


Table-62 Assessment and Characterization of Plastic Waste at CGO Complex

Zone				New Delhi
Location				CGO Complex
Date of Survey				20.12.2019
Site Geocodes	**Latitudes**			28°35'08.5"N
	Longitudes			77°14'12.5"E
Ward Number				SSC; NWM; DBT & ITBP
Dhalao Number				No Dhalao
Area Category				Institutional Area
Quantity of waste received per day (Secondary Information)				500-600 Kg
Quantity of Waste Processed for Segregation of Plastic Waste				90 Kg
Plastic Waste Quantification	Sorted Total Quantity			9.335 Kg
	Plastic Waste Kg/MT			103.72
	Plastic Waste (%)			10.37
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	1.73	19.22	18.53
2 and 4	HDPE & LDPE	4.88	54.22	52.28
3	PVC	0.241	2.68	2.58
5	PP	0.226	2.51	2.42
6	PS	0.437	4.86	4.68
7	Others	1.821	20.23	19.51

Table-63 Assessment and Characterization of Plastic Waste at Tis Hazari Court

Zone				Central
Location				Tis Hazari Court
Date of Survey				18.12.2019
Site Geocodes	**Latitudes**			28°39'57.8"N
	Longitudes			77°12'55.1"E
Ward Number				83
Dhalao Number				Damaged
Area Category				Office Complex
Quantity of waste received per day (Secondary Information)				4-5 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				103 Kg
Plastic Waste Quantification	Sorted Total Quantity			11.880 Kg
	Plastic Waste Kg/MT			115.34
	Plastic Waste (%)			11.53
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	2.510	24.37	21.13
2 and 4	HDPE & LDPE	5.320	51.65	44.78
3	PVC	0.134	1.30	1.13
5	PP	0.221	2.15	1.86
6	PS	0.659	6.40	5.55
7	Others	3.036	29.48	25.56

Table-64 Assessment and Characterization of Plastic Waste at Civic Centre

Zone				Central
Location				Civic Centre
Date of Survey				06.01.2020
Site Geocodes	**Latitudes**			28°38'19.5"N
	Longitudes			77°13'47.1"E
Ward Number				-
Dhalao Number				-
Area Category				Office Complex
Quantity of waste received per day (Secondary Information)				600-700 Kg
Quantity of Waste Processed for Segregation of Plastic Waste				50 Kg
Plastic Waste Quantification	Sorted Total Quantity			4.370
	Plastic Waste Kg/MT			87.40
	Plastic Waste (%)			8.74
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.312	6.24	7.14
2 and 4	HDPE & LDPE	2.360	47.20	54.00
3	PVC	0.121	2.42	2.77
5	PP	0.147	2.94	3.36
6	PS	0.179	3.58	4.10
7	Others	1.251	25.02	28.63

Figure-73: Plastic Waste at Tis Hazari Court

Figure-74: Plastic Waste at CGO Complex

Figure-75: Plastic Waste at Civic Centre

(F) Plastic Waste Generation at Educational Institutions

(I) Coverage of Educational Institutions

The educational institutions covered for the Assessment and Characterization of Plastic Waste, are illustrated in table-65. The plastic waste assessment and characterization data of these areas, are summarized hereinafter.

Table-65 The coverage of educational institutions

District/ Zone	Areas Description	Category	Date of Survey
North	Miranda House & Khalsa College	College in North Campus of DU	11.02.2020
South	Venktesh College	College in South Campus of DU	15.02.2020
East	DAV School, Shreshtha Vihar	School	11.02.2020
East	Ryan International school, Mayur Vihar	School	15.02.2020

(II) Plastic Waste at Miranda House and Khalsa College

The data is summarized in table-66. The total plastic waste at this location is quantified to 117.94 Kg/MT of total SW (11.79%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 44.53% of the total plastic waste, followed by PET material, which amounted to 27.82%. While PS material, PP material and PVC material constituted 19.43%, 1.19% and 1.05% respectively, other plastic waste apart from above materials constituted 5.98% of total plastic waste.

(III) Plastic Waste at Venktesh College

The data is summarized in table-67. The total plastic waste at this location is quantified to 130.61 Kg/MT of total SW (13.06%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 37.19% of the total plastic waste, followed by PET material, which amounted to 11.64%. While PS material, PVC material and PP material constituted 10.70%, 1.14% and 1.00% respectively, other plastic waste apart from above materials constituted 38.33% of total plastic waste.

(IV) Plastic Waste at DAV School, Shreshtha Vihar

The data is summarized in table-68. The total plastic waste at this location is quantified to 172.40 Kg/MT of total SW (17.24%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 41.76% of the total plastic waste, followed by PP material, which amounted to 16.01%. While PVC material, PET material and PS material constituted 15.43%, 14.04% and 12.76% respectively of total plastic waste, other plastic waste apart from above materials were found Nil (Practically not seen).

(V) Plastic Waste at Ryan International School, Mayur Vihar

The data is summarized in table-69. The total plastic waste at this location is quantified to 191.07 Kg/MT of total SW (19.11%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 43.93% of the total plastic waste, followed by PS material, which amounted to 36.45%. While PET material constituted 19.63% of total plastic waste, the PVC material, PP material and other plastic waste apart from above materials were found Nil (Practically not seen).

Figure-76: Assessment & characterization of PW at Educational Institutions

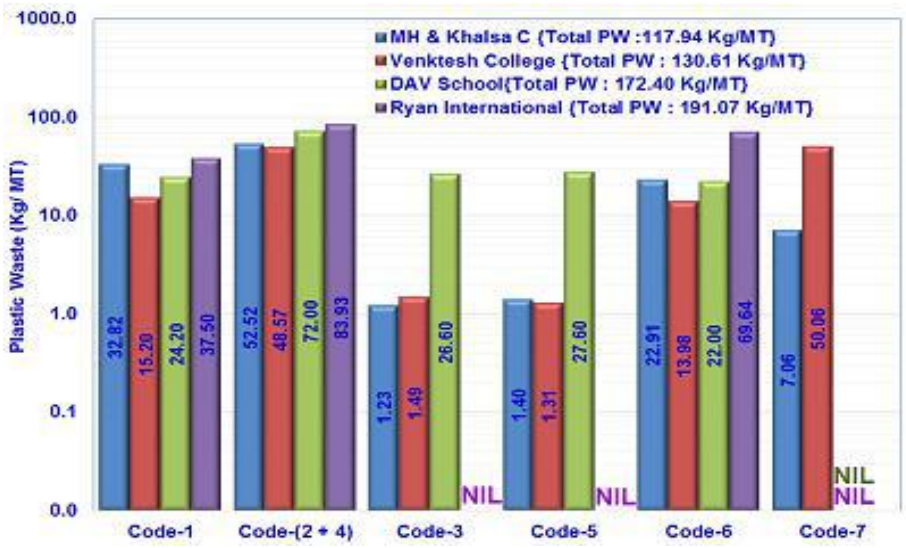


Table-66 Assessment and Characterization of Plastic Waste at Miranda House & Khalsa College

Zone				North
Location				DU North Campus
Date of Survey				11.02.2020
Site Geocodes	**Latitudes**			28°41'36.31"N
	Longitudes			77°12'32.25"E
Specific Site	Miranda House & Khalsa College			
Dhalao Number				Own Bin
Area Category				Educational
Quantity of waste received per day (Secondary Information)				4-6 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				103 Kg
Plastic Waste Quantification	Sorted Total Quantity			12.148 Kg
	Plastic Waste Kg/MT			117.94
	Plastic Waste (%)			11.79
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	3.380	32.82	27.82
2 and 4	HDPE & LDPE	5.410	52.52	44.53
3	PVC	0.127	1.23	1.05
5	PP	0.144	1.40	1.19
6	PS	2.360	22.91	19.43
7	Others	0.727	7.06	5.98

Table-67 Assessment and Characterization of Plastic Waste at Venktesh College

Zone				South
Location				DU South Camus
Date of Survey				15.02.2020
Site Geocodes	**Latitudes**			28°35'1.76"N
	Longitudes			77°9'54.3"E
Specific Site				Venktesh College
Dhalao Number				Own Bin
Area Category				Educational
Quantity of waste received per day (Secondary Information)				1-2 TPD
Quantity of Waste Processed for Segregation of Plastic Waste				98 Kg
Plastic Waste Quantification	Sorted Total Quantity			12.800 Kg
	Plastic Waste Kg/MT			130.61
	Plastic Waste (%)			13.06
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	1.490	15.20	11.64
2 and 4	HDPE & LDPE	4.760	48.57	37.19
3	PVC	0.146	1.49	1.14
5	PP	0.128	1.31	1.00
6	PS	1.370	13.98	10.70
7	Others	4.906	50.06	38.33

Table-68 Assessment and Characterization of Plastic Waste at DAV School

Zone				East
Location				DAV School, Shreshtha Vihar
Date of Survey				11.02.2020
Site Geocodes	**Latitudes**			28°39'29.63"N
	Longitudes			77°18'59.37"E
Specific Site				School Premises
Dhalao Number				Own Bin
Area Category				Educational
Quantity of waste received per day (Secondary Information)				50-60 Kg
Quantity of Waste Processed for Segregation of Plastic Waste				5 Kg
Plastic Waste Quantification	Sorted Total Quantity			0.862 Kg
	Plastic Waste Kg/MT			172.40
	Plastic Waste (%)			17.24
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.121	24.20	14.04
2 and 4	HDPE & LDPE	0.360	72.00	41.76
3	PVC	0.133	26.60	15.43
5	PP	0.138	27.60	16.01
6	PS	0.110	22.00	12.76
7	Others	0.000	0.00	0.00

Table-69 Assessment and Characterization of Plastic Waste at Ryan International School

Zone				East
Location				Ryan International School, Mayur Vihar
Date of Survey				15.02.2020
Site Geocodes	**Latitudes**			28°36'54.85"N
	Longitudes			77°20'16.74"E
Specific Site				School Campus
Dhalao Number				Own Bin
Area Category				Educational
Quantity of waste received per day (Secondary Information)				30-40 Kg per day
Quantity of Waste Processed for Segregation of Plastic Waste				5.6 Kg
Plastic Waste Quantification	Sorted Total Quantity			1.070 Kg
	Plastic Waste Kg/MT			191.07
	Plastic Waste (%)			19.11
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.210	37.50	19.63
2 and 4	HDPE & LDPE	0.470	83.93	43.93
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	0.390	69.64	36.45
7	Others	0.000	0.00	0.00

Figure-77: Plastic Waste at College in DAV School

Figure-78: Plastic Waste at College in South Campus of DU

Figure-79: Plastic Waste at College in North Campus of DU

Figure-80: Plastic Waste at Ryan International School

(G) Plastic Waste at Miscellaneous Areas

(I) Coverage of Miscellaneous Areas

The miscellaneous landuses covered for the Assessment and Characterization of Plastic Waste, are illustrated in table-70. The plastic waste assessment and characterization data of these areas, are summarized hereinafter.

Table-70 The coverage of miscellaneous areas

District/ Zone	Areas Description	Category	Date of Survey
North	Kamla Nehru Ridge	Ridge and Park	20.12.2019
East	CBD Karkardooma	Community Centre	11.02.2020

(II) Plastic Waste at Kamla Nehru Ridge

The data is summarized in table-71. The total plastic waste at this location is quantified to 304.88 Kg/MT of total SW (30.49%). The characterization of plastic waste indicates that HDPE and LDPE materials together constituted 58.67% of the total plastic waste, followed by PP material, which amounted to 34.67%. While PET material constituted 6.67% of total plastic waste, PVC material, PS material and other plastic waste apart from above materials, were found Nil (Not practically seen).

(III) Plastic Waste at CBD Karkardooma

The data is summarized in table-72. The total plastic waste at this location is quantified to 226.79 kg/MT of total SW (22.68%). The characterization of plastic waste indicates PET material constitutes 38.58% of total plastic waste, followed by HDPE and LDPE materials together, which constituted 30.71%. While PS material constituted 16.54% of total plastic waste, the PVC material and PP material were found Nil (practically not seen). Other plastic waste apart from above materials constituted 14.17%.

Table-71 Assessment and Characterization of Plastic Waste at Kamla Nehru Ridge

Zone				Central
Location				Kamla Nehru Ridge
Date of Survey				20.12.2019
Site Geocodes	**Latitudes**			28°40'54.5"N
	Longitudes			77°12'54.7"E
Ward Number				Ridge Area
Dhalao Number				Own dustbin
Area Category				Miscellaneous
Quantity of waste received per day (Secondary Information)				75 Kg
Quantity of Waste Processed for Segregation of Plastic Waste				2.46 Kg
Plastic Waste Quantification	Sorted Total Quantity			0.750 Kg
	Plastic Waste Kg/MT			304.88
	Plastic Waste (%)			30.49
Plastic Waste Categorization				
Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.050	20.33	6.67
2 and 4	HDPE & LDPE	0.440	178.86	58.67
3	PVC	Nil	Nil	Nil
5	PP	0.260	105.69	34.67
6	PS	NA	NA	NA
7	Others	NA	NA	NA

Table-72 Assessment and Characterization of Plastic Waste at CBD Karkardooma

Zone		East
Location		CBD Karkardooma
Date of Survey		11.02.2020
Site Geocodes	**Latitudes**	28°39'36.3"N
	Longitudes	77°18'01.06"E
Ward Number		225
Dhalao Number		Own dustbin
Area Category		Miscellaneous
Quantity of waste received per day (Secondary Information)		15-20 kg per day
Quantity of Waste Processed for Segregation of Plastic Waste		5.6 Kg
Plastic Waste Quantification	Sorted Total Quantity	1.27 Kg
	Plastic Waste Kg/MT	226.79
	Plastic Waste (%)	22.68

Plastic Waste Categorization

Code No. of Plastic Waste	**Category**	**Quantification and Characterization of PW**		
		Kg PW	**Kg/MT of Total SW**	**Percentage of PW**
1	PET	0.49	87.50	38.58
2 and 4	HDPE & LDPE	0.39	69.64	30.71
3	PVC	Nil	Nil	Nil
5	PP	Nil	Nil	Nil
6	PS	0.21	37.50	16.54
7	Others	0.18	32.14	14.17

Figure-81: Assessment & characterization of PW at miscellaneous landuse

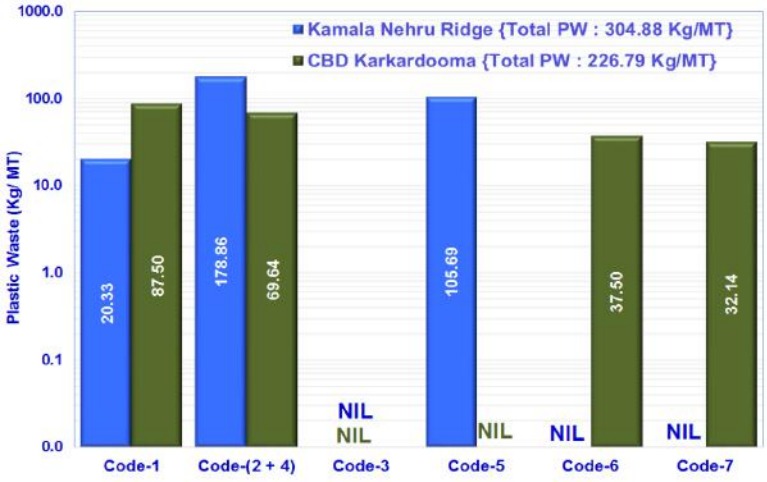


Figure-82: Plastic Waste at CBD Karkardooma

Figure-83: Plastic Waste at Kamla Nehru Ridge

(H) Plastic Waste Generation in Open Areas and Drains

Over a period, the generation of plastic waste and its dumping into the drain has bad effects by chocking the storm water drains/ *nallas* in Delhi. As plastic wastes are non-degradable in nature and accumulate and block the flow and also reduce the discharge capacity.

Figure-84: Stretch of Najafgarh Drain in Delhi choked with plastic waste (Photo taken on 13/01/2020 by SRI)

The plastic bottles, bags, food wrappers and other detritus have gushed out of a drain that ends in the shanty, leaving stinking sewer water clogging the roads at Taimur Nagar Slum Area.

Figure-85: Chocking of Taimur Nagar Slum area near drain with plastic waste
(https://www.nst.com.my/world/2018/06/376609)

Shahdara Drain

As per the EPCA Report No. 106, the Irrigation and Flood Control Department is removing floating material/ MSW from Shahdara drain. It is mentioned in the report that 8139 MT of floating material/ MSW has been lifted from Shahdara drain (Trunk Drain No. 1) from the point at RD 260 m near Patparganj Industrial Area during the period 17/01/2019 to 14/02/2019 and disposed off at SLF site of EDMC at Shinghota, Khampur, Tikari

As part of present study, the photograph of Shahdara drain at various locations have been taken during July-2020, as depicted in figures-86, 87 and 88.

Figure-86: Shahdara drain picture at Anand Vihar (July-2020)

Figure-87: Shahdara drain picture between Patparganj & Karkardooma (July-2020)

Figure-88: Shahdara drain near Sahibabad (July-2020)

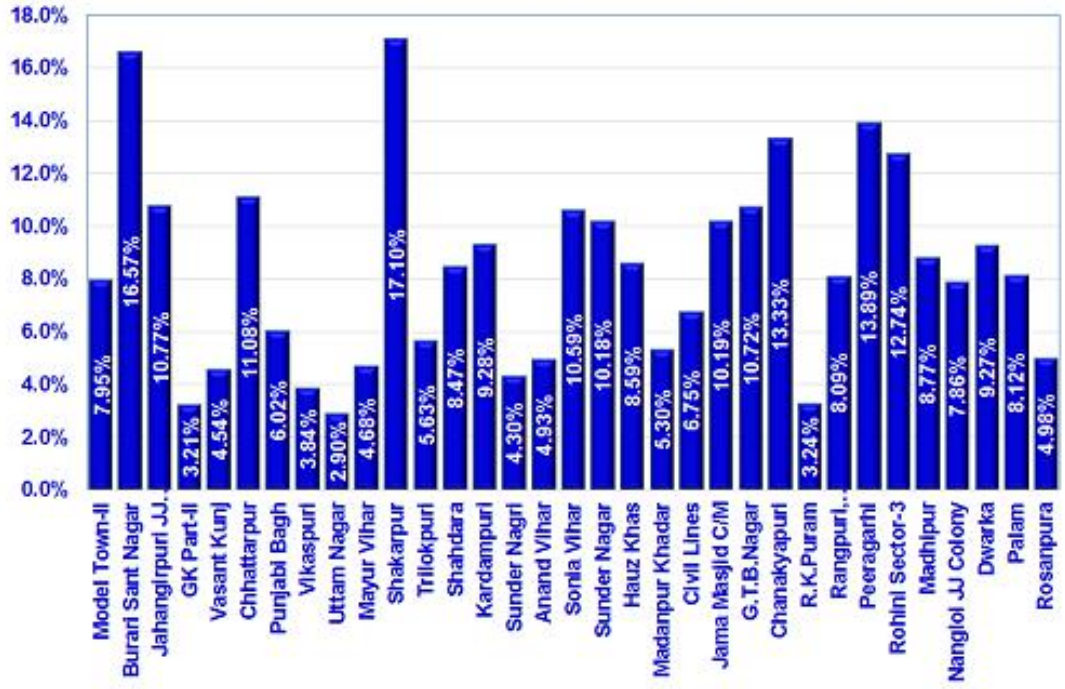
4. Summation of Plastic Waste Assessment and Characterization at various Areas

The comprehensive study of plastic waste assessment and characterization, as illustrated in previous chapters, can be summed up hereinafter.

4.1 Trend of Plastic Waste at Residential Areas

Maximum quantity of plastic waste amounting to 17.1% (or 171.02 Kg/MT) of total solid waste, was estimated at Shakarpur, whereas minimum quantity amounting to 2.90% (or 28.99 Kg/MT) of total solid waste was estimated at Uttam Nagar. The average quantity of plastic waste at residential areas has been estimated as 8.30% (or 83.00 Kg/MT) of total solid waste.

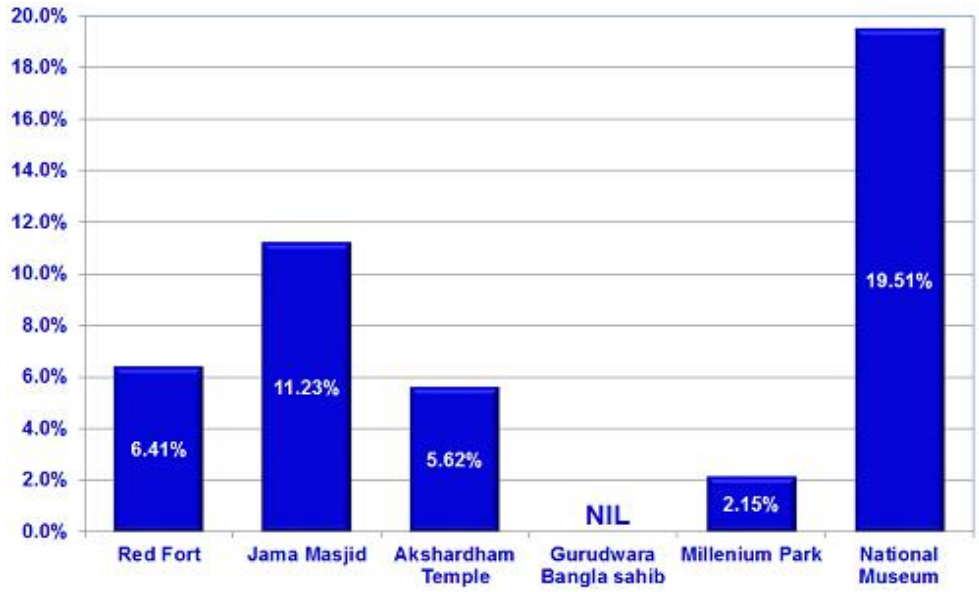
Figure-89: Trend of Plastic Waste at Residential Areas



4.2 Trend of Plastic Waste at Tourist Areas

Maximum quantity of plastic waste amounting to 19.5% (or 195.08 Kg/MT) of total solid waste, was estimated at National Museum (here total solid waste quantity is quite less which is 20-30 Kg per day; only 6.1 Kg of available solid waste was processed for estimation of plastic waste, which was found 1.190 kg), whereas minimum quantity was found Nil (practically not seen) at Gurudwara Bangla Sahib (as *Langar/ Bhandara/ Prasad* is now being served in leaves plates, the waste of which is being sent for composting). The average quantity of plastic waste at tourist areas has been estimated as 7.49% (or 74.90 Kg/MT) of total solid waste.

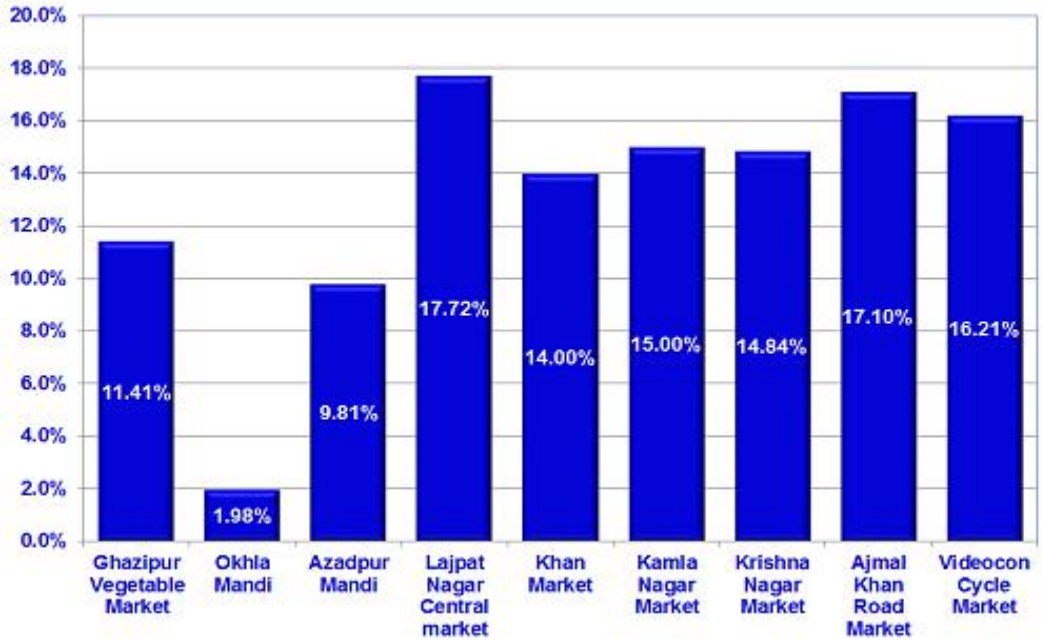
Figure-90: Trend of Plastic Waste at Tourist Areas



4.3 Trend of Plastic Waste at Market Places and Commercial Areas

Maximum quantity of plastic waste amounting to 17.7% (or 177.24 Kg/MT) of total solid waste, was estimated at Lajpat Nagar Central Market, whereas minimum quantity amounting to 1.98% (or 19.82 Kg/MT) of total solid waste was estimated at Okhla Mandi. The average quantity of plastic waste at Market Places and Commercial Areas has been estimated as 13.12% (or 131.19 Kg/MT) of total solid waste.

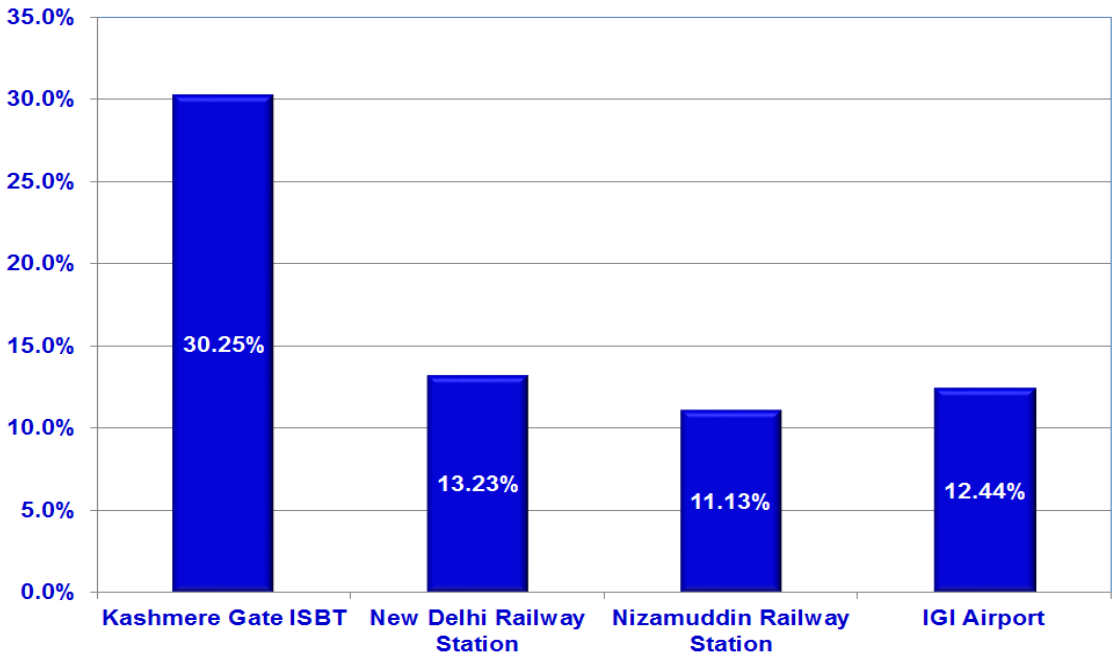
Figure-91: Trend of Plastic Waste at Market Places and Commercial Areas



4.4 Trend of Plastic Waste at Public Places

Maximum quantity of plastic waste amounting to 30.25% (or 302.51 Kg/MT) of total solid waste, was estimated at Kashmere Gate ISBT (the waste at this location is dominated by plastic disposable mainly PET bottles, glasses etc.) whereas minimum quantity amounting to 11.13% (or 111.25 Kg/MT) of total solid waste was estimated at Nizamuddin Railway Station. The average quantity of plastic waste at public places has been estimated as 18.20% (or 182.03 Kg/MT) of total solid waste (high quantity of plastic waste is attributed to the use of disposable material by the floating population).

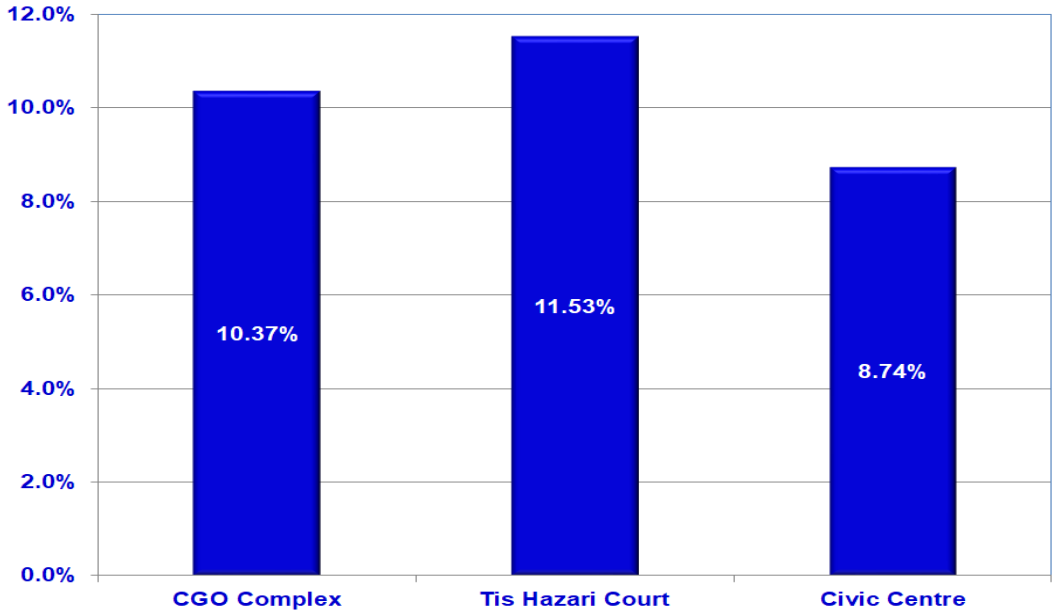
Figure-92: Trend of Plastic Waste at Public Places



4.5 Trend of Plastic Waste at Institutional Areas and Office Complexes

Maximum quantity of plastic waste amounting to 11.53% (or 115.34 Kg/MT) of total solid waste, was estimated at Tis Hazari Court whereas minimum quantity amounting to 8.74% (or 87.40 Kg/MT) of total solid waste was estimated at Civic Centre. The average quantity of plastic waste at Institutional Areas and Office complexes has been estimated as 10.22% (or 102.15 Kg/MT) of total solid waste.

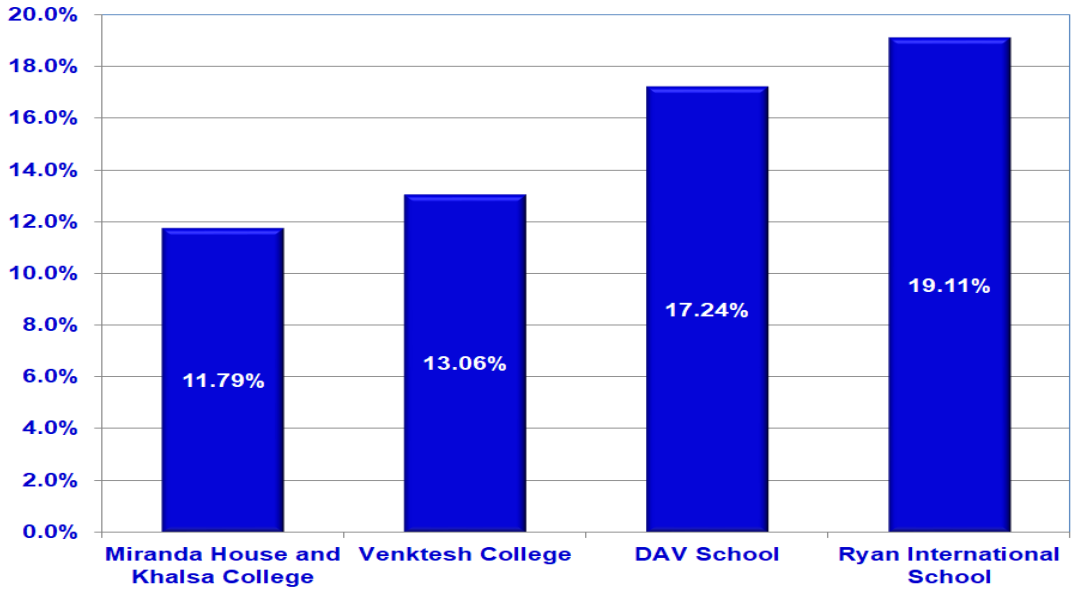
Figure-93: Trend of Plastic Waste at Institutional Areas and Office complexes



4.6 Trend of Plastic Waste at Educational Institutions

Maximum quantity of plastic waste amounting to 19.11% (or 191.07 Kg/MT) of total solid waste, was estimated at Ryan International School whereas minimum quantity amounting to 11.79% (or 117.94 Kg/MT) of total solid waste was estimated at Miranda House and Khalsa College. The average quantity of plastic waste at Educational Institutions has been estimated as 15.30% (or 153.01 Kg/MT) of total solid waste.

Figure-94: Trend of Plastic Waste at Educational Institutions



4.7 Trend of Plastic Waste at Miscellaneous Areas

Total plastic waste at Kamala Nehru Ridge was estimated 30.49% (or 304.88 Kg/MT) of total solid waste (only 2.46 Kg of solid waste available at the time of survey was processed for sorting as approximately 75 Kg per day of solid waste is generated at the location).

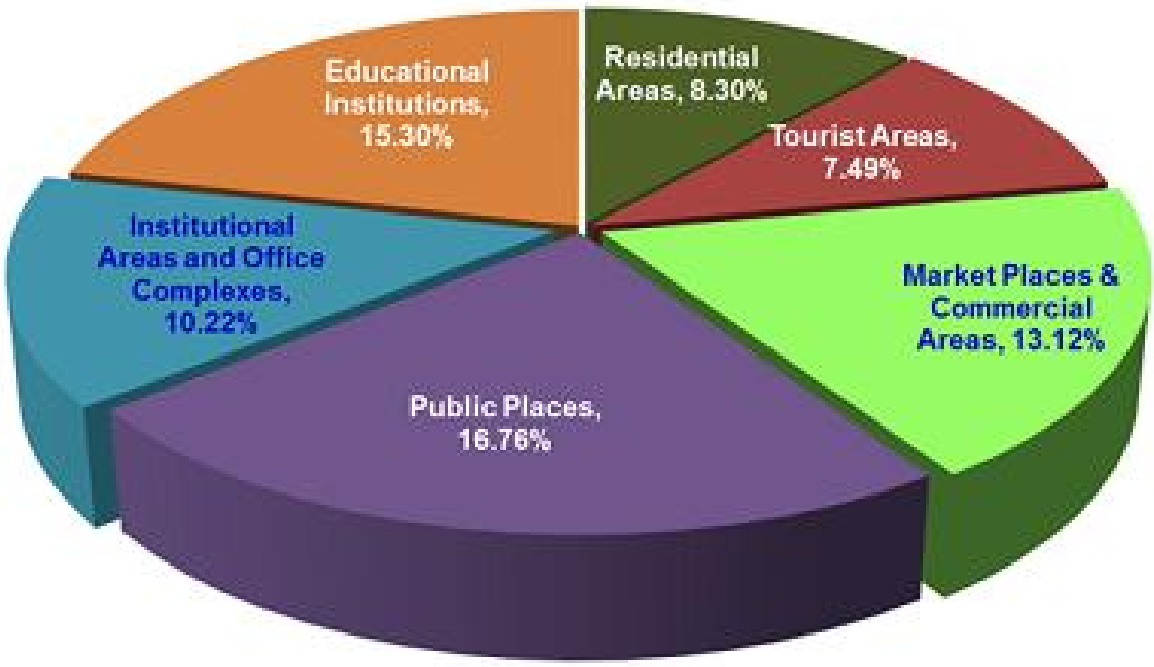
Total plastic waste at CBD Karkardooma has been estimated 22.68% (or 226.79 Kg/MT) of total solid waste (only 5.6 Kg of available waste at the time of survey was processed and generally 15-20 Kg of mixed waste is generated per day as food/wet waste generated during function is sent separately for composting and is not the part of mixed waste).

Due to very low sample size, the plastic waste available at above locations, has not been considered for further interpretation, collation and summation.

4.8 Inferences with respect to Plastic Waste Generation at various areas

In context to various areas, the plastic waste generation in the NCT of Delhi is estimated to be ranged between 7.49% to 16.76% of total solid waste, with overall average value 10.10% of total solid waste, as shown in following figure.

Figure-95: Plastic Waste at various areas of NCT of Delhi



5. Recycling of Plastic Waste in Delhi

5.1 Plastic Waste Recycling Operation[26]

Recycling of plastics generally involves 'down-cycling' into inferior quality products. The recycling starts with the sorting of plastic waste on the basis of parameters like colour, transparency, hardness, density, opacity etc. of the scrap material. The sorted waste is then sent to granulators to obtain granules using conventional mechanical and grinding techniques. The converters use these granules to make finished plastic products. The majority of such units (granulators and convertors) function as single-machine extruding units. Scrap storage is done in the backyards, and washing is done in open drums. These activities are often termed as backyard recycling. The technologies used in these recycling industries are generally obsolete and have detrimental impacts on environment. The recycling units, mainly depends upon the informal sector such as rag pickers and waste collectors involved in collection of plastic waste; this sector channelizes the items to small dealers/ aggregators, from where the collected items reaches the medium/ large dealer and finally, to the recycling units

5.2 Legal Framework for Recycling of Plastic Waste[9]

The Plastic Waste Management Rules, 2016, as amended 2018, has provision for the recycling of plastic waste as follows:

- The rule 4 (g) states that recycling of plastic waste shall conform to the Indian Standard: IS 14534:1998 titled as Guidelines for Recycling of Plastics, as amended from time to time.

- The rule-5 (a) states that plastic waste, which can be recycled, shall be channelized to registered plastic waste recycler and recycling of plastic shall conform to the Indian Standard: IS 14534:1998 titled as Guidelines for Recycling of Plastics, as amended from time to time, whereas as per rule-5 (b) local bodies shall encourage the use of plastic waste (preferably the plastic waste which cannot be further recycled) for road construction as per Indian Road Congress guidelines or energy recovery or waste to oil etc. The standards and pollution control norms specified by the prescribed authority for these technologies shall be complied with. The rule-5 (d) states that the inert from recycling or processing facilities of plastic waste shall be disposed of in compliance with the Solid Waste Management Rules, as amended from time to time.

- As per the rule-11 (2) Each recycled carry bag shall bear a label or a mark "recycled" as shown in the figure and shall conform to the Indian Standard: IS 14534: 1998 titled as "Guidelines for Recycling of Plastics", as amended from time to time.

- As per the rule-13 (1), “No person shall manufacture carry bags or recycle plastic bags or multilayered packaging unless the person has obtained a registration from the State Pollution Control Board or the Pollution Control Committee of the Union Territory concerned, as the case may be, prior to the commencement of production”. In accordance to rule-13 (3), every person recycling or processing waste or proposing to recycle or process plastic waste shall make an application to the State Pollution Control Board or the Pollution Control Committee, for grant of registration or renewal of registration for the recycling unit, in Form II given in the annexure of said rules. As per rule-13 (5) the State Pollution Control Board or the Pollution Control Committee shall not issue or renew registration to plastic waste recycling or processing units unless the unit possesses a valid consent under the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974) and the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981) along with a certificate of registration issued by the District Industries Centre or any other Government agency authorized in this regard.

- As per the rule-17 (1) every person engaged in recycling or processing of plastic waste shall prepare and submit an annual report in Form-IV to the local body concerned under intimation to the concerned State Pollution Control Board or Pollution Control Committee by the 30th April, of every year.

5.3 The Impacts of Recycling of Plastic Waste[6]

The problems associated with the plastics recycling are related to its processing mechanism. The recycling process, in general, is much more problematic in comparison to processing virgin polymers as the oxygenated groups formed during the processing or during the use considerably accelerate the degradation of plastic materials.

This phenomena result into the deterioration of end properties of the secondary materials. In order to obtain recycled materials with acceptable properties, it is desirable to protect materials from thermo-mechanical degradation occurring during recycling operations. Further, to enhance the properties of the secondary materials, benign stabilizers and modifier agents are to be added to make the blends of mixed plastics compatible.

The recycled plastics are therefore, more detrimental to the environment than the virgin products due to the mixing of additives, colours, stabilizers, halogenated flame retardants, and so on. Lead and cadmium pigments, commonly used in most of the plastics as additives are hazardous in nature and are known to have leachability effects. Halogenated flame retardants include chlorinated and brominated products which have undesirable effects of varying magnitude on the environment.

5.4 Recycling Locations of Plastic Waste in Delhi[26]

The recycling industries in Narela and Bawana recycles the higher grade plastic scraps into pellets, which are used to make equivalent lower quality of plastic products. The daily ‘market rate’ of plastic scrap is decided by the retail markets of Delhi, such as Sadar Bazar and Inderlok; traders in these markets are specialised in trading in wholesale quantities of items made from recycled plastic grains. This rate sets the price slab from which appropriate prices for plastic scrap are deduced at every stage of the value chain (from manual segregation of scrap to the finally recycled pellets).

The market receives plastic scrap from *kabadiwallahs* operating in or outside Delhi; the scrap is sold depending on its resin quality. The collection and transportation of the waste is primarily driven by small trading operators. *Chugnewallahs* (rubble segregators) sell their ware to *panni* (plastic carry bag) dealers; *kabadiwallahs* (itinerant buyers) sell to *kabadi* shops. The *panni* dealers and *kabadi* shops, in turn, sell to bigger *kabadiwallahs*, who sells it further to the traders in the PVC market.

Usually, *kabadiwallahs* sell their plastic scraps in the market for a negotiable amount. Sometimes, the traders themselves demand a particular resin (HDPE, PP, LDPE or PVC). When the mixed waste arrives in the market, workers segregate materials according to resin and colour of the plastic scrap. Dismantling follows grinding, washing and drying. Notably, the sorting unit of the market is specialised in black PP scrap trading: it can segregate PP into three different categories namely, good; medium and low, depending on its quality. The first category of PP is good and pure. The second (medium) is one which has already passed through a recycling process. Both these categories can be sent to factories for pellet formation. The third category (low) contains different varieties of plastics that cannot be separated.

5.5 Survey Done by SRI at Recycling Facilities of Plastic Wastes in Delhi

The SRI team visited the plastic waste recycling facilities at Narela and Bawana. The information was elicited from President, Vice-president and Secretary of plastic waste recycler association.

- Approx. 200 plants are involved in recycling operations each in Narela and Bawana, but due to lockdown imposed after March-2020, only few are now operational. About 10 numbers of plants are processing HDPE and about 30 numbers of plants are processing LDPE in each industrial area.

- The spectrum of waste being processed include milk pouch, seat cover, roll cover of medicine plant liner waste.

- Each plant has capacity of 700 -750 kg of waste LDPEs, but due to less availability for the scarp dealers these plants are processing approximately 500 kg of LDPE tablets per day.

- The wastes is being received mainly from the scarp dealers of Madipur and Karol Bagh area of Delhi.

- The waste received is sorted as per the material, colour etc. to make different type and grade of LDPE tablet to feed the plants, which are making Pipe, tarpaulin, EVA sole etc..

Maximum recycling capacity, taking into account 400 number of recyclers (200 each in Narela and Bawana) each having the capacity of 750 kg, estimated to 300 MT per day.

Figure-96: Sorting of waste at recycling plants

Figure-97: Recycling Process

6. Plastic Waste Quantification as "per capita Generation"

6.1 Population Dynamics at various Areas

The study included status of plastic waste at various areas amongst which fixed population locations are residential, institutional and educational areas whereas population dynamics is of floating type at areas such as tourist areas, market places, public places, ridge and community centre. The activities at landuses other than residential areas and public places may be restricted to 5 to 10 hours per day.

Table-73 Population Dynamics at Various Areas

Area Description	Plastic with respect to Solid Waste		Population residency/ mobility scenario	
	%age	Kg/MT	Type	Activity Frequency
Residential Areas	8.30	83.00	Fixed	Round the clock
Tourist Areas	7.49	74.88	Floating	8-10 hrs/ day
Market Places & Commercial Areas	13.12	131.19	Floating	10 to 12 Hrs /day
Public Places	16.76	167.60	Floating	Round the clock
Institutional Areas and Office Complexes	10.22	102.15	Fixed	8-10 Hrs/ day
Educational Institutions	15.30	153.01	Fixed	8-10 Hrs/ day

6.2 Plastic Waste Generation per day

The average per day plastic waste generation of all locations studied, is estimated 10.10% of total solid waste, as illustrated in following table.

Table-74 Area wise and location wise plastic waste (%age to total SW)

Area Description	Location	Plastic Waste (% of total SW)
Residential Areas	Model Town-II	7.94
	Burari Sant Nagar	16.57
	Jahangirpuri JJ cluster	10.77
	GK Part-II	3.21
	Vasant Kunj	4.55
	Chhattarpur	11.08
	Punjabi Bagh	6.02
	Vikaspuri	3.85
	Uttam Nagar	2.90
	Mayur Vihar	4.68
	Shakarpur	17.10
	Trilokpuri	5.63
	Shahdara	8.47
	Kardampuri	9.28
	Sunder Nagri	4.30
	Anand Vihar	4.93
	Sonia Vihar	10.59
	Sunder Nagar	10.18
	Hauz Khas	8.59

Area Description	Location	Plastic Waste (% of total SW)
	Madanpur Khadar	5.30
	Civil Lines	6.75
	Jama Masjid C/M	10.19
	G.T.B.Nagar	10.72
	Chanakyapuri	13.33
Residential Areas	R.K.Puram	3.24
	Rangpuri, Mahipalpur	8.09
	Peeragarhi	13.89
	Rohini Sector-3	12.74
	Madhipur	8.77
	Nangloi JJ Colony	7.86
	Dwarka	9.27
	Palam	8.12
	Rosanpura	4.98
Tourist Areas	Red Fort	6.41
	Jama Masjid	11.23
	Akshardham Temple	5.63
	Gurudwara Bangla Sahib	0.00
	Millenium Park	2.15
	National Museum	19.51
Market Places and Commercial areas	Ghazipur Vegetable Market	11.42
	Okhla Mandi	1.98
	Azadpur Mandi	9.81
	Lajpat Nagar Central market	17.72
	Khan Market	14.00
	Kamla Nagar Market	15.00
	Krishna Nagar Market	14.85
	Ajmal Khan Road Market	17.10
	Videocon Cycle Market	16.21
Public Places	Kashmere Gate ISBT	30.25
	New Delhi Railway Station	13.23
	Nizamuddin Railway Station	11.13
	IGI Airport	12.44
Institutional	CGO Complex	10.37
	Tis Hazari Court	11.53
	Civic Centre	8.74
Educational	Miranda House and Khalsa College	11.79
	Venktesh College	13.06
	DAV School	17.24
	Ryan International School	19.11
Average of all locations		**10.10**

6.3 Plastic Waste Quantification in Delhi[25, 46]

As per the annual review report on implementation of solid wastes management rules, 2016 (CPCB, May 2017), the NCT of Delhi generates 9,260 Tonnes per Day (TPD) of Municipal Solid Waste (MSW).

As per document of MOEF&CC, Government of India; Lok Sabha unstarred Question No. 4553; the total solid waste generation in Delhi is 3,832,500 Metric Tonnes per Annum (MTPA), which amounts to 10,500 TPD.

The average plastic waste of all the locations with fixed and floating population is estimated as 10.10% (or 101 Kg/MT) of solid waste, which can be extrapolated for quantification of plastic waste in Delhi to the tune of 1060 TPD.

6.4 Plastic Waste Generation in Delhi – per capita[17-21]

The decadal growth rate of population of Delhi during the decade 2001-2011 was recorded 21.2 per cent. The absolute population during the decade escalated from 13,850,507 persons to 16,787,941 persons. The annual growth of population is thereby calculated to 2.0 percent. With this extrapolation, the population of Delhi during 2019-20 is extrapolated to 19,780,000 persons. Considering this population, the per capita per day plastic waste generation in Delhi is calculated to 53.6 gram.

7. Single-use Plastic (SUP) Waste Generation

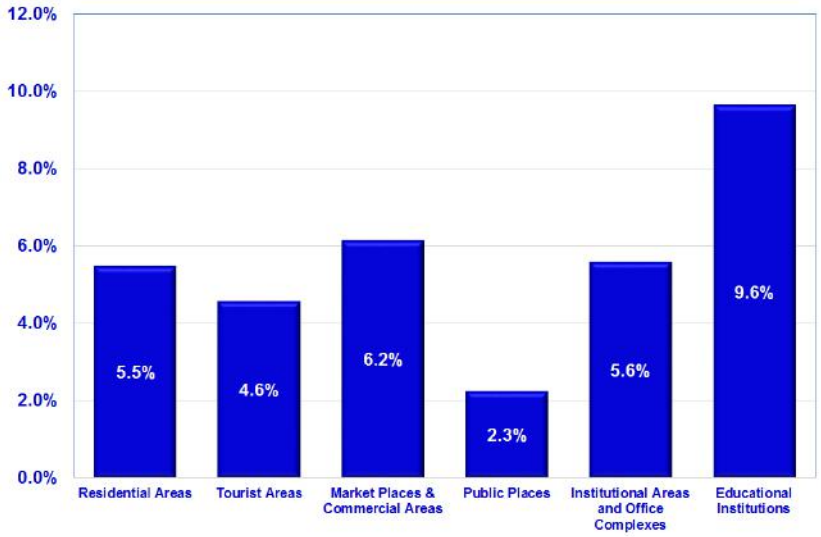
7.1 Single-use Plastic (SUP) [29]

Single-use plastics, often also referred to as disposable plastics, are commonly used for plastic packaging and include items intended to be used only once before being thrown away or recycled. These comprise polythene bags, plastic drinking bottles, plastic bottle caps, food wrappers, plastic sachets, plastic wrappers, straws, styrofoam cups or plates etc.

7.2 Single-use Plastic (SUP) Generation

The trend with respect to the average quantity of Single-use Plastic (SUP) generation at various areas of the NCT of Delhi, as assessed, is shown in following figure.

Figure-98: Single-use Plastic (SUP) waste generation in NCT of Delhi



The SUP with respect to total solid waste (SW) at residential areas is found 5.5% (or 54.8 Kg/MT), whereas at tourist areas, market places & commercial areas, public places, institutional areas and educational institutions, the SUP is assessed as 4.6% (or 45.9 Kg/MT), 6.2% (or 61.5 Kg/MT), 2.3% (or 22.54 Kg/MT), 5.6% (or 56.0 Kg/MT), 9.6% (or 96.4 Kg/MT respectively of total SW.

On average, the SUP in NCT of Delhi is assessed as 5.6% (or 56.0 Kg/MT) of total SW.

7.3 Legal Framework on Single Use Plastic

Under the Plastic Waste Management Rules 2016,

Rule-4 (c) specifies that “carry bag made of virgin or recycled plastic, shall not be less than fifty microns in thickness”.

Rule-4 (d) specifies that “plastic sheet or like, which is not an integral part of multilayered packaging and cover made of plastic sheet used for packaging, wrapping the commodity shall not be less than fifty microns in thickness except where the thickness of such plastic sheets impair the functionality of the product”.

Rule-4 (f) specifies that “sachets using plastic material shall not be used for storing, packing or selling gutkha, tobacco and pan masala”.

7.4 Ban on the use of SUP by various states

The states have power under the Environmental (Protection) Act, 1986 under section 5 to issue directions: Various state governments have introduced regulations for management of plastic waste (full or partial ban on plastic carry bags) as follows:

(a) The Tamil Nadu Government vide notification G.O (Ms) No. 84 dated 25.06.2018 implemented the ban on “one time use and throwaway plastics irrespective of the thickness such as plastic sheets used for food wrapping, spreading on dining tables etc., plastic plates, plastic coated tea cups and plastic tumbler, water pouches and packets, plastic straw, plastic carry bag and plastic flags with effect from 01.01.2019 under the provision of Environment (Protection) Act, 1986.

(b) The Himachal Pradesh Government vide notification No. STE-F (9)-1/ 2018 dated 06/07/2018, under section 3-A of the Non-Biodegradable Garbage (Control) Act, 1995 issued directions that “no person including shopkeepers, vendors, wholesalers, retailers, hawkers, *rehriwala* etc. shall use “thermocols cutlery” i.e cups, plates, glasses, spoons or any other item used for serving and consuming food in any form manufactured from non-biodegradable material as listed in the Schedule appended to the Himachal Pradesh Non-Biodegradable Garbage (Control) Act, 1995.

The Himachal Pradesh Government has further issued notification vide No. STE-F (9)-1/2018 dated 31/08/2018 after the manufacturer of thermocol cutlery, submitted represention to the Environment Science and Technology Department of the State, to permit manufacturing of thermocol cutlery items in their already established industries in the state with the view that employees (80% of these are Himachalis) do not lose their jobs apart from loss of revenue in crores to the state exchequer. Hence, under the above said notification and keeping in view of submissions of the manufacturers of the thermocol cutlery, the Himachal Pradesh Government accorded approval that all the manufacturers of thermocol cutlery in the state, may be allowed to manufacture this product in their already established units with the condition of its sale outside the State of Himachal Pradesh. There will be complete ban on the sale of thermocol cutlery in Himachal Pradesh.

(c) The Government of Sikkim vide notification No. 26/Home/2016 dated 19/05/2016 issued directions to ban the use of disposable items such as cups, plates, spoons, containers etc. made from Styrofoam throughout the state, considering the fact that these items are being used not only in the bazaar areas but also in the rural areas thereby a huge quantity of municipal waste is created in the form of used Styrofoam and other disposable products.

In addition to implementation of rules, the Education and Communication (IEC) activities are also essential to generate awareness about the harmful impact of plastic waste, and encouraged citizens to stop the use of disposable plastic products.

8. Aspects of Extended Producer Responsibility (EPR) and Brand Audit

8.1 Extended Producer Responsibility (EPR) [9, 26-27]

The Extended Producer Responsibility (EPR) has been incorporated for the first time in Plastic Waste Management Rules, 2016. The rules mandated that producers and brand owners, within six months of the notification of the rules, must work out modalities (either individually or collectively) for the waste collection system based on EPR through their own distribution channels or through the local body concerned, and by involving the State Urban Development Departments.

Further, the rules stipulated that the primary responsibility for collection of used multi-layered plastic sachets or pouches or packaging lies with producers, importers and brand owners who introduce the products into the market. Various EPR tools like buy-back pricing, incentivising the informal sector through inducing value to MLP, etc have been attempted by producers but on ground these measures are not very successful.

Producer responsibility can be executed through a variety and combination of different policy instruments, a lot of which are being implemented successfully in other countries. These instruments range from product take-back schemes, “pay-as-you-throw” or waste users’ fees, advance disposal fees, deposit refund schemes, and recycling and composting incentives.

8.2 Brand Audit[27]

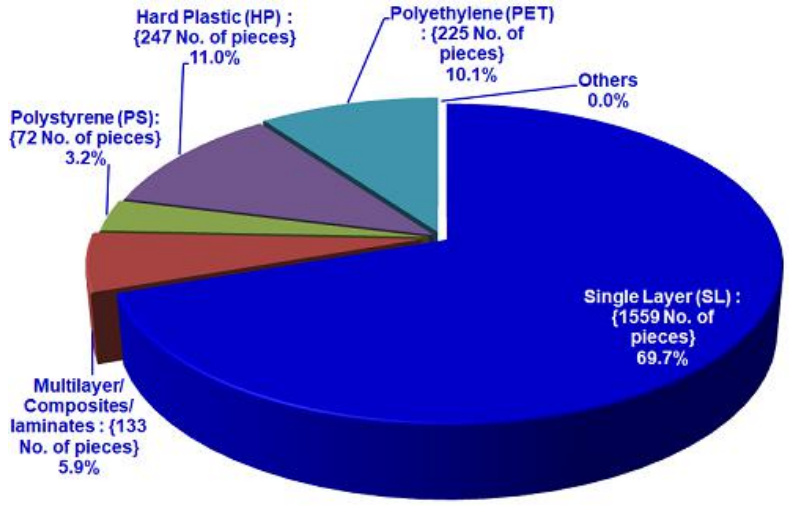
To understand the proliferation of problematic plastic packaging in the environment, the brand audits have been reported by GAIA[27] in 250 sites across 15 cities in 18 Indian states in May 2018. Participating groups conducted the audits in different sites such as public parks, water bodies, and resource recovery centres. As per this report the random samples of branded plastics were audited to record the brand and identify the manufacturer. These were categorised into product types (food, household and personal care), and type of plastic packaging (single layer, multilayer/ composites/ laminates, polystyrene, expanded polystyrene, hard plastics, polyethylene, foil, and others).

(a) With respect to packaging type, the plastic waste randomly collected in Delhi, is reported to have composition as illustrated in table-75 and figure-99.

Table-75 Plastic Waste reported with respect to Packaging Type *(Data Source GAIA)*

Packaging Type	No. of Pieces	%age
Single Layer (SL)	1559	69.7
Multilayer/ Composites/ laminates	133	5.9
Polystyrene (PS)	72	3.2
Hard Plastic (HP)	247	11.0
Polyethylene (PET)	225	10.1
Others	0	0
Total	2236	100.0

Figure-99: Plastic Waste with respect to packaging type in Delhi *(Data source GAIA)*

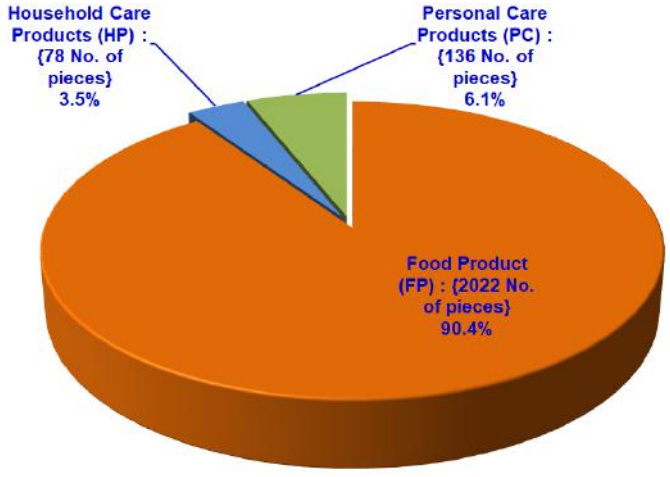


(b) With respect to product categories, the plastic waste randomly collected in Delhi, is reported to have composition as illustrated in table-74 and figure-34.

Table-76 Plastic Waste reported with respect to product categories *(Data Source GAIA)*

Type of Product	No. of Pieces	%age
Food Product (FP)	2022	90.4
Household Care Products (HP)	78	3.5
Personal Care Products (PC)	136	6.1
Total	2236	100.0

Figure-100: Plastic Waste with respect to product categories in Delhi *(Data source GAIA)*



There is a need to implement a comprehensive Extended Producer Responsibility (EPR) policy that will clearly identify accountability and responsibility all through the life of a product. Interventions at different stages of the production and waste management systems will influence the value and quality of plastics and determine its reusability and recyclability.

8.3 Brand Audit undertaken by SRI Packaged Milk Outlets in Delhi

Milk booths, one each of Amul and Mother Dairy selected on random basis, were surveyed to assess the per day sale of milk and milk products from the outlets. The information collected is based on the sale data provided by the booth owner. The sale of products varies widely from booth to booth and location to location, as indicated by data in tables-77 and 78.

Figure-101: Amul Milk Product booth where brand audit has been conducted

Table-77: Per day sale data of Amul products at randomly selected booth (provided by booth owner)

Description	No. of Pieces per Day
Milk pack 500 ml capacity	9600
Milk pack 1000 ml capacity	4800
Milk pack 2000 ml capacity	300
Chhachh (Butter milk) pack 500 ml capacity	2400
Dahi (Curds) pack 200 gm capacity	625

Table-78: Per day sale data of Mother Dairy products at randomly selected booth (provided by booth owner)

Description	No. of Pieces per Day
Milk pack 500 ml capacity	600
Milk pack 1000 ml capacity	100-125
Chhachh (Buttermilk) Bottle 200 ml	250
Chhachh Tadka (500 ml)	20-40
Cheese (200 gm)	15-20

Above data indicates that there is a tremendous variation in the sale of branded products, the magnitude of which varies widely. Hence, sale data at randomly selected shop, may not be helpful in inferring out the information on brands. The SRI team also attempted to collect data with respect to the sale of non-alcoholic beverages as well as bottled water (various prominent brands) from the randomly selected shops and departmental stores. But shop owners/ stores have shown reluctancy, even after lot of follow-up, towards providing information with respect to per day sale of brands.

8.4 Legal Framework with respect to EPR

The Plastic Waste Management Rules, 2016 defines the Extended Producer's Responsibility (EPR), as responsibility of a producer for the environmentally sound management of the product until the end of its life. Rule 9 of the Plastic Waste Management Rules, 2016 (PWMR, 2016), sets out modalities for implementation of EPR under the ambit of the rules. The producers are required to set out modalities for waste collection system based on Extended Producers Responsibility and involving State Urban Development Departments, either individually or collectively, through their own distribution channel or through the local body concerned.

9. Plastic Waste Reduction Pathways including Reuse and Disposal

9.1 Options for Plastic Waste Management

Recycling of plastics has to be carried out using a process, which shall not only be resource efficient but also exert minimal impacts on the environment and occupational health. Plastics recycling technologies have been divided into four general types viz. primary, secondary, tertiary and quaternary.

Primary recycling involves processing of a waste/scrap into a product with characteristics similar to those of original product.

Secondary recycling involves processing of waste/scrap plastics into materials that have characteristics different from those of original plastics product.

Tertiary recycling involves the production of basic chemicals and fuels from plastics waste/scrap as part of the municipal waste stream or as a segregated waste.

Quaternary recycling retrieves the energy content of waste/scrap plastics by burning / incineration.

(a) Steps Involved in the Recycling Process

Selection: The recyclers / re-processors have to select the waste / scrap which are suitable for recycling /reprocessing.

Segregation: The plastics waste shall be segregated as per the Codes 1 to 7 mentioned in the BIS guidelines (IS: 14534:1998) and are illustrated in Chapter-2.

Processing: After selection and segregation of the pre-consumer waste (factory waste) shall be directly recycled. The post-consumer waste (used plastic waste) shall be washed, shredded, agglomerated, extruded and granulated

(b) Plastic Recycling Technologies

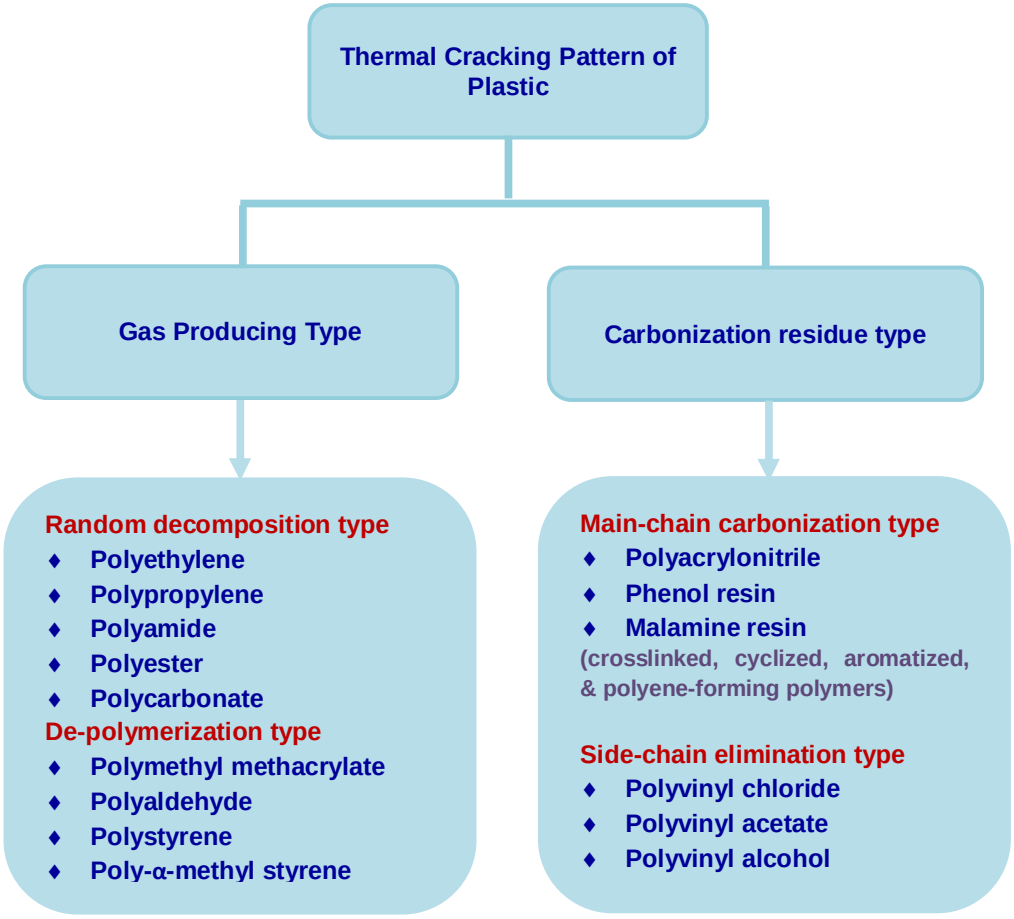
Recycling of plastics should be carried in a manner to minimize pollution during the process and enhance efficiency and conserve the energy. There is different type of technology include following aspect:

Mechanical Recycling	**:**	Recycling of plastics waste into reusable product.
Chemical Recycling	**:**	Gasification, blast furnace etc.
Incineration	**:**	Burning of waste plastics to obtain energy.
Pyrolysis	**:**	Conversion of waste plastics into liquid fuels.

(c) Thermal Behavior/ Cracking Pattern of Plastic[11,29-32]

In order to process plastic waste for chemical/ thermal treatment, it would be essential to understand its cracking pattern and products. The thermal cracking of plastic occurs at high temperature and involves many concurrent elementary reactions. The thermal cracking splits the main (C-C bond) of a gas producing plastic, reduces its molecular weight and finally decomposes it into oil and gas products at room temperature. The main chain may be separated by random decomposition or de-polymerization. Random decomposition severs the main chain randomly. PE and PP are typical examples. De-polymerization breaks a weakly bonded main chain and successive splits monomers at their chain ends. PS and polymethyl methacrylate (PMMA) are typical examples. When the thermal cracking temperature is reached, these plastics form monomers and dimers, but not intermediates so that residues are high in the degree of polymerization and do not change. Thermal cracking eliminates a side chain of lower bond dissociation (e.g C-Cl bond) in a plastic of the carbonization residue type. Thermal cracking then causes the decomposition, cyclization and other secondary reactions of the plastic, and carbonizes all of its molecules. PVC is a typical example.

Figure-102: Process of Thermal Cracking of Plastic



(d) Type of plastic and its contents

Types of plastic and its content are described in following table:

Table-79 Types plastic and its contents

Type of plastics	Contents	Product on thermal degradation
PE (HDPE/ LDPE); PP; PS	Hydrocarbons	Liquid fuels
PET, PVA, PF	Hydrocarbons with oxygen	Terephthalic acid; Benzoic Acid
PVC, PVDC	Hydrocarbons with chlorine	HCl gas; Carbonous Products; Organo-halides.
Nylon (polyamide), PU	Hydrocarbon with nitrogen	Carbonous Products, Amide

Most of plastics get soften between 100-170°C except PVC. There is no emission of any gas during softening. Physical properties of plastics are explained in following table:

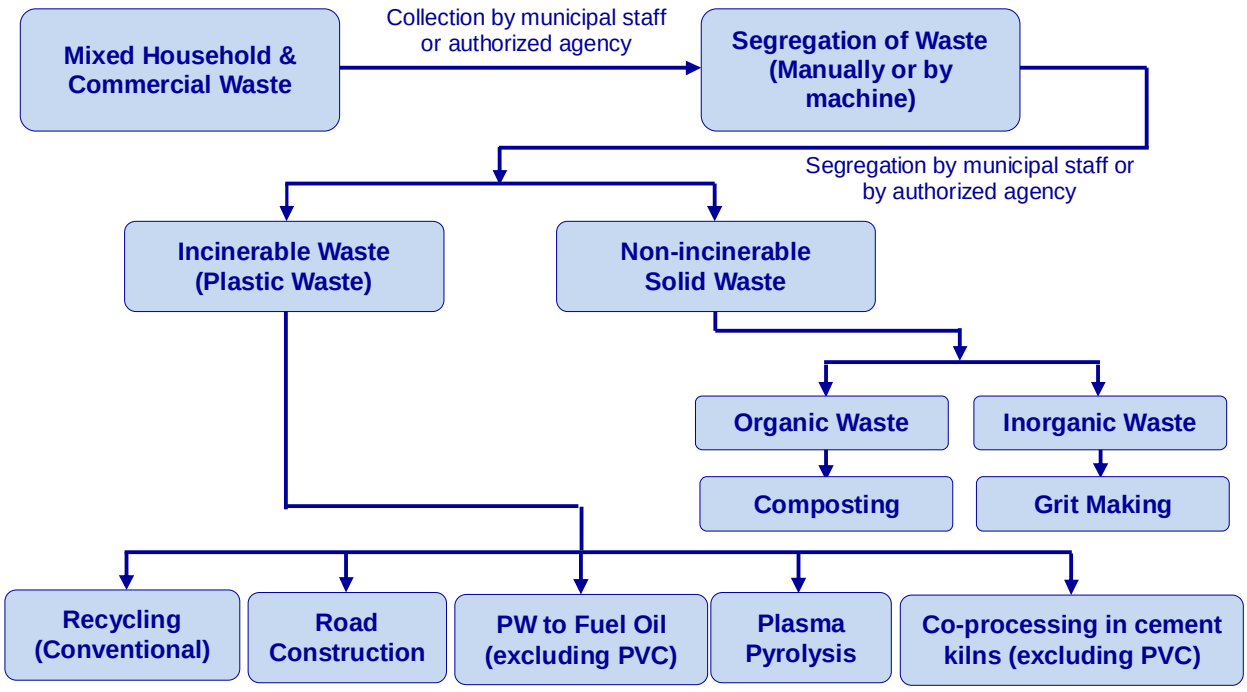
Table-80 Physical properties of different types of plastics

Polymer	Softening		Decomposition		Ignition	
	Temp °C	Product	Temp °C	Product	Temp °C	Product
PE Film	100-120	No gas	289-335	CH_4, C_2H_6	>700	CO, CO_2
PP	140-160	No gas	271-329	C_2H_6	>700	CO, CO_2
PS	110-140	No gas	300-350	C_2H_6	>700	CO, CO_2
PE Foam	120-125	No gas	309-385	CH_4	>700	CO, CO_2
Tea Cup	130-150	No gas	313-420	C_2H_6	>700	CO, CO_2

9.2 Process for Collection, Segregation and Utilization of Plastic Waste[30]

The CPCB guidelines for collection, segregation and utilization of plastic waste, are explained in following flowchart:

Figure-103: Process of collection, segregation and utilization of plastic waste



9.3 Polymer Coated Bitumen Roads (Use of Thermoplastic Material) [28, 31, 32]

(a) Objectives of Bitumen Roads from Waste Plastic

The best way of disposal of waste plastic is its recycling to the maximum extent. Various studies have revealed that waste plastics have great potential for use in bituminous construction as its addition in small doses, about 5-10%, by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous mix, leading to improved longevity and pavement performance. The use of waste plastic thus contributes to construction of green roads. The guidelines of Indian Road Congress for the use of waste plastic in hot bituminous mixes (dry process) in wearing courses are given in IRC: SP: 98-2013.

(b) The Polymer Coating of Aggregates and Specifications

The waste plastics can be shredded into small pieces molten and thereafter be coated over hot aggregate at 150-170°C, mixed with hot bitumen, plastics melt to form an oily coating which spread over the aggregate and act as binder. The mixture is laid on the road surface like a normal tar road. The plastics cannot be melted separately to use for coating. The stone is heated to 170°C and the shredded plastic film is sprayed over the hot stone. On contact with the surface of the hot stone the plastic gel softened and coated over the aggregate. The shredded plastics should be less than the surface area of the aggregate to obtain uniform coating. Otherwise the binding will not be effective. However as per IRC: SP: 98-2013, following need to be ensured for better performance:

- The material shall consist of only Low Density Polyethylene (LDPE) or High Density Polyethylene (HDPE), PU (available in limited quantity as waste) and PET.
- Black coloured plastic waste is a result of repeated recycling and should not be used.
- PVC shall not be used since they release lethal levels of dioxins.
- The Thermo Gravimetric Analysis (TGA) of thermoplastics revealed gas evolution and thermal degradation may occur beyond 180°C. Thus misuse or wrong implementation of this technology may result in release of harmful gases, premature degradation, if the temperatures are not maintained during construction.

As per IRC: SP: 98-2013, following criteria has to be met:

Bitumen

The bitumen for bituminous mixes for wearing course with waste plastic shall comply with the Indian Standard Specifications for viscosity graded paving bitumen IS 73. Guidelines for selection for grade of viscosity graded paving bitumen shall be in accordance with the IRC: 111-2009. .

Aggregates

The aggregates shall comply to IRC: 111-2009, for dense graded mixes and IRC: 14-2004, IRC: SP: 78-2008 and IRC: 11 0-2005 for open graded mixes respectively.

Filler

The filler for dense graded mixes shall comply with IRC: 111-2009.

Waste Plastic

- The waste plastic shall conform to the size passing 2.36 mm sieve and retained on 600 micron sieve. However, as per CPCB, the shredded plastic should be in the range of 4.2 mm to 1.18 mm.

- Dust and other impurities shall not be more than 1 percent. An easy method to determine the quantity of impurity is to determine the ash content at 600°C.

- To ascertain the ability of plastic to mix with the binder, the melt-flow value shall be tested as per ASTM D 1238-2010.

Design of Mix

The requirement for waste plastic modified design for dense graded mixes and open graded mixes as per IRC: SP: 98-2013 is given below:

(i) Dense graded mixes : The requirements for waste plastic modified dense graded bituminous pavement layers are given below :

♦ **Minimum stability (kN at 60°C)**	:	12.0
♦ **Minimum flow, mm**	:	2
♦ **Maximum flow, mm**	:	4
♦ **Marshall Quotient (kN/mm)**		2.5-5
♦ **Compaction level (Number of blows)**	:	75 blows on each of the two faces of specimen
♦ **Per cent air voids**		3-5
♦ **Retained stability (%)**	:	98
♦ **ITS (min) MPa**	:	0.9
♦ **VMA**	:	16
♦ **VFB**		65-75
♦ **Quantity of waste plastic (% by weight of bitumen)**	:	6 to 8 depending on low rainfall or high rainfall area

(ii) Open graded mixes

Waste plastic at the rate of 6 to 8% of the weight of the bitumen can be used for open grade premix surfacing and mix seal surfacing. Quantity of bitumen can be reduced correspondingly.

Voids in the Mineral Aggregate (VMA) are the volume of inter-granular void space between the aggregate particles of a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of total volume of the specimen.

Voids Filled with Bitumen (VFB) are the voids in the mineral aggregate frame work filled with bitumen binder. This represents the volume of the effective bitumen content. It can also be described as the percent of the volume of the VMA that is filled with bitumen. VFB is inversely related to air voids and hence as air voids decreases, the VFB increases.

VFB = (VMA-VA)/VMA x 100; where, VA is air voids in the mix and VMA is the voids in the mineral aggregate.

The decrease of VFB indicates a decrease of effective bitumen film thickness between aggregates, which will result in higher low-temperature cracking and lower durability of bitumen mixture since bitumen perform the filling and healing effects to improve the flexibility of mixture.

Indirect Tensile Strength (ITS) is used to evaluate the relative quality of bituminous mixture in conjunction with laboratory mix design testing and for estimating the potential for rutting or cracking. The results can also be used to determine the potential for field pavements moisture damage when results are obtained on both moisture conditioned and unconditioned specimens.

(iii) Construction

Construction operation shall be in accordance with the IRC: 111-2009, IRC: 14-2004, IRC: 11 0-2005 and IRC: SP: 78-2008 for dense graded and open graded mixes respectively.

(iv) Controls

Controls shall be in accordance with the IRC: 111-2009, IRC: 14-2004 and IRC: 110-2005 and IRC: SP: 78-2008 for dense graded and open graded mixes respectively. Besides, plastic shall be tested for impurity and melt flow value. Three sample be tested for each day work or when there is change in the source of plastic.

(c) The Process of Roads Construction using Waste Plastic

The process of road laying using waste plastics is given below. This technique is being implemented successfully for the construction of flexible roads at various places in India. Several roads have been built in this manner in the State of Tamil Nadu, Puducherry, Maharashtra, Kerala and Andhra Pradesh using polymer-coated–bitumen aggregate.

Figure-104: Process Diagram for Laying Road using Waste Plastic-aggregate Bitumen Mix

(d) Salient Features of Polymer Coated (waste plastic) Bitumen Roads

Plastic coated over stones shows improved surface property of aggregates as reported by various studies. Coating is an easy process & temperature required is same as road laying temperature. The salient features of polymer coated (waste plastic) bitumen roads, as reported in the literature include:

- The coating of plastics over aggregate improves Impact, Los Angeles Abrasion and Crushing Value, with the increase in the percentage of plastics.
- The extracted bitumen shows almost near value for Marshall Stability.
- The roads are having good skid resistance and texture values and all the stretches in the roads have been found reasonably strong.
- The unevenness index values of these roads are nearly 3000 mm/km, which indicate a good surface evenness.
- The plastic tar roads have not developed any potholes, rutting, raveling or edge flaw, even though these roads are more than four years of age.
- Polymer coated aggregate bitumen mix performs well compared to polymer modified bitumen mix.
- Higher percentage of polymer coating improves the binding strength of the mix. Foam plastics have better binding values.

Figure-105: Road made from Plastic Waste

9.4 Process Engineered Fuel (Solid) From Waste Plastic [Use of Thermoplastic Material]

(a) Aspects of Solid Fuel from Waste[13,33]

Solid fuel can be prepared both from municipal and industrial non-hazardous waste. It excludes coal and coal-derived fuels as well as solid biofuels such as firewood and dried manure but it may contain biofuels as a component. Two types of solid fuel are: refuse derived fuel (RDF), also called solid recovered fuel (SRF) and refuse-derived paper and plastic densified fuel (RPF).

The RDF is mainly produced from processing of municipal solid waste. Due to the presence of kitchen waste, prior to the conversion to a fuel, a drying process is required to remove the moisture from such waste to allow the solidification of the waste in suitable shapes and densities. This process is seen as a disadvantage due to the large amount of energy that the process requires. Solid Recovered Fuel (SRF) is also defined in the European Committee for Standardization technical specification (CEN/TS 15359:2006).

The RPF can be prepared from used paper, waste plastics and other dry feedstocks. Within the plastics, the thermoplastics play a key role as a binder for the other components such as thermosetting plastics and other combustible wastes, which cannot form pellets or briquettes without a binding component. Approximately 15% by weight of thermoplastics is the minimum required to be used as a binder to solidify the other components; however excessive amounts, higher than 50% by weight, would cause a failure in the pellet preparation. The components of RPFs are mainly sorted from municipal solid wastes or industrial and commercial wastes and are sometimes also obtained from well-separated municipal waste.

In both cases RDF and RPF, the plastic contents can be varied (within a range) to meet the needs of fuel users. The shape of the fuel will vary according to the production equipment (e.g. a screw extruder is often used to create cylindrical-shaped fuel with a variable diameter and length). In the production of solid fuel, the contamination of the targeted plastics with other plastics containing nitrogen, halogens (Cl, Br, F), sulfur and other hazardous substances may cause air and soil pollution by the flu gas emission and the incineration ash disposal (e.g. inorganic components such as aluminum in multilayer film of food packages produces fly ash and bottom ash). Other contaminants such as hydrogen chloride might cause serious damage to the boiler by corrosion.

(b) Production Method of Solid Fuel[13,33]

The solid fuel production process usually involves two steps, pretreatment and pellet production:

- Pretreatment includes coarse shredding and removal of non-combustible materials.
- Pellet production comprises secondary shredding and pelletization (<200°C).

Process Engineered Fuel (PEF) developed by many researchers has been made from biomass, plastic, paper, derived from commercial and residential sources. The plastic waste feed stocks is generally in rigid plastic form. PEF can be produced and marketed in both densified and fluff forms using biomass, plastic waste and coal. It is recommended to use polyolefinic waste. The waste material is first dried in a chamber with high heat. Second thing the dried waste is removed and grinded into powder and converted to a pellet form by giving a high pressure. The fuel obtained will give nontoxic smoke while burning and can be stored easily since it is inert in nature. The fuel runs between 14541 kJ to 18610 kJ per kg which is said to be cleaner than the coal burning.

Figure-106: PEF Developed from Polyolefins

(c) Characteristics of Solid Fuel[13,33]

Heating value is an important characteristic of solid fuels. Some examples of heating values of several types of waste and solid fuel are listed below:

Table-81 Calorific Values Comparison with Conventional Fuels

Solid Recovered Fuel/ Fossil Fuel	Typical Calorific Value (kcal/Kg)	Remarks
RDF	4000-5000	Depends upon waste composition
RPF	6000-8000	Can be controlled by plastic composition in fuel production process
Coal	6000-8000	Depends upon rank of coal
Heavy oil	9500	-
Wood/ Paper	4300	-
Plastic (polyethylene)	11000	-
Typical MSW	1000-1500	Depends upon waste composition

The heating values of solid RDFs and RPFs may vary depending upon the composition of these materials. Especially in RDF, fluctuations in the heating values are often observed due to changes in the composition of the municipal waste (which is difficult to control) and according to the degree of drying of the municipal waste used in the production process. RPF heating values can usually be controlled easily due to the use of dry and sorted plastics, paper and other combustible waste. Other important features of the solid fuels are its content of ash, moisture and the content of potential hazardous substances like nitrogen, chlorine, sulfur and heavy metals, which are to be controlled.

Classification of Solid recovered fuel (SRF) as per standard of European Committee for Standardization Technical Specification (CEN/TS 15359:2006) is given below:

Table-82 Standard of Solid Recovered Fuel (CEN/TS 15359:2006)

Classification property	Statistical measure	Unit	Classes				
			1	2	3	4	5
Net Calorific Value (NCV)	Mean	MJ/Kg	≥25	≥20	≥15	≥10	≥0
Chlorine (Cl)	Mean	% (d)	≤0.2	≤0.6	≤1.0	≤1.5	≤3
Mercury (Hg)	Median	mg/MJ	≤0.02	≤0.03	≤1.0	≤1.5	≤3
	80th Percentile	mg/MJ	≤0.04	≤0.06	≤0.16	≤0.30	≤1.00

9.5 Liquid Fuel from Waste Plastic (Use of Thermoplastic Material)

(a) Pyrolysis of Polymer[13,30, 32,33,34]

Pyrolysis is a thermal cracking reaction of the large molecular weight polymer carbon chains under an oxygen free environment and produces small molecular weight molecules. Conventional disposal for post-consumed plastics are landfills or incineration. However, landfill of the post-consumed plastics has potential problems because of limited land resource and high durability of plastics. Incomplete incineration may generate toxic substances and causes serious health problems. HDPE, LDPE, PP and PS are all hydrocarbons consisting entirely of carbon and hydrogen, which are similar to hydrocarbon fuels such as Liquefied Petroleum Gas (LPG), petrol and diesel. Plastics are derived from petroleum and have calorific values in a similar range as those of LPG, petrol and diesel as illustrated here. Several types of thermoplastics undergo thermal decomposition to yield liquid hydrocarbons used as liquid fuel.

Table-83 Calorific value of different plastic material and their comparison with conventional fuel

Material	Calorific Value
Polyethylene	46.3
Polypropylene	46.4
Polystyrene	41.4
Polyvinyl Chloride	18.0
Coal	24.3
Liquefied Petroleum Gas	46.1
Petrol	44.0
Kerosene	43.4
Diesel	43.0
Light Fuel Oil	41.9
Heavy Fuel Oil	41.1

PE, PP, and PS, are preferred for the feedstock of the production of liquid hydrocarbons. The addition of thermosetting plastics, wood, and paper to the feedstock not only leads to the formation of carbonous substance but also results in lowering the rate and yields of liquid products.

- Depending upon the components of the waste plastic being used as feedstock for fuel production, the resulting liquid fuel may contain other contaminants such as amines, alcohols, waxy hydrocarbons and some inorganic substances.
- Contamination of nitrogen, sulfur and halogens gives flue gas pollution. Unexpected contamination and high water contents may lower the product yields and shorten the lifetime of the reactor for pyrolysis.

Liquid fuel users require petroleum substitutes such as gasoline, diesel fuel and heavy oil. In such fuels, various additives are often mixed with the liquid hydrocarbons to improve the burner or the engine performance. The fuel properties such as viscosity and ash content shall conform to the specifications of the fuel user's burners or engines. No additives would be needed for fuel used in a boiler. Skillful operators and a well-equipped facility are the

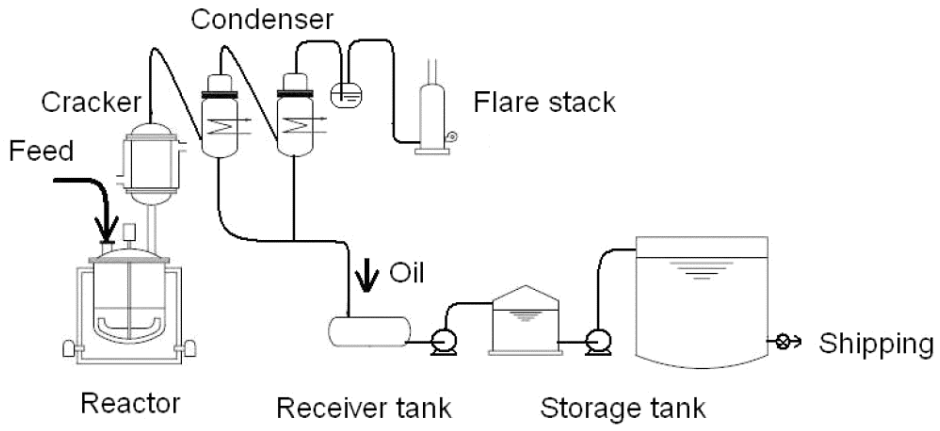
essential pre-requisites keeping in view of the formation of highly flammable liquids and gases.

(b) Production Process[13,32,34]

The production method for the conversion of plastics to liquid fuel is based on the pyrolysis of the plastics and the condensation of the resulting hydrocarbons. Pyrolysis refers to the thermal decomposition of the matter under an inert gas like nitrogen.

The plastics which are suitable for the conversion are introduced into a reactor where decomposition occurs at 450 to 550°C. Depending on the pyrolysis conditions and the type of plastic used, carbonous matter gradually develops as a deposit on the inner surface of the reactor. After pyrolysis, this deposit should be removed from the reactor in order to maintain the heat conduction efficiency of the reactor. The resulting oil (mixture of liquid hydrocarbons) is to be distilled continuously once the waste plastics inside the reactor are decomposed enough to evaporate upon reaching the reaction temperature. The evaporated oil is further cracked with a catalyst. The boiling point of the produced oil is controlled by the operation conditions of the reactor, the cracker and the condenser. In some cases, distillation equipment is to be installed to perform fractional distillation to meet the requirements. After the resulting hydrocarbons are distilled from the reactor, some hydrocarbons with high boiling points such as diesel, kerosene and gasoline are to be condensed in a water-cooled condenser. Subsequently, the liquid hydrocarbons are to be collected in a storage tank through a receiver tank. Gaseous hydrocarbons such as methane, ethane, propylene and butanes cannot be condensed and therefore to be incinerated in a flare stack. This flare stack is required when the volume of the exhaust gas emitted from the reactor is expected to be large.

Figure-107: Schematic Process Diagram for a Production Plant of Plastic-derived Liquid Fuel



(c) Feeding Method[13, 34]

Variations in the feeding methods may depend upon the characteristics of the waste plastic. The most convenient way is to simply inject the waste plastics into the reactor without any pretreatment. Soft plastics such as films and bags are to be treated with a shredder or a melter (hot melt extruder) in order to feed them into the reactor otherwise these occupy a large volume of the reactor.

(d) Types of Reactor and process[13, 34]

There are different types of reactors and heating equipment. Both kiln-type and screw-type reactors can be used, while induction heating by electric power can also be used as an alternative to using a burner. Due to the tendency for formation of carbonous matter in the reactor, which may acts as a heat insulator, in some tank reactors the stirrer has to be used to remove the carbonous matter rather than for stirring. After the liquid product of the pyrolysis is distilled, the carbonous matter is to be taken out either with a vacuum cleaner or in some cases reactors are to be equipped with a screw conveyor at the bottom of the tank reactor to remove the carbonous matter.

(e) Products and Byproducts[13,34]

The properties of waste plastic-derived fuel and petroleum fuels are given herewith to compare whole distillate and middle distillate of waste plastic pyrolytic oil with the petroleum fuels. After considering the burner or engine operating stability, it is possible to mix plastics-derived oil with petroleum fuel. Some plastics yield residual substances such as carboneous matter and other inorganic matter during pyrolysis. Carbonous matter can be used as a feedstock for solid fuel.

Table-84 Properties of Pyrolytic Oil (Source UNEP[13])

Properties		Waste plastic pyrolytic oil		Diesel Fuel	Heavy Oil
		Whole Distillate	Middle Distillate		
Specific gravity (15°C), g/cm^3		0.8306	0.8430	0.8284	0.8511
Flash point (°C)		-18 (PM)	68.0 (Tag)	69.0 (Tag)	64 (PM)
Kinematic Viscosity (30°C/50°C), mm^2/s		1.041	1.73	3.822	2.29
Carbon residue on 10% bottom, % by mass		-	0.85	0.01	0.46
Ash, % by mass		0.0	<0.001	-	0.006
Gross Heating Value (cal/g)		11294	10746	-	10708
Total chlorine, ppm by weight		47	10	<1	1.6
Nitrogen, % by mass		0.14	0.033	-	0.015
Sulphur, % by mass		100	910	310	0.41 (%)
Cetane Index		27.0	42.9	58.4	46.3
Distillation Temperature °C	Initial	47.0	180.0	-	164
	10%	69.0	199.0	-	195
	50%	148.0	233.0	-	276
	90%	294.5	323.5	344.0	347
	End	374.0	351.5	-	>370

(Source: UNEP[24])

Pyrolysis of mixed plastics with nitrogen-containing plastics produces the corresponding liquid fuel with nitrogen compounds, which in turn produces nitrogen oxide in the flue gas emission due to combustion. The liquid fuel derived from waste plastics containing chlorine will cause corrosion to the reactor and burner and will also pose the tendency for the formation of hydrogen chloride and dioxins. Suitable and adequate flue gas treatment shall therefore be considered appropriately to avoid the potential risks of these chemicals on environment and occupational health.

9.6 Gaseous Fuel from Waste Plastic (Use of Thermoplastic Material)

(a) Aspects of Gaseous Fuels from Waste Plastic[13]

The gaseous fuel refers to the flammable gases obtained from the thermal treatment of waste plastics. Types of gaseous fuel:

- Gaseous hydrocarbon: hydrocarbons that are in a gaseous state under normal temperature and pressure.

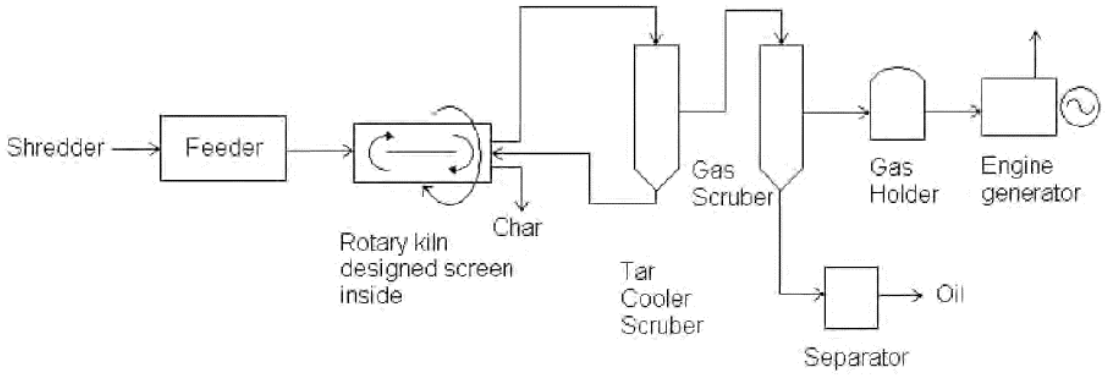
- Synthesis gas or syngas: mixture of hydrogen and carbon monoxide

During conversion of plastics to gaseous fuel, the waste plastics undergo thermal decomposition in a tank reactor, resulting in the formation of liquid fuel as the main product and gaseous fuel up to about 20 % by weight, as the minor product. Gaseous hydrocarbons become the main product after extended residence time in the reactor at reaction temperature under controlled decomposition conditions. Under specific conditions, carbon and carbohydrates can be used as feedstocks for the production of gaseous fuel like methane and hydrogen.

(b) Production Method of Gaseous Fuel[13]

The gasification process includes a series of steps such as pretreatment, gasification, gas cleaning and storage. Polyethylene and polypropylene thermally decomposes at temperatures up to about 700°C and under an inert atmosphere forms the mixture of gaseous hydrocarbons such as methane, ethane, ethylene, propane, propylene, and various isomers of butane. On the other hand, most of the organic substances undergo gasification to yield syngas.

Figure-108: Schematic Process Diagram for a Production Plant of Plastic-derived Gaseous Fuel



Gasification proceeds at elevated temperatures, higher than 800 and practically around 1000 °C. Depending on the types of reactors and reaction conditions, carbonous matter and carbon dioxide are formed, and nitrogen from the air is to be contained in the product gas. There are various types of gasification reactors such as moving-bed, fluidized-bed and entrain-bed reactors. If the product has to be stored, a large gas holder would be required.

The gasification technique is already used commercially for coal and there are several examples of commercial operations using biomass and waste plastics to produce low-and medium-BTU gas.

Techno-economic feasibility analysis would be an important factor with respect to the amount of collected waste, the transportation distance and the commercial value of the resultant products such as electricity and gaseous fuel. In any case, this technology is required, skillful operators and careful handling is must to avoid hydrogen explosion. Various gasification methods, type of waste and typical products are given below:

Table-85 Gasification Process and Conditions (Source UNEP[13])

Type of gasification	Conditions	Typical Products
Pyrolysis	>700°C under inert atmosphere	Aliphatic hydrocarbons including polyethylene and polypropylene
Partial oxidation	>1000°C under oxygen or air	Carbon monoxide from carbon, hydrocarbon and carbohydrates including wood. Hydrogen will also form
Steam gasification	>800°C under oxygen or air	Methane, carbon monoxide and hydrogen
Hydrogasification	Around 500-600°C under hydrogen	Methane, carbon monoxide and water

Table-86 Type of Conditions and Pyrolysis Conditions (Source UNEP[13])

Type of Waste	Pyrolysis conditions	Typical Products
Polyethylene, polypropylene	Inert atmosphere at 700-800°C	High BTU gas (9000 kcal/Nm^3); Gaseous hydrocarbons like methane and ethylene; Liquid hydrocarbons like benzene and toluene.
Aromatic polymer, carbohydrates like wood	Air/ steam atmosphere at temperature above 1000°C	Low-BTU gases (800-1800 kcal/Nm^3); Methane formation increases the heating value to give medium BTU gases.

The heating values of the gaseous products will vary according to the type of waste used, the contamination of nitrogen from the air and/or from feed shall be treated adequately. However, the calorific value of Syngas ranges between the calorific value of biogas and LNG/LPG.

9.7 Management of Thermoset Plastic Waste (As per CPCB Guidelines)

(a) Aspects of Thermoset Plastic Waste[11,12,13]

Thermoset plastics are so named because there is a chemical change during processing to yield hard solids. Thermosets are highly cross-linked polymers that have a three-dimensional molecular mesh or network of polymer chains. Thermoset plastics, because of their tightly cross-linked structure, resist higher temperatures and provide greater dimensional stability than do most thermoplastics. Thermosets undergo a chemical as well as a phase change when they are heated. Once cured they cannot be melted or remolded and are resistant to solvents. Thermosets are tough, durable with high temperature performance, and have found applications in a wide variety of fields.

The extensive utilization of Thermoset Polymers including Sheet Moulding Compound (SMC)/ Fibre Reinforced Plastics (FRP) is due to the combination of their mechanical and physical properties at the lowest system cost, without compromising on quality. Thermoset plastics are used in a broad range of applications, such as:

- **Automotive:** cars, trucks and other commercial and agricultural vehicles (body
- parts, structure and engine parts)
- **Mass transport:** trains, trams, light railways and monorail
- **Electrical & electronics:** housing, fuses, switchgear, etc.
- **Building & construction:** civil engineering and household fixtures
- **Domestic appliances:** coffee machines, toasters, irons etc.
- **Sanitary:** bathroom suites and hygienic surfaces.
- **Power utilities:** MCB boxes etc.

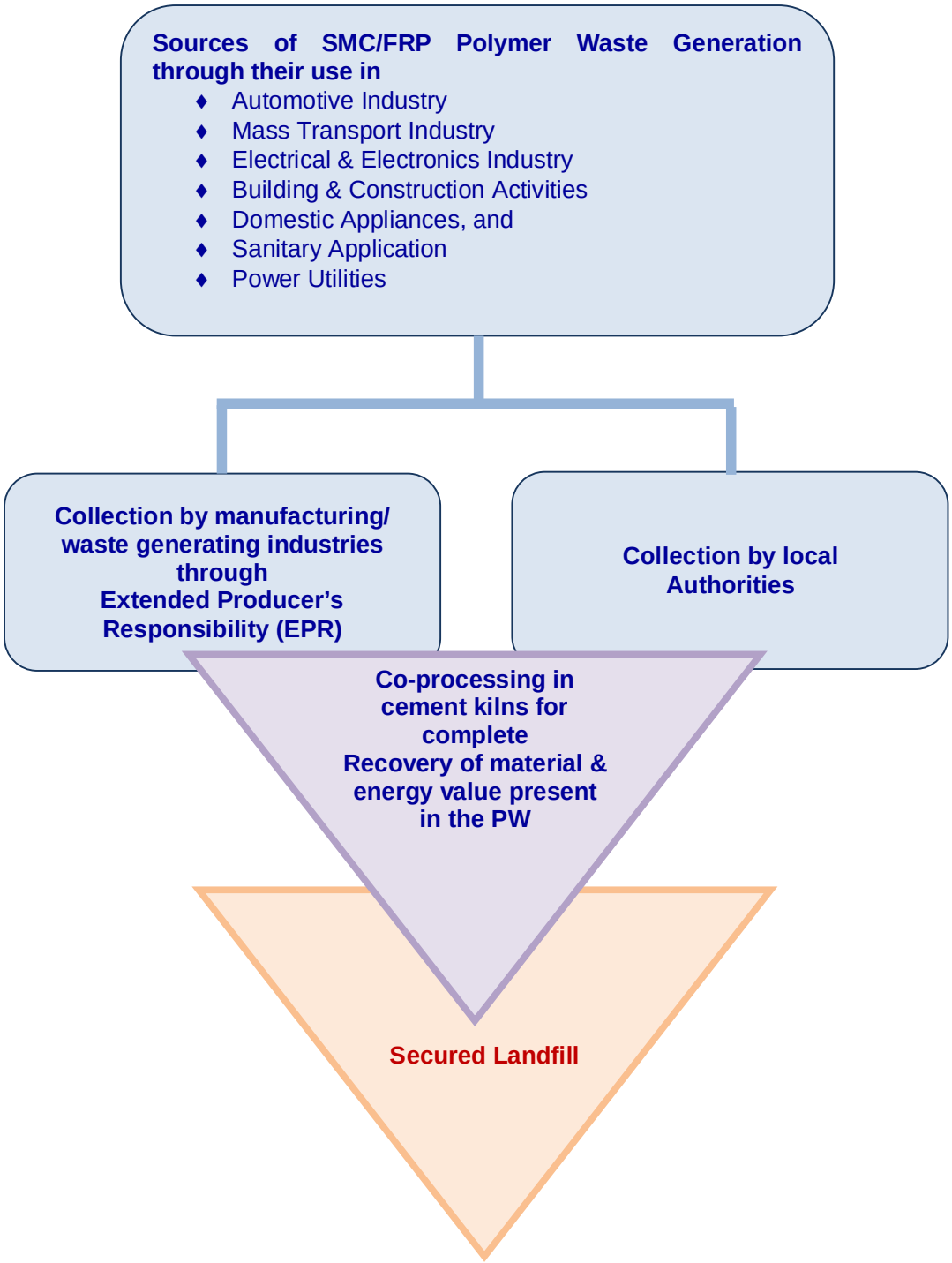
Sheet Moulding Compound (SMC) or Sheet Moulding Composite is a ready to mould glass-fiber reinforced polyester material primarily used in compression moulding. This is manufactured by dispersing long strands (usually >1") of chopped fiber (commonly glass fibers or carbon fibers on a bath of resin (commonly polyester resin, vinylester resin or epoxy resin). The longer fibers in SMC result in better strength properties than Standard Bulk Moulding Compound (BMC) products[13].

The Fibre Reinforced Plastic (FRP) are both thermoset and thermoplastic, FRP products having thermoset base material are discussed here. FRP composite materials consist of two or more distinct physical phases, one of which, the fibrous, is dispersed in a continuous matrix phase. Composites offer the designer a combination of properties not available in traditional materials. It is possible to introduce the fibres in the polymer matrix at highly stressed regions in a certain position, direction and volume to obtain maximum efficiency from the reinforcement, and then, within the same member to reduce the reinforcement to a minimal amount at regions of low stress. Other advantages offered by the material are its lightness, resistance to corrosion, resilience, translucency and greater efficiency in construction compared to the more conventional materials[13].

(b) Minimizing the waste generation[13]

The most preferred option is minimization of use of SMC/FRP/Polycarbonate polymer products & promoting use of alternate material, which could be easily recyclable/ reusable/ degradable.

Figure-109: Collection and Disposal of SMC/ FRP Waste (Source: CPCB)[13]



(c) Co-processing of Thermosetting polymer waste in cement plants kilns[13]

Co-processing is a more environmentally friendly and sustainable method of waste disposal as compared to land filling and incineration because of reduced emissions and no residue after the treatment. Co-processing refers to the use of waste materials in industrial processes as alternative fuels or raw material (AFR) to recover energy and material from them. Due to the high temperature and long residence time in cement kiln, all types of wastes can be effectively disposed without any harmful emissions. As per the Basel Convention (1992), variety of wastes including hazardous wastes, get disposed in an environmentally safe and sound manner through the technology of co-processing in cement kiln. Disposal of SMC / FRP wastes through co-processing is practiced in many countries as a regular method for their environmentally sound disposal. In India also, the capability of disposing FRP in an environmentally sound manner has been demonstrated through a co-processing trial carried out by ACC Limited in their Madukkarai Cement Works in Tamil Nadu. The results of this trial have demonstrated that there is no untoward impact of co-processing of FRP in the cement kiln on emissions or on the product quality. This trial was carried out at a Thermal Substitution Rate (TSR) of 0.924% which was reviewed by CPCB and permission to regularly co-process FRP waste in cement kiln at Madukkarai Cement Works granted.

Pre requisites for Co-processing of SMC/FRP polymer waste in cement plants

Following should be considered as a prerequisite for permitting Co-processing of SMC/FRP wastes in cement plants.

a) The Producers of thermoset plastic, major user like industries, Electricity authority etc in consultation with local authority shall arrange to collect the SMC/FRP waste and handover to cement plants. They shall maintain a record of quantity generated and handed over to cement plant.

b) The Cement plant shall maintain a record of quantity received and utilised by them.

c) The producers of SMC/FRP, major user like industries, Electricity authority etc. shall assist the cement plants for establishment of required facilities for utilization of SMC/FRP like shredding, feeding system, safety measures as applicable for co-incineration, online emission monitoring for PM, SO_2 and NO_x, and stack monitoring of heavy metals, dioxin and furans based on Extended Producer Responsibility (EPR).

(d) Secured Landfill[13]

Secured landfill is another option that can be utilised for disposal of the thermoset waste. The experience has however demonstrated that the land utilised for the landfill purpose gets locked and the liability associated with this land, filled-up with materials tends to continue forever, besides the land remains unusable. Most countries have stopped the practice of utilising landfill as the option for disposal of wastes. The cost of landfill expected to keep on increasing over the time due to increase in land and fuel coils. Further, availability of land is a major issue in the cities/ towns, therefore, this method could be ranked as least preferred option. The producers of thermoset plastic SMC/FRP boxes in collaboration with power utilities may also explore the possibility of establishing common.

9.8 Separation of Plastic Waste from Legacy Waste Bio-mining[35]

As per CPCB Guidelines for Disposal of Legacy Waste (Old Municipal Solid Waste) Bio-remediation & Bio-mining of Old Municipal Dumpsites is to be done through the excavation of old dumped waste and to make windrow of legacy waste thereafter stabilization of the waste through bio-remediation i.e. exposure of all the waste to air along with use of composting bio-cultures, i.e. screening of the stabilized waste to recover all valuable resources (like organic fines, bricks, stones, plastics, metals, clothes, rags etc.) followed by its sustainable management through recycling, co-processing, road making etc. The procedures for separation of intrinsically mixed plastic from other materials are illustrated hereunder.

(a) Separation of Plastic from Waste Stream: Need and Challenges[36-38]

As wide-spectrum of methods are available, which are techno-economically viable for plastic waste management, the major challenge exists in the separation of plastic from the mixed waste. In case of material being excavated during landfill mining, the task is quite cumbersome keeping in view of the fact that plastic material has to be separated from rest of the waste and thereafter separation of various components of plastic to isolate PVC and thermosetting material from the stream of recyclable plastic. The process of separation of high-quality re-usable plastic from waste stream is generally hampered by the presence of extraneous material including metals, fibres, other plastic, dirt, stones, wood, paper, glass etc. Manual sorting of different type of plastic from waste stream is not a feasible option as it is not only a labour intensive but also a time consuming process. The combustion of several types of plastics as means of recovering energy, especially those containing halogens, involve the potential environmental risks of producing toxic or carcinogenic gases.

(b) Selective Separations using Wet Method[36-38,41]

Density/ Specific gravity separation method for recycling plastics are based on particles of plastics floating or sinking in a separation media of a given density, usually under the force of gravity. Since the process uses a feed with a lamellar displacement of the separation media, production capacities are critically depending upon the particle size (6-10 mm size may be optimally considered). The selective float/ sink concept relies on the specific gravities of the various materials processed in the tank relative to the specific gravity of the base solution.

The materials with specific gravity higher than that of the base solution will sink while those with a lower specific gravity will float. The specific gravity of the base solution can be changed by means of addition of chemical additives to facilitate selective separation. Water is commonly used for plastics with higher specific gravity. The advantage is that plastic mixture is first expose to wet grinding, where the paper labels and dirt particles are removed and disadvantage is that separation can be slow. In this method, HDPE, LDPE, PP & PS can easily be separated from PS, PETE & PVC in water medium as their specific gravity is lower than that of water (1.0 g/cm^3). The average specific gravity of PVC (1.41 g/cm^3) is having a very narrow range of difference from that of PETE (1.37 g/m^3) and generally shows overlapping phenomena. However, 40% w/v $CaCl_2$ solution in DM water (having specific gravity of 1.39 g/ cm^3) can be tried to separate PVC from PETE. However, this solution is quite useful to separate PS from PETE and PVC.

Figure-110: Plastic Separation Methods (Sink/ Float Method)

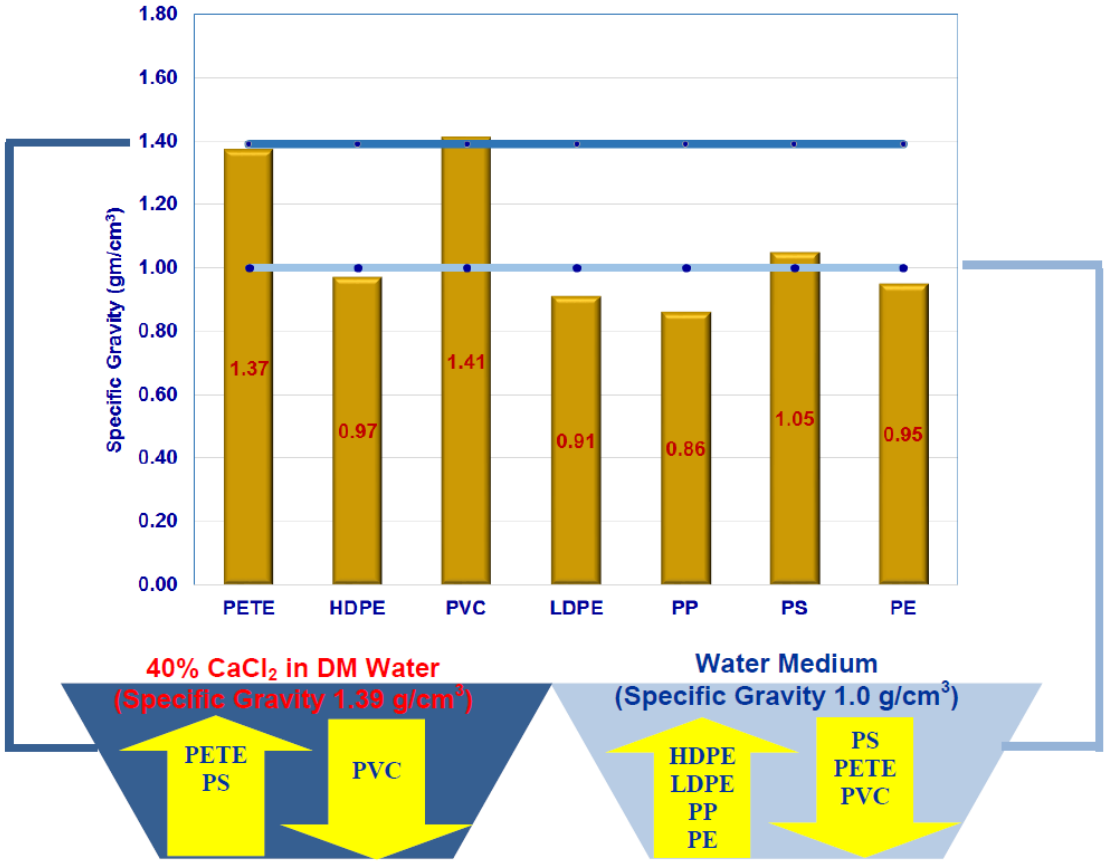


Figure-111: Example of Floatation Tanks with Air Blower *(Source: Haith)*

The LARCODEMS separators though designed for treating coal, has also been proven suitable for treating iron ore. It is presently supplied in six versions with manufacturers recommended processing capacities and maximum particle sizes varying in proportion with the cylinder diameter of the devices. The device consists of a cylindrical separating chamber inclined at 30º from the horizontal. The separating media can be injected tangentially at the lower end, forming a vortex with a central air core. Dry or moist material to be separated is fed at the top end to flow into the vortex. Dense fragments must settle through the ascending separating media circulating around the inner circumference of the cylinder to exit through the upper port (underflow) while the lower density material floats down the surface of the vortex to exit at the lower port (overflow). [36-41]

The behavior of PVC and PET in a LARCODEMS dense medium separator using calcium chloride solutions as the medium shown that particle thickness and surface conditioning can have a significant influence on plastic behavior within the separator. Thus, given the complexity of a mixture of shredded plastics in terms of size, shape and thickness, density separation using the LARCODEMS is likely to be only considered as a pre-concentration step. The drum type separator offers the advantage of being a combined device for both sink & float mechanism.[36-41]

Figure-112: Schematic Diagram of Tri-Flo Separator[36]

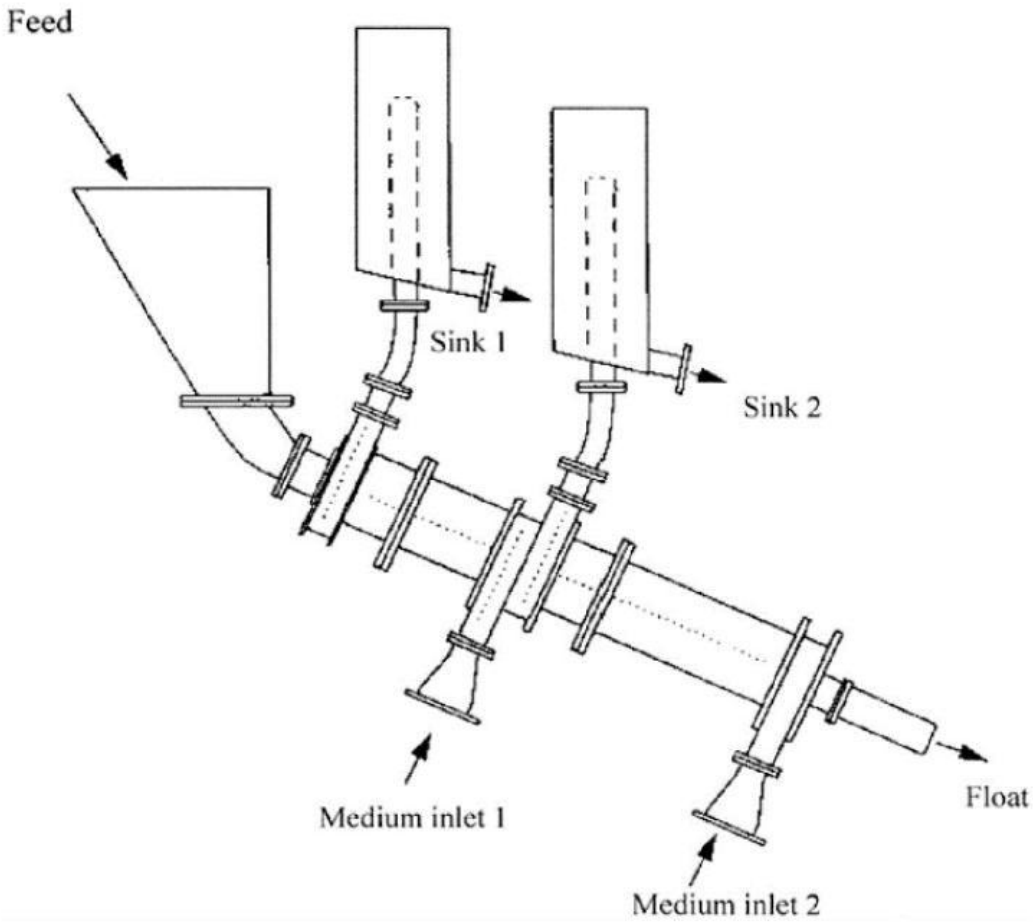


Figure-113: Schematic Diagram to Illustrate the Operation of LARCODEMS Separator [36]

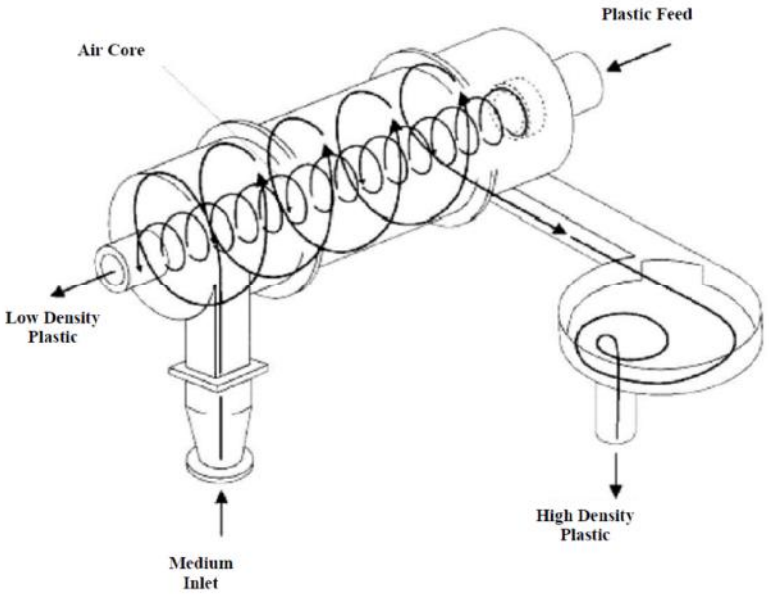
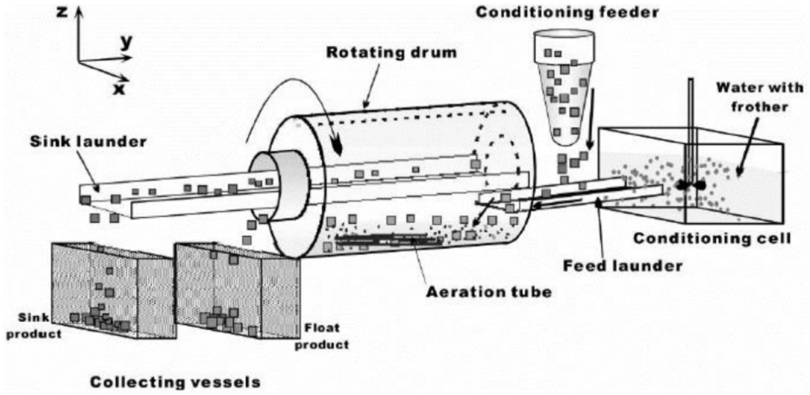


Figure-114: Schematic Design of Drum Separator that uses Combination of Sink-Float [36]



(c) Electrostatic Separation of PVC from PETE[36-41]

As the specific gravity for PVC materials is generally overlapping to that of PETE materials, thereby separation of PVC from the mixed materials by density separation processes pose difficulties. Electrostatic separation is a broadly applicable dry processing technique in the recycling plastic wastes, mineral processing industry, and coal beneficiation. This process separates materials based on one or more of their electrical properties such as work function or triboelectric charging series. When two materials are in contact, electrons move until the energy of electrons in each material at the interface is equalized. The material with a higher affinity for electrons gains electrons and charges negatively, while the material with the lower affinity loses electrons and charges positively. A measure of the relative affinity for electrons is called the work function. The work function of PVC and PET materials is 4.58 and 4.25 eV,

respectively. When PVC and PET particles come into contact with one another, the PVC becomes negative and the PET positive and hence gets separated from the mixture.

Figure-115: Fluidized Bed Triboelectric Separator [36]

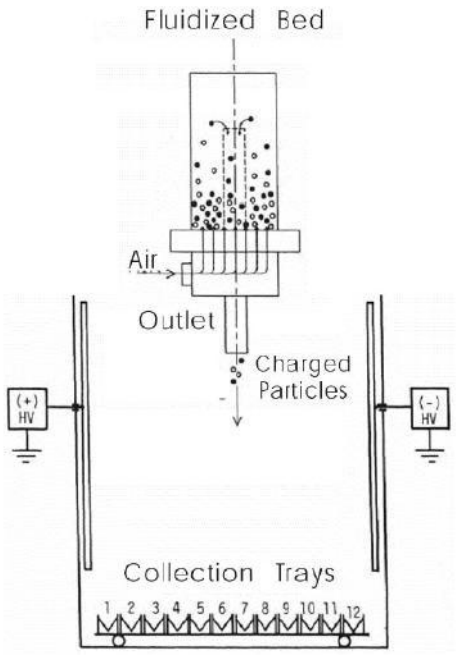
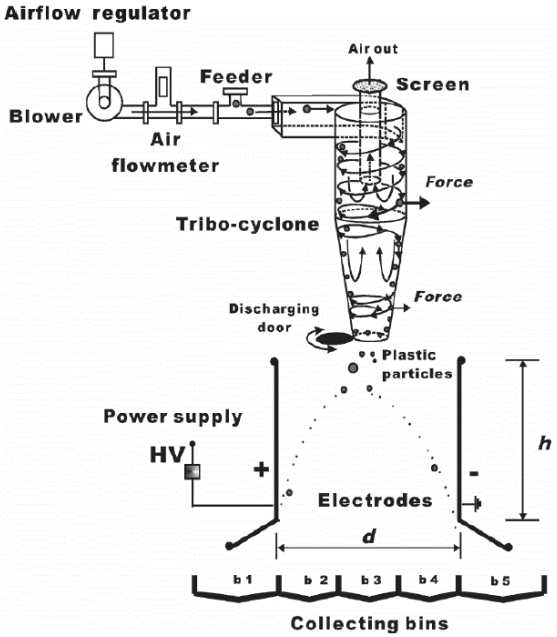


Figure-116: Schematic Design of Triboelectric Cyclone Separator [36]



Electrostatic separation by means of corona charging has been successfully applied to separate metal/non-metal mixtures, i.e. aluminium or copper from plastics or paper. Furthermore, a technique that makes use of the eddy currents can also be employed to separate plastic particles from a metal/plastic mixture. However, these techniques can only be applied to separate good conductors (such as metallic particles, etc.) from dielectrics, due to difficulty in separation of a mixture of dielectric particles such as mixed plastics. Triboelectric separation is the technique most frequently used to selectively separate two solid species of dielectric materials. Nevertheless, application of Triboelectric Cyclone Separation of plastics is relatively a novel process.

As illustrated in this section, various techniques for separating plastics materials have recently been developed and are being practiced world over. These techniques can broadly be divided in two main categories, i.e. wet separating techniques and dry separating techniques. Though separation of mixed plastic waste derived from old landfill may pose varying magnitude of challenges, considering the local matrix, the process can be successfully optimized both in terms of techno-economic feasibility involving recovery of material and reclamation of landfill space and best management of mixed plastic waste from environmental angle.

10. Alternative to Plastic

10.1 Aim to Develop Alternative Materials[6, 26, 42]

The exponential growth rate in plastic consumption over the years together with stringent regulations warrants the need for exploring options alternative to plastic. It is neither possible nor desirable to remove all plastics from society, but alternatives can have a significant role in minimising dependence on it. However, the use of alternatives must be part of a broader strategy towards more sustainable production patterns, particularly for packaging and other single-use items, including the principles of redesign, reduce, reduce and facilitating recycling. In recent years, there has been the growing interest world over to develop polymers with 'greener' credentials. This has led to the greater utilisation of renewable biomass-based feedstock, as well as materials that are more readily degraded in the environment.

10.2 Compostable Plastic [6, 9, 26, 42]

As per the Rule 3 (e) (Definitions) of PWM Rules, 2016 "compostable plastics" mean plastic that undergoes degradation by biological processes during composting to yield CO_2, water, inorganic compounds and biomass at a rate consistent with other known compostable materials, excluding conventional petro-based plastics, and does not leave visible, distinguishable or toxic residue.

As per CPCB Standard Operating Procedure for Issuing Certificate to Manufacturers/Sellers of Compostable Plastic Carry Bags/ Products:

Biodegradable during composting: Material that undergoes degradation by biological processes during composting to yield CO_2, water, inorganic compounds & biomass at a rate consistent with other known compostable materials & leave no visible, distinguishable or toxic residue.

Catalyst: Substance, used in small proportion, that augments the rate of a chemical reaction and in theory, remains unchanged chemically at the end of the reaction.

Compost: Organic soil conditioner obtained by biodegradation of mixture consisting principally of vegetable residues, occasionally with other organic material & having a limited mineral content.

Composting: Aerobic process designed to produce compost.

IS/ISO: 17088 Standard specifies procedures and requirements for the identification and labelling of plastics, and products made from plastics, that are suitable for recovery through aerobic composting. The four following aspects are to be addressed:

(a) Biodegradation,
(b) Disintegration during composting,
(c) Negative effects on the composting process and facility,
(d) Negative effects on the quality of the resulting compost, including the presence of high levels of regulated metals and other harmful components.

This specification is intended to establish the requirements for the labelling of plastic products and materials, including packaging made from plastics, as "compostable" or "compostable in municipal and industrial composting facilities" or "biodegradable during composting" (for the purposes of this International Standard, these three expressions are considered to be equivalent). The labelling will, in addition, have to conform to all international, regional, national or local regulations.

The purpose of IS/ISO:17088 specification is to establish standards for identifying and labelling plastic products and materials that will compost satisfactorily in well-managed composting facilities where the typical conditions of composting can be consistently obtained (i.e. a long thermophilic phase, aerobic conditions, sufficient water content, a suitable carbon/nitrogen ratio, etc.). Products meeting the requirements are appropriate for labelling as "compostable", "compostable in municipal & commercial facilities" or "biodegradable during composting". The test simulates an intensive aerobic composting process. It measures

- The ultimate-level of aerobic biodegradation of the test material
- The degree of disintegration obtained
- Any negative effects on the finished compost
- The maximum concentration of regulated metals in the compost

The test is terminated when the plateau phase of the biodegradation has been attained, the standard time fortermination is 45 days, but the test could continue for up to six months.

Basic Requirement: In order to compost satisfactorily, a plastic product or material shall demonstrate each of the following characteristics:

i. **Disintegration during composting:** The plastic product or material shall disintegrate during composting such that any remaining plastic is not readily distinguishable from the other organic materials in the finished compost. Additionally, the plastic product or material shall not be found in significant quantities during screening prior to final distribution of the compost.

ii. **Ultimate aerobic biodegradation:** The ultimate level of aerobic biodegradation shall be established by testing under controlled conditions.

iii. **No adverse effect on ability of compost to support plant growth**: The plastic product or material tested shall have no adverse effect on the ability of the compost to support plant growth, when compared to blank composts to which no test or reference substance has been added at the start of testing. In order to ensure that the composting of plastic products or materials does not have any harmful effects on the finished compost or on the environment and complies with appropriate regional & national regulations, following requirements shall be met:

(a) The concentrations of regulated metals & other toxic substances in the plastic product or material shall be <50 % of those prescribed for sludges, fertilizers and composts in the country where the final product will be placed on the market or disposed off.

(b) The plastic product or material shall contain a minimum of 50 % of volatile solids.

(c) The seedling germination rate of the finished compost and the plant biomass in the compost shall not be <90% of that of corresponding blank composts to which no test or reference material was added at the start of testing, determined in accordance with OECD Guideline 208 with the modifications specified in Annex E of EN 13432:2000.

iv. **Compliance with national regulations:** Based on the relevant national and/or regional regulations, the plastic product or material shall not, upon decomposition, release unacceptably high levels of regulated metals or other toxic substances into the environment. It is the responsibility of the user to conform to the applicable national and/or regional regulations dealing with metals, other elements and toxic substances in the environment.

v. **The term"biodegradable":** shall not be used to describe the performance of plastics which meet this specification unless the conditions typically found in composting and described in ISO:14855-1 & ISO 14855-2 are Included (for example "biodegrdable during composting").

Disintegration during composting:

A plastic product is considered to have demonstrated satisfactory disintegration if, after 84 days in a controlled composting test, no more than 10 % of its original dry mass remains after sieving through a 2 mm sieve. The test shall be carried out in accordance with ISO 16929, ISO- 20200, ISO-14855-1 or ASTM-D5338 under thermophilic composting conditions without the CO2-trapping equipment.

Ultimate aerobic biodegradation:

- A plastic product is considered to have demonstrated a satisfactory rate and level of biodegradation, when tested in accordance with ISO-14855-1, ISO-14855-2/ASTM-D5338, it achieves the ratio of conversion to carbon dioxide (CO_2) within specified time period The ultimate aerobic biodegradability shall be determined for the whole material and for each organic constituent which is present in the material at a concentration of more than 1% (by dry mass). Constituents which are present at concentrations of less than 1% do not need to demonstrate biodegradability, however, the sum of such constituents shall not exceed 5%.

- For all polymers, 90% of the organic carbon (relative to a positive-control reference material) shall have been converted to carbon dioxide by the end of the test period. Both the positive control and the test sample shall be composted for the same length of time and the results compared at the same point in time after the activity of both has reached a plateau. The positive control used shall be micro crystalline cellulose.

- As an alternative, 90 % (in absolute terms) of the organic carbon shall have been converted to carbon dioxide by the end of the test period.

- The test period shall be no longer than 180days.

Marketing and labelling:

i. Plastic products or materials meeting all the requirements specified In Clause ‘6’(IS/ISO:17088) may be labled as "compostable" or "biodegradable during composting"

ii. The labelling shall conform to international, national, regional or local regulations.

iii. The name of the country where the plastic product or material is to be marketed or recycled by composting shall be indicated.

Test report:

The test report shall provide all pertinent information, including:

i. All information necessary to identify and describe the product or material tested.

ii. References to all standards, guidelines and regulations regarding the content of regulated metals and other toxic substances (a table of regulated *metals* and other *toxic* substances shall be presented, specifying each such reference and stating the prescribed limit for each metal and other toxic substance, the concentration determined in the test and the percentage of the prescribed limit).

iii. A description of other relevant requirements in the referenced documents & a statement, for each such requirement, as to whether the test result was in conformity with the requirement or not.

Testing Laboratory:

The compostable products made from 100% bio-based material can be tested in the laboratory, recognized by CPCB for this purpose. The test shall be carried out as per Indian Standard IS/ISO-17088, as amended time to time. The test report shall include the results of following test:

- Disintegration during composting.
- Ultimate aerobic biodegradation.
- Heavy metal analysis
- Seed germination.

10.3 Starch based polymers

(a) Thermoplastic Starch

The thermal and mechanical processing is required to disrupt the complex structure of starch and achieve partial or complete gelatinization. Closed cell expanded foams require the least disruption, with the addition of water and elevated temperatures, followed by extrusion into a variety of shapes. This material has good thermal insulation and shock-absorbing properties. Applications include loose fill to protect packaged goods in transit. The eventual goal is to produce a material that can replace EPS, especially for food packaging. Much of the research has focused on the use of cassava starch, an important staple crop and therefore readily available. Minimally-modified starch foam readily dissolves in water, is compostable under domestic conditions and degrades rapidly in the environment.

At higher temperatures and lower water content, it is possible to produce thermoplastic starch (TPS) with the addition of a plasticiser such as sorbitol or glycerine. More conventional chemical treatments could be used but these may introduce potential unwanted by-products requiring an additional purification phase. TPS is transformed from native starch using the same manufacturing techniques as conventional plastics, producing a homogenous molten phase that is then extruded. The structure of the feedstock can vary

with geographical source and growing season as well as plant variety making it more difficult to control the properties of the synthesised TPS. In addition, the properties of TPS may make it unsuitable for some applications, such as food packaging, without further modification, for instance to improve moisture sensitivity.

(b) Starch-based bio-composites

Starch-based micro and nano bio-composites are produced by composting TPS polymer with filler such as cellulose or lignin fibres. This is done to improve the properties of the finished product and to increase the range of applications. The addition of cellulose fibres to a TPS matrix has been reported to bring the following benefits:

- Higher mechanical properties
- Higher thermal resistance
- Reduced water sensitivity
- Reduced post-processing ageing

The potential for starch based bio-composites to replace conventional plastics in many packaging applications appears to be very promising although further work is required to maximize this potential in particular, to make improvement in some fundamental aspects, such as mechanical properties and moisture sensitivity, before this category of polymers can replace conventional polymers in wider range of applications.

(c) Starch composites with synthesized polymers

Starch-based composites can also be produced with the addition of synthetic polymers, to improve performance and increase the range of potential applications. Starch-PCL is the most common starch blend, as it has a low melting temperature and can be readily hydrolysed. PCL is compostable but is derived from fossil fuel. Other starch blends included composites with biomass based polymers, such as polylactic acid (PLA), polybutylene succinate (PBS), PBSA (polybutylene succinate-co-butylene adipate), polyvinyl acetate (PVA) and polyhydroxyalkanoates (PHA). These compounds can be produced by fermentation of biomass, this is the additional advantage. The composition and environmental behavious of the finished product will be influenced by the proportion and properties of the added polymer.

(d) Non-starch thermoplastic bio-composite

It is possible to produce thermoplastic materials from natural sources other than starch including alginate and chitosan. Alginate is extracted from species of brown algae and has many industrial uses. Chitosan-based composites are manufactured using chitin, which is abundant globally, forming the exoskeletons of insects and crustacean such as shrimp. Chitosan is created by partial de-acetylation of chitin with sodium hydroxide, with the degree of acetylation determining the crystallinity.

(e) Behaviour of starch-based polymers on environment

The behaviour of starch based polymers, biomass source and common uses together with biodegradable and composting properties (based on reported observations), are given in table-85. Domestic composting: C-d; Industrial composting: C-i; biodegradable: B; Degradation rate: High (H), Medium (M) and Low (L)

Table-87 Behaviour of starch based polymers (Source UNEP[13])

Material	Polymer	Common biomass source	Example of common use	Terrestrial			Aquatic
				C-d	C-i	B	B
Expanded starch foams	Starch	Maize, cassava, potato, rice	Loose packaging fill	H	H	H	H
Thermoplastic Starch	Starch	Maize, cassava, potato, rice	Thin-film bag	M	H	M	M
TPS-polymer composite	Starch-PCL/PLA	Maize	Films, Agricultural mulch	M	H	M	M
TPS-bio-composites	Starch-cellulose	Alpaca	Clothing, other fabrics	M	H	M	M

10.4 Synthetic biomass based polymers[13, 42-45]

A variety of plant and animal based raw materials can be used to synthesize biomass based polymers, depending on the intended use and process employed. Cellulose and starch are the most common sources of biomass. Polylactic acid or polylactide (PLA) and polyhydroxyalkanoates (PHA) are reported to be synthesised based on this process.

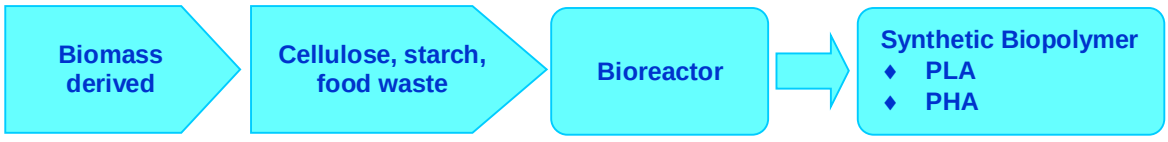
(a) PLA production and use

PLA is synthesised by polymerization of lactic acid produced by bacterial fermentation of sugar derived from a variety of biomass sources. The main applications have been for various forms of packaging and in the catering industry as it is safe to use in contact with food. It has been reported that products such as bottles and films manufactured from PLA and PHA, visually appears to be indistinguishable from conventional plastics but properties such as vapour permeability and flexibility can be more difficult to achieve compared to equivalent polymers used for similar applications such as PET and PS.

(b) PHA production and use

PHAs represent a large group of biogenic polyesters that can be generated by the bacterial fermentation of sugar or lipids extracted from a range of biomass sources. PHAs exhibit thermoplastic or elastomeric properties.

Figure-117: Simplified schematic of the production of PLA and PHA



(c) Behaviour of PLA and PHA in the environment

PLA is reported more acceptable substitute for conventional plastics in the catering sector, where PLA plates along food waste can be collected and the combined waste sent to either industrial composting or anaerobic digestion. This approach works better in a controlled closed loop environment, such as institutional catering, to prevent cross-contamination of PLA/ PHA plastics with conventional plastics.

There is a very limited degradation of PLA at ambient temperatures in soil and domestic composting, although degradation of PLA composites may be enhanced by the addition of natural fibres such as *abaca* and *kenaf*. There is some concern that the extensive use of PLA for agricultural films may lead to build up of PLA in soils. In contrast, degradation of PLA and PHA occurs under commercial thermophilic composting (50-60°C) conditions and by anaerobic digestion. The behaviour of PLA and PHA, biomass source and common uses together with biodegradable and composting properties (based on reported observations), are given in table-86. Domestic composting: C-d; Industrial composting: C-i; biodegradable: B; Degradation rate: High (H), Medium (M) and Low (L).

Figure-118: Schematic Business Model for Compostable Polymer

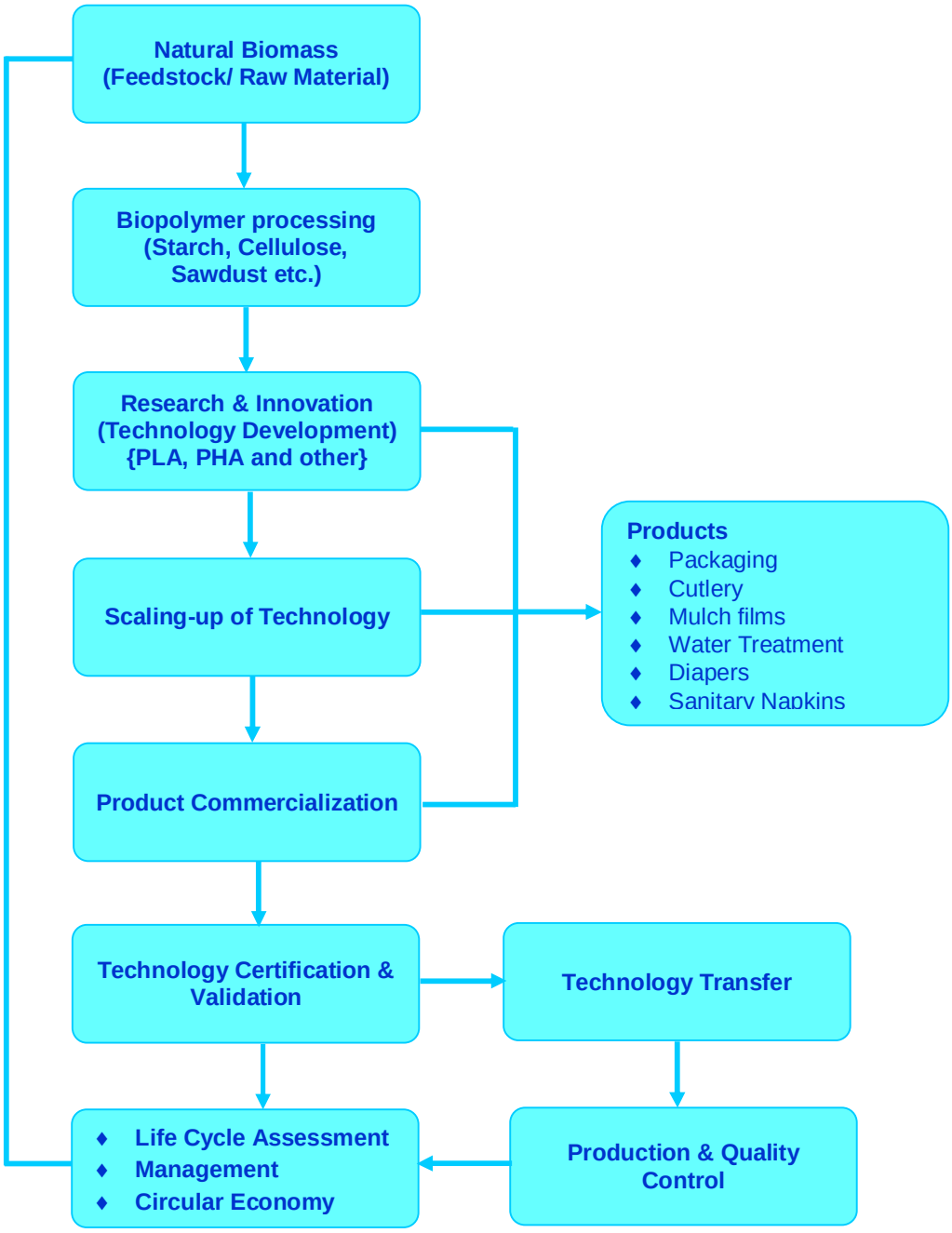


Table-88 Behaviour of PLA and PHA in environment (Source UNEP[13])

Material	Polymer	Common biomass source	Example of common use	Terrestrial			Aquatic
				C-d	C-i	B	B
PHA	Polyhydroxyalkanoates	Biomass derived sugars	Films, packaging, catering products	H	H	H	H
PLA	Polylactic acid	Maize, cassava	Films, packaging, hygiene products, catering products	M	H	M	M

10.5 Utilization of Alternative Material[2, 6, 9, 26, 42-45]

As reported in literature, there is a considerable scope to increase the use of agricultural and horticultural waste as a source of natural fibres and as a raw material for biopolymer production. The biomass-based biopolymers such as PLA, PHA and TPS have been reported to show great potential, especially for Packaging and other single use provided these are to be used in closed loop-systems. Their promotion as a greener alternative is unjustified in the absence of the effective provision of industrial composting or anaerobic digestion facilities; i.e. such material may not be suitable for dispensing in uncontrolled public spaces.

The focus for these plastics should be more on 'bio-based content' rather than biodegradability. The quality and performance in terms of strength and thermal stability should be at par or close to that of synthetic polymers. There is no dedicated testing and certification facility which is of vital importance to assess the quality parameters.

Research shall focus on development of innovative biodegradable products with an emphasis on performance, technology development, shelf life, and related financial aspects. Investment, apart from research funding, should also include strategies for market outreach and the development of sustainable business models.

Policy aspects also need to be included vis-à-vis framework, promotional measures, and incentives along with the facilitation of testing and certification standards.

Biodegradability issues, such as ambient conditions for degradability, also need to be specified; for example, products may be labelled as industry or home compostable, soil or marine degradability, and so on. Investments for the development of bio-plastic products would ease the burden on plastic waste management, conserve petrochemical reserves, boost agriculture sector, and thus reduce the environmental impact and carbon footprint.

11. Conclusion and Policy Recommendations

11.1 Conclusion

The Assessment and Characterization of Plastic Waste in NCT of Delhi as illustrated in this report can be summed-up to following conclusion:

(a) The average plastic waste of all the locations is estimated as 10.10% (or 101 Kg/MT) of total solid waste. The plastic waste in Delhi is quantified to the tune of 1060 TPD.

(b) The per capita per day plastic waste generation in Delhi is calculated to 53.6 gram.

(c) On average, the Single-use Plastic (SUP) is estimated as 5.6% (or 56.0 Kg/MT) of total SW.

11.2 Policy Recommendations

As consumption of plastic has increased exponentially in recent years, the indiscriminate dumping and littering of plastic waste is exerting wide spectrum of detrimental impacts on environment. The effective implementation/ enforcement of Plastic Waste Management Rules 2016, amended 2018, in totality is always a challenge for local authorities. In order to devise efficient ways of Plastic Waste Management, the following policy recommendations may be envisaged:

(a) Local Authorities/ Municipal Corporations shall devise an implementation procedure/ standard operating procedure (SOP) for management of plastic waste in adherence to the Plastic Waste Management Rules-2016 (amended 2018) ensuring door to door segregation of dry and wet waste and also at all places.

(b) The ward-wise material recovery facilities (MRF) are to be developed and optimised for their best performance. The integration of MRF with Extended Producer Responsibility (EPR), if possible, would be helpful towards the development of circular economy model.

(c) Producers and brand owners must partner with local authorities/ municipalities to ensure the formulating an EPR plan together with the procedures for its effective implementation as per The Ministry of Environment, Forests and Climate Change (MOEF&CC) / Central Pollution Control Board (CPCB) National Framework.

(d) The innovative economic models may be developed together with their implementation procedures to prompt citizens to recycle plastic waste.

(e) Inter-alia other sustainable alternatives of PWM, the co-processing of plastic in cement kilns, would provide environmentally viable mechanism to process non-recyclable, combustible plastic waste in addition to addressing the troubleshootings of waste management.

(f) Development of value added chain for recycled products requires optimisation of innovative solutions considering mechanical properties at par with virgin plastic. Such products can cater to the demand of building sector, furniture industry, packaging, and automobile industry.

(g) The MOEF&CC/ CPCB may take-up the matter with Bureau of Indian Standards (BIS) for formulation of Standard Specification for recycled plastic products.

(h) Bio-based compostable plastics provides sustainable alternatives to minimize plastic waste. The use of biodegradable plastic must be promoted, especially in large-scale applications, such as manufacturing of agricultural mulch films, superabsorbent composites used for waste water treatment, and sustained release of pesticides. There is a further need for the up-scaling and commercialization of these products through a facilitation of research and industrial collaboration.

(i) In order to create enabling environment to implement rules and procedures, it would be more appropriate to conduct capacity building programmes for stakeholders on regular basis to share best practices world over, in areas of Plastic Waste Management.

References

1. Ministry of Chemicals and Fertilizers, Department of Chemicals and Petrochemicals; Annual Report 2018-19.

2. PLASTINDIA (2018); Report on the Indian Plastic Industry; Ed.2; January 2018.

3. MOHUA (March 2019); Plastic Waste Management – Issues, solutions and case studies.

4. Sustainable Recycling Industries (SRI); January-2018; Feasibility study for a certification of sustainably recycled plastics in India.

5. MOEF&CC (2018); Beat Plastic Pollution: Good News from India.

6. TERI (2018); Challenges and Opportunities Plastic Waste Management in India.

7. TERI (June-2018); Factsheet on Plastic Waste in India.

8. CPCB (June-2015); Assessment & Characterization of Plastic Waste Generation in 60 Major Cities.

9. The Plastic Waste Management Rules 2016 amended on 27th March 2018.

10. CPCB (October-2019); Annual Report for the year 2018-19 on Implementation of Plastic Waste Management Rules (As per Rule '17(4)' of PWM Rules, 2018).

11. CPCB (2013); Overview of Plastic Waste Management.

12. CPCB (2016); Guidelines for Disposal of Thermoset Plastic Waste including Sheet moulding compound (SMC)/ Fiber Reinforced Plastic (FRP) (As per Rule 5(c) of Plastic Waste Management Rules, 2016 dated 18th March, 2016).

13. UNEP (2009); Converting Waste Plastics into a resource: Compendium of Technologies.

14. Carlo Giacomo Avio et al (2016); Plastics and microplastics in the oceans: From emerging pollutants to emerged threat; Marine Environmental Research; 1-10.

15. Ministry of Environment and Food of Denmark, Environment Protection Agency (March-2017); Microplastic in Danish wastewater-Sources, occurrences and fate.

16. Plastic Waste (Management and Handling) Rules, 2011.

17. Census of India 2011 (Directorate of Census Operations, Delhi); District Census Handbook-All the Nine Districts of NCT of Delhi; Part XII-A, Series 8; Village and Town Directory.

18. Census of India 2011 (Directorate of Census Operations, Delhi); District Census Handbook-All the Nine Districts of NCT of Delhi; Part XII-B, Series 8; Village and Town wise Primary Census Abstract.

19. Planning Department, Government of NCT of Delhi (2018); Economic Survey of Delhi, 2017-18.

20. Directorate of Economics & Statistics, Government of NCT of Delhi; Delhi Statistical Handbook 2017.

21. Directorate of Economics & Statistics, Government of NCT of Delhi; Statistical Abstract of Delhi 2016.

22. Central Ground Water Board, State Unit Office, New Delhi; Aquifer Mapping and Ground Water Management Plan of NCT Delhi.

23. ASTM D 5231-92 (Reapproved 2003); Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste.

24. IS 14534: 2016; Indian Standard on Plastics-Guidelines for the Recovery and recycling of Plastic Waste; 1st Revision.

25. CPCB (May 2017); Consolidated Annual Review Report on Implementation of Solid Wastes Management Rules, 2016.

26. CSE (2019); the Plastic Factsheet 3.

27. GAIA-CAG (2019); breakfreefromplastic; Are Businesses Ready to Beat Plastic Pollution.

28. CPCB (2008); Performance Evaluation of Polymer Coated Bitumen Built Roads.

29. UN Environment (2018); Single-use Plastic: A roadmap for sustainability.

30. CPCB (Sept-2017); Consolidated Guidelines for Segregation, collection and disposal of Plastic Waste.

31. IRC: SP: 98-2013; Guidelines for the Use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in Wearing Courses.

32. CPCB (2012); Material on Plastic Waste Management.

33. Rima Ingle, Rahul Masal, Atul Gargade (2014); Obtaining fuel from plastic; IJRITCC; Vol 2; Apr-2014.

34. Arun Joshi, Rambir and Rakesh Punia (2014); Conversion of Plastic Wastes into Liquid Fuels - A Review; Recent Advances in Bioenergy Research Vol. III 2014.

35. CPCB (February-2019); Guidelines for Disposal of Legacy Waste (Old Municipal Solid Waste).

36. G.Dodbiba and T.Fujita (2004); Progress in separating plastic materials for recycling; Physical Separation in Science and Engineering; Vol.13, No.3-4, Sept-Dec, 2004.

37. Biswajit Ruj *et al* (2015); Sorting of plastic waste for effective recycling; Int. Journal of Applied Sciences and Engineering Research, 4 (4) 564-571, 2015.

38. Jae-Keun Lee and Jin-Houk Shin (2001); Triboelectrostatic Separation of PVC materials from mixed plastics for waste plastic recycling; Korean J.Chem.Eng, 19 (2), 267-272, 2001.

39. EPA530-F-97-001 (July-1997); Landfill Reclamation.

40. www.srcf.ucam.org/awtbi/documents/Landfillmining.

41. Malcom R. Gent *et al*; Enhanced Plastic Recycling by Cyclone Media Separation; University of Oviedo.

42. CPCB (Amended SOP: 15-02-2018: 1/10); Standard Operating Procedure (SOP) for Issuing Certificate to Manufacturers/Sellers of Compostable Plastic Carry Bags/Products; (Rule 4(h) of Plastic Waste Management (PWM) Rules, 2016).

43. Ezeoha S and Ezenwanne,J (2013); Production of biodegradable plastic packaging film from cassava starch; IOSR Journal of Engineering (IOSRJEN) 3 (10),14-20.

44. Emadian, s.M, Onay, T.T and Demiral, B (2017); Biodegradation of bioplastics in natural environments; Waste Management, (59), 526-536.

45. Edhirej, A, Sapuan, S.M, Jawaid, M and Zahari, N.I (2017); Preparation and characterization of cassava bagasse reinforced thermoplastic cassava starch; Fibres and Polymers; 18 (1), 162-171.

46. MOEF&CC, Government of India; Lok Sabha Unstarred Question No. 4553 (to be answered on 19/07/2019);total quantum of solid waste generated in country, state/UT wise.

Addendum to Report

Recommendations

The study of "Assessment and Characterization of Plastic Waste in NCT of Delhi" carried out during 2019-20, indicates the average plastic waste as 10.10 percent (or 101 Kg/MT) of total solid wastes. The quantum of total plastic waste in Delhi is estimated to be 1060 Tonnes per Day (TPD). The per capita per day plastic waste generation in Delhi is calculated to be 53.6 gram. The Single-use Plastic (SUP), on average, is estimated as 5.6 percent (or 56.0 Kg/MT) of total SW.

As consumption of plastic has increased exponentially in recent years, the indiscriminate dumping and littering of plastic waste is exerting wide spectrum of detrimental impacts on environment. The effective implementation/ enforcement of Plastic Waste Management Rules 2016, amended 2018, in totality is always a challenge for local authorities. In order to devise efficient ways of Plastic Waste Management, the following recommendations are envisaged:

1. **The Material Recovery Facilities (MRF) are to be developed and optimised for their best performance. The integration of MRF with Extended Producer Responsibility (EPR), would be helpful towards the development of circular economy model.**

(a) Implementation Options for NCT of Delhi

The municipal corporation wise area details, wards/ circles population size, total solid waste generation and estimated plastic waste is summarised as follows[1] in table-1:

Table-1: Municipal Corporation wise total solid waste generation and estimated plastic waste in Delhi[1]

Attributes	**North-DMC**	**South-DMC**	**East-DMC**	**NDMC**	**DCB**
Area, sq.km	636.00	659.91	105.98	42.67	42.80
Population, lakhs	90	70	50	2.57	1.332
No. of wards (Circle in NDMC)	104	104	64	14	8
SWM Generation, TPD	4013	3500	2700	185.57	72
*Estimated Plastic Waste @ 10.1 percent, TPD	405	354	273	19	7
Total Waste Processed/ Treated	2013	1700	1250	185.57	42
Percentage of Total Waste Processed/ Treated	50.2	48.6	46.3	100	58.3

North-DMC: North Delhi Municipal Corporation
South-DMC: South Delhi Municipal Corporation
East-DMC: East Delhi Municipal Corporation
NDMC: New Delhi Municipal Council
DCB: Delhi cantonment Board.

[1] http://dpcc.delhigovt.nic.in; Annual Report in Form V in respect of NCT of Delhi for the year 2019-2020 on the implementation of Solid waste Management Rules, 2016 vide reference F.No. DPCC/WMC-II/2018/AR/SWM/3844-3846 dated 28.07.2020.
*Estimated during study.

As per the advisory of *Swachh Bharat Mission*[2], the Urban Local Bodies (ULBs) with population 10 lakhs plus and waste generation of 500 plus TPD, assuming more than 75 percent door to door collection and segregation of waste, needs MRFs with the design capacities in range of 100 to 300 TPD, provided the indicative percentage of dry fraction including plastic waste is in range of 55-60%. The design criteria and other aspects for various population sizes are as follows:

Table-2: Design criteria for development of MRFs in Delhi[2]

Population Size (1 to 5 lakh)		
Design Capacity		50 to 100 TPD
Type of Facility		Semi-automatic
Area requirement per MRF		6,000 to 8,000 sq. m (approx.)
Indicative CAPEX (excluding land cost)		Rs.4.5 to 6.0 crores per facility
OPEX		Rs.60 to 70 lakhs per year (which includes salary of 20 to 30 manpower), regular operation and maintenance, consumables and miscellaneous expenditure.
Population Size (10 lakh plus)		
Design Capacity		100 to 300 TPD
Type of Facility		Semi-automatic/ Automatic
Area requirement per MRF		10,000 to 20,000 sq. m (approx.)
Indicative CAPEX per facility (excluding land cost)	**100 TPD**	4.5 to 6.0 crores for semi-automatic
		18 to 20 crores for automatic
	200 TPD	24 to 26 crores for automatic
	300 TPD	29 to 31 crores for automatic
OPEX		Rs.60 to 80 lakhs per year (which includes salary of 30 to 50 manpower), regular operation and maintenance, consumables and miscellaneous expenditure.

CAPEX: Capital Expenditure; OPEX: Operational Expenditure

The automated/ fully mechanised MRF have limitations in segregation of mixed waste, hence it is required that the automated facilities shall receive only dry waste.

Hence, corporation wise setting-up of MRFs in NCT of Delhi may be considered as follows:

100 to 300 TPD design capacity	♦ North Delhi Municipal Corporation	: 7 to 20 MRFs
	♦ South Delhi Municipal Corporation	: 6 to 18 MRFs
	♦ East Delhi Municipal Corporation	: 5 to 15 MRFs
50 to 100 TPD design capacity	♦ New Delhi Municipal Council	: 1 to 2 MRFs
	♦ Delhi Cantonment Board	: One MRF

(b) Regulatory Aspects

Facilities to secure Consent to Establish and Consent to Operate as per the procedures of Delhi Pollution Control Committee.

[2] Swachh Bharat Mission-Urban (June-2020); Advisory on Material Recovery Facility (MCF); CPHEEO; Ministry of Housing and Urban Affairs, Government of India.

(a) Measures to Maximize Sustainability

In order to maximize impacts following aspects need to be envisaged:

(i) The EPR aspects to be integrated with MRF.
(ii) Buffering of facilities with tree and green cover to enhance aesthetic ambience and visual impacts as well as to attenuate odour and operational noise.
(iii) Development and implementation of Standard Operating Procedures (SOP) and Work Instruction Manual (WIM) for operation.
(iv) Occupational Health and Safety norms to be followed to minimise operational risk to prevent accidents.
(v) Facilities may set objectives to acquire ISO certification (9001, 14001 and 45001) to showcase as demonstrative model.

(b) Key Performance Indicators (KPIs)

(i) Compliance to the conditions of Consent to Operate
(ii) Productivity Targets (per person basis benchmarking and mapping).
(iii) Process Audit (yearly basis).
(iv) Safety Assessment
(v) Sustainability/ Life Cycle Assessment

2. Recycling Options for Plastic Waste

(I) Implementation Options for NCT of Delhi

The recycling options are described in Chapter-9 of the Detailed Project Report, which includes following aspects.

Table-3: Plastic Waste Recycling Options for Delhi

Type of Recycling	**Mechanical Recycling**
Status in Delhi	The recycling of plastic waste is already being practised
Reference in Report	Chapter-5 and Chapter-9 (Section-9.1 and 9.2)
Measures to Maximize Sustainability	♦ Adherence to the occupational safety norms. ♦ Development and implementation of SOP and WIM. ♦ Setting-up and implementation of QA/QC norms.
Type of Recycling	**Incineration**
Status in Delhi	The incineration of plastic waste (as part of RDF) is already being practised at Water to Energy (WTE) plants.
Reference in Report	Chapter-9 (Section-9.4)
Measures to Maximize Sustainability	♦ Adherence to the occupational safety norms. ♦ Development and implementation of SOP and WIM. ♦ Setting-up and implementation of Quality System Procedures (QSPs). ♦ Facilities may set objectives to acquire ISO certification (9001, 14001 and 45001).

Table-3: Plastic Waste Recycling Options for Delhi

Type of Recycling	**Polymer Coated Bitumen Roads**
Status in Delhi	This process can be implemented in Delhi. SRI has developed these roads in collaboration with Gas Authority of India limited (GAIL) at two locations in Delhi viz. Rajpur Road and Ramjas Road in Delhi University.
Reference in Report	Quality Control Norms are given in the chapter-9 (Section-9.3)
Measures to Maximise Sustainability	♦ Compliance to QA/ QC norms. ♦ Adherence to the occupational safety norms. ♦ Development and implementation of SOP and WIM.
Key Performance Indicators (KPIs) for Recycling	
♦ Compliance to the conditions of Consent to Operate ♦ Adherence to QA/QC norms. ♦ Productivity Targets (per person basis benchmarking and mapping). ♦ Process Audit (yearly basis). ♦ Safety Assessment ♦ Sustainability/ Life Cycle Assessment.	

(II) Future Options for NCT of Delhi

The Research and Innovation options like pyrolysis (recovery of fuel from plastic waste) can be explored as future options which may include prototype development for demonstration.

3. Regular Capacity Building and Training of Stakeholders, specifically to discourage the utilization of Single-use Plastics (SUP).

(a) Implementation Options for NCT of Delhi

- Creation of enabling environment for implementation Capacity Building and Social Behavior Change Communication (SBCC) programmes.
- Training of Trainers.

(b) Ways for implementation and maximising sustainability

- Contextualization and Development of Communication and Outreach Modules.
- Development of e-learning tools such as short video clips.
- Development of e-brochure and e-infographics.
- Communication through social media.
- Delivery of webinars/ consultation workshops.
- Regular evaluation of communication and outreach programmes to assess effectiveness.

4. Bio-based compostable plastics provides sustainable alternatives to minimize plastic waste.

The use of biodegradable plastic must be promoted, especially in applications, such as manufacturing of agricultural mulch films, superabsorbent composites used for waste water treatment, and sustained release of pesticides, as packaging material etc. There is a further need for the up-scaling and commercialization of these products through a facilitation of research and industrial collaboration.