Waste Characterization Handbook:

Understanding Municipal Waste Streams to Develop Data-Driven Methane Mitigation Strategies

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Exhibits

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The United States Environmental Protection Agency (U.S. EPA) on behalf of the Global Methane Initiative developed this Waste Characterization Handbook to help interested parties learn about the process and steps needed to complete a municipal solid waste characterization.

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1. Introduction

The municipal solid waste sector (MSW) contributes to 9.7 percent of global anthropogenic methane emissions.[1] In the MSW sector, methane is generated primarily through the decomposition of organic wastes (e.g., food waste, green waste) in anaerobic (i.e., oxygen-free) environments such as dumpsites and landfills. According to the World Bank, food and green waste make up approximately 44 percent of the waste stream.[2] Because total global waste generation is expected to increase by more than three times by 2050, reducing waste sector methane emissions is a key opportunity to mitigate climate change and yield energy, economic, environmental, and public health benefits.

Effective waste management plans, programs, and policies to improve waste practices and reduce the climate impacts from the sector are dependent on the availability of accurate and detailed information about the MSW stream. Developing waste management programs, policies, and projects without a clear understanding of the waste stream can lead to numerous problems, ranging from sub-optimal operations to project failure.

The Global Methane Initiative (GMI) Waste Characterization Handbook and accompanying Excel tool were developed to help decision-makers and solid waste professionals plan and conduct hand-sort[3] waste characterization studies. Waste characterization is a systematic approach used to understand the composition and proportion of each material or product in the waste stream.

The handbook includes recommended activities and resources to:

- Plan an appropriate study for specific site conditions.
- Conduct field activities to collect the data.
- Analyze the data to help make informed solid waste planning decisions.

The resulting waste characterization data can be used to:

- Establish baseline waste management conditions.
- Develop new waste management strategies, including reduction and diversion.
- Assess and select waste processing and treatment technologies.
- Understand contamination of recyclable and organic materials.
- Evaluate and improve existing programs.

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[1] Global Methane Initiative (GMI). GMI Fact Sheet. Available online: https://www.globalmethane.org/index.aspx

[2] Kaza et al., What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Available online: https://openknowledge.worldbank.org/entities/publication/d3f9d45e-115f-559b-b14f-28552410e90a. In low- and middle-income countries, food and green waste represented 50 percent or higher of the waste stream. As income rises, organic waste percentages drop to approximately 32 percent of the waste stream.

[3] Hand-sorting involves manually sorting the waste components into selected categories. Hand-sorting of waste is most appropriate for residential, commercial, and institutional waste streams that are typically bagged.

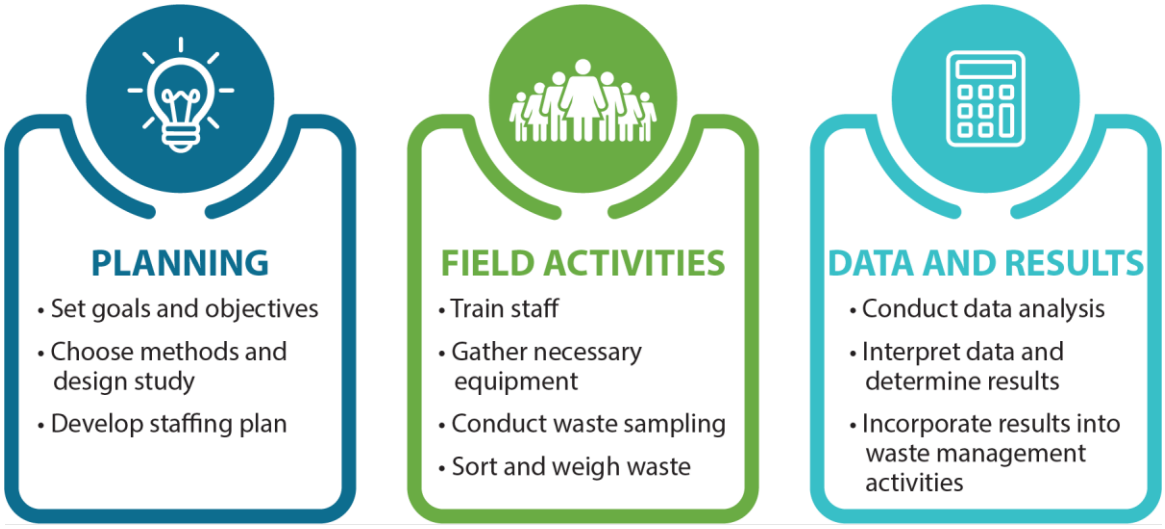
The Global Methane Initiative (GMI) Waste Characterization Handbook is not the only guide on waste characterization and can serve as an input to existing internationally accepted processes. If a comprehensive review of a city's MSW management performance is required (e.g., for reporting on Sustainable Development Goal 11.6.1[4] on waste collected and adequately discharged by cities), users may wish to consult the UN Habitat Waste Wise Cities Tool (WaCT).[5] This handbook focuses on collected MSW; for information on how to study and characterize uncollected waste directly from households refer to the UN Habitat WaCT.[6]

1.1 What Does MSW Characterization Entail?

Waste characterization is a systematic approach to identify and quantify the types of wastes (e.g., plastics, paper, organics) in a waste stream (e.g., residential waste, commercial waste). The basic steps of waste characterization are summarized in Exhibit 1.

Waste characterization studies can range in scope and duration from one facility at one period of time or may include multiple sites/locations over multiple seasons. For example, a vegetable market may conduct a waste characterization study to determine the type and quantities of wastes generated (e.g., plastic bags, paper containers, vegetable waste, fruit waste).

Exhibit 1. Steps Involved in Waste Characterization Studies



[4] United Nations (UN) Sustainable Development Goals (SDG): 11 Sustainable Cities and Communities. Available online: https://unstats.un.org/sdgs/metadata/?Text=&Goal=11&Target=11.6

[5] UN Habitat. 2021. Waste Wise Cities Tool. Available online: https://unhabitat.org/wwc-tool. This Handbook focuses on collected waste characterization which corresponds with WaCT Step 6: Waste Composition at Disposal Facilities by focusing primarily on the composition of waste at disposal facilities.

[6] UN Habitat. 2021. Waste Wise Cities Tool (WaCT). Available online: https://unhabitat.org/wwc-tool

1.2 What Information Does Waste Characterization Provide?

Waste characterization studies identify the specific types of materials in a waste stream. The number of waste types identified and measured depends on the goals and objectives of the study, but typical studies identify between 15 and 70 different materials or products.

Waste samples are sorted according to these material or product types, and the weights of the sorted materials are used to calculate the proportion of each material or product category in each waste sample. This information from sampling MSW is then used to develop an estimated average waste composition for a specific facility, neighborhood, city, or a specific waste stream.

1.3 How Can Waste Characterization Information be Used?

The data collected from a waste characterization study can be used in many ways, including:

1.3.1 Establishing Baseline Waste Management Conditions

Waste characterization studies can help cities understand baseline conditions, which is necessary to measure the progress of existing solid waste programs and understand their effectiveness or impact. Waste characterization studies provide information on the current waste management system, such as diversion and disposal conditions, which can be used to establish goals for reducing or diverting waste.

1.3.2 Developing Reduction and Diversion Strategies

Waste characterization studies provide important data on what materials or products are most prevalent in the waste stream, and thus the most promising targets for waste reduction or diversion strategies.

For example, a study might reveal that textiles comprise a significant portion of the waste stream, which could identify an opportunity to develop a clothing or textiles reuse or donation program. Similarly, if polystyrene (used in disposable coffee cups and cutlery) is identified to be prevalent in the waste stream and no opportunities exist for recycling this plastic, the local government might consider encouraging or requiring food establishments and other businesses to substitute polystyrene with another material or product that can be reused, recycled, or composted.

1.3.3 Selecting Waste Processing and Management Technologies to Reduce Greenhouse Gas Emissions

The composition of the waste stream is one of the most important factors to consider when selecting the mix of programs and technologies to manage a community's solid waste, specifically helping cities plan for and decide on technology, project sizing, and capacity.

Understanding the composition of the waste stream can help waste professionals select new technologies to manage solid waste more efficiently. For example, cities with a high proportion of organic material in the waste stream (e.g., food scraps and yard waste) can focus their efforts on capturing and diverting organic waste to composting or anaerobic digestion projects. The

composition of organic material available for diversion would influence the selection of anaerobic digestion technology (i.e., wet or dry) or the composting system (e.g., in-vessel, windrow, aerated static pile).

Understanding the types and quantities of waste disposed in an area can help solid waste professionals plan for the **proper capacity** of a waste diversion or disposal facility. In addition, estimating the fraction of organic or recyclable waste that can be diverted from a landfill allows waste professionals to make better projections on a landfill's estimated lifespan, may help them decide on the feasibility of establishing centralized or decentralized materials recovery facilities (MRFs), and can identify end-market linkages for the sale or donation of materials.

Using the waste characterization study data in existing GMI tools improves the accuracy of results and can help decision makers better understand organic waste management and methane mitigation options. For example:

- Data on the average composition of collected waste (e.g., food waste, paper, cardboard, textiles, plastic) can be entered into the Solid Waste Emissions Estimation Tool (SWEET) to understand the emissions impacts of various management strategies and technologies (e.g., composting, anaerobic digestion (AD), waste combustion, recycling).[7]
- Data on specific organic waste types and quantities (e.g., mixed food waste, coffee grounds, bananas) can be entered into the Anaerobic Digestion (AD) Screening Tool to assess AD project feasibility.[8] The AD Screening Tool outputs include annual biogas and digestate production, methane emissions reductions, and potential end uses of biogas.
- Data on the annual disposal rate (metric tons/year) of a city or community can be input into the Landfill Gas (LFG) Screening Tool.[9] The tool provides an estimate of how much LFG can be collected at a dumpsite or landfill and provides initial recommendations on whether that fuel supply is likely sufficient to support a modest-sized LFG energy (LFGE) project. LFGE project types include combusting LFG directly to produce heat (e.g., for industrial applications), using LFG to generate electricity, and – in some cases – converting LFG into compressed natural gas (CNG) to fuel vehicles.

If a waste characterization study identifies portions of the waste stream with high energy value, the data can be used to help size waste-to-energy facilities, where residual waste is incinerated to

[7] The Solid Waste Emissions Estimate Tool (SWEET) was developed by the U.S. EPA on behalf of GMI. SWEET is an open access Excel-based tool that quantifies emissions of methane, black carbon, and other pollutants from sources in the municipal solid waste sector. The tool provides emissions and emissions reduction estimates at the project-, source-, and municipality-level.

[8] The Anaerobic Digestion (AD) Screening Tool was developed by the U.S. Environmental Protection Agency (EPA) on behalf of GMI. The AD Screening Tool enables users to conduct pre-feasibility analyses to evaluate AD opportunities for a variety of feedstocks, including organic municipal solid waste, livestock manure, agricultural residues, and wastewater.

[9] The Landfill Gas (LFG) Screening Tool was developed by the U.S. Environmental Protection Agency (EPA) on behalf of GMI. The LFG Screening Tool assist cities in assessing the potential feasibility of a landfill gas energy (LFGE) project based on five data inputs.

generate electricity. Each material component of a waste stream has a specific calorific value (i.e., the amount of heat the material releases when combusted) and moisture content. These individual calorific values, multiplied by the quantity of each waste component, can then be summed together to estimate the overall energy value of the waste stream. After completing a waste characterization, the study team may consider additional analysis for moisture content and calorific value by an accredited laboratory. For more information on waste-to-energy, see the United Nations Waste to Energy Considerations for Informed Decision-Making.

1.3.4 Understanding Contamination of Recyclables and Organic Materials

Waste characterization data can be used to assess the types and levels of contamination in recyclable or compostable material streams. This is important because recycling and composting facilities typically have stringent requirements on the quality of materials that can be accepted. Facilities often require customers (e.g., local governments) to demonstrate that the materials collected or otherwise delivered to the facility meet the facility's quality standards.

During a waste characterization study, samples of source-separated recyclable or compostable materials can be selected and sorted into different categories, usually "acceptable [for recovery and recycling]" and "contaminated" materials. Additionally, it is beneficial in these studies to identify the most common materials or products contaminating the recyclable or compostable material streams. Using information on the most common contaminants, cities can design targeted public education and outreach programs that identify those materials and products as not acceptable in recycling and composting programs.

1.3.5 Evaluating and Improving Programs

Waste characterization studies are used to understand the success of existing waste diversion programs. For example, waste characterization studies can identify the types and quantities of recyclable materials and products still being disposed in the municipal waste stream that should – ideally – be diverted through recycling efforts. Local decision-makers can use this information to enhance their outreach to households about recycling requirements, or design new programs to create incentives for recycling certain materials and products.

2. Planning and Study Design

Proper planning is essential for a successful waste characterization study. This section describes the different waste characterization studies that solid waste professionals may conduct, including important design parameters, and sampling plan design. The study goals and objectives will influence how these considerations are addressed in the study's planning phase.

Standards for conducting waste characterization studies provide guidance on how to obtain reliable data. Many countries have established their own standards, and it is best to use the standard developed for the country or location, keeping in mind that some modifications may need to be made. If there are no local or regional standards, projects can consider using the technical standards developed by ASTM International[10], which is the standard used for waste characterization studies in the United States.

2.1 Define Study Goals and Objectives

Setting a clear goal and objective will provide the foundation for designing a study that produces the necessary information.

Example goals for different types of waste characterization studies include:

- Identify the composition of organic materials in the waste stream to assess possible opportunities, including but not limited to composting and anaerobic digestion.
- Quantify the types of recyclables that are in the waste stream.
- Assess the contamination rate of collected recyclables.

2.2 Determine Waste Generating Sectors and Types

Waste Control. In the planning stage, identify who has control of the waste materials generated in a community and how to access the waste from the collection, processing, recovery, and disposal stages of the solid waste system.

During various stages in the waste management process, several entities may have control of a community's waste. Residents may bring their waste to local centers for processing or transport to a disposal facility, or their waste may be collected by waste haulers or individuals. Individuals or organizations collecting or consolidating the waste are often different from the owner of the processing or disposal facility where the materials are taken, which requires coordination, an agreement, or permission to access the waste materials for sorting and characterization.

A local government commissioning a waste characterization study may need to approach the entity controlling the waste material (e.g., waste collector or landfill owner) to request support. Waste characterization teams can send a letter of introduction to provide project background and

[10] The ASTM International, Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste, D5231-92 (2016) is available for purchase online: https://www.astm.org/Standards/D5231.htm.

informed consent information when project teams request access to waste material for a characterization study. An example letter format can be found in Appendix C: Sample Letter of Introduction.

Waste Generating Sectors. The study goals and objectives determine what waste generating sectors are included as part of a study. Municipal solid waste is often described by sector and categorized as residential, commercial, or institutional, as described in Exhibit 2. Additionally, waste characterizations can analyze the composition of waste based on a multitude of factors. For example, waste composition from a low-income region may be compared to the waste composition of a high-income region.

Exhibit 2. Common Waste Generating Sectors

Sector	Description	Common Waste Types
Residential	Includes all types of households including single-family homes, apartments, and other formal and informal housing.	Organic wastes, textiles, paper, cardboard, glass, metals, plastics, and household hazardous waste, including paints, solvents, cleaning agents, batteries, and electronics.
Commercial	Includes office buildings, shopping malls, hotels, airports, restaurants, markets, and event venues (e.g., weddings, banquet halls).	Many commercial sources tend to have a high percentage of organic waste, especially food waste from event venues, restaurants, farmers' markets, and hotels. Offices and hotels tend to generate large quantities of paper, cardboard, plastic, and glass.
Institutional	Includes schools, medical facilities, and prisons.	Paper, organic wastes and food waste. Medical facilities and prisons may generate hazardous wastes, which should not be handled with municipal solid waste.

Waste Material and Product Types. The study goals and objectives determine what material and product types are targeted for sorting and separation. Experts caution against designating too many material types, as it often results in low quantities of several material types that can limit the data's usefulness.

Exhibit 3 provides an example list of material categories and types for use during waste characterization studies. Material and product categories do not have an agreed upon international definition or standardization. Exhibit 3 includes the most common material categories and was drafted to be closely aligned with the UN Habitat WaCT[11]. Users are encouraged to edit, remove, or create categories as necessary for their given local context and conditions.

[11] UN Habitat. 2021. Waste Wise Cities Tool (WaCT). Available online: https://unhabitat.org/wwc-tool

Exhibit 3. Material categories and types

Category	Material type	Examples
Organic waste or bio-waste[12]	Food waste[13]	Bones, meat, vegetables, breads, food scraps
	Yard waste or garden waste	Grass, grass clippings, bushes, shrubs, and clippings from bushes and shrubs
	Other organics	Cotton materials, towels, rags, compostable paper
Paper and Cardboard	Newspaper/print	Newspapers
	Mixed paper	Magazines, junk mail, paperboard, catalogs, phone books
	Compostable paper	Tissues, napkins, paper towels
	Corrugated cardboard	Packing/shipping boxes
	Office paper	Envelopes, copier paper, letterhead
	Wax-coated containers	Milk and juice cartons, shelf stable packaging including aseptic and gable top containers
Plastic – dense or rigid	Plastic containers and bottles (resin codes #1–7 and unidentified)	Yogurt cups, drink bottles (soda, water, milk), butter tubs, prescription pill bottles, detergent bottles
	Polystyrene	Expanded or regular clamshells, cutlery, cups
Plastic – film	Plastic film	Shopping/garbage bags, loose film, food packaging
Metal	Non-ferrous containers	Soda cans, beer cans
	Ferrous containers	Pet food cans, soup cans, aerosols
	Other scrap metal	Other ferrous and non-ferrous scrap metal
Glass	Clear glass	Clear glass drink bottles, jars
	Colored glass	Colored (green, brown, etc.) glass drink bottles, jars
Textiles, clothing, and shoes	Textiles, rubber, leather	Fabric, towels, rags, shoes, leather
Wood	Wood (processed and unprocessed)	Pallets, scrap wood
Other non-hazardous solid wastes	Sanitary items (non-hazardous)	Disposable diapers, rubber gloves, face masks
	Tires	Tires – heavy duty (heavy equipment), tires – light duty (passenger vehicles)
	Earthenware and ceramics	Dishes, cups
	Construction materials	Gravel, bricks, asphalt, concrete, dirt
	Fine residue	Small indistinguishable materials, usually 0–2 cm
	Other waste	Materials that do not fit any other category (e.g., Tetrapak)
Electronics	E-waste (electronics and electrical equipment)	Cell phones, computers, televisions
	Batteries	Lead-acid batteries, lithium-ion batteries
Hazardous	Hazardous materials and household hazardous waste	Paint, oils, solvents, other chemicals, sharp medical instruments, medical waste

[12] Organic waste and bio-waste may be used interchangeably. The European Union Waste Framework Directive defines bio-waste as *"biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plant."* For more information: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

[13] Food waste is used here to refer to both edible and inedible foods. The U.S. Environmental Protection Agency provides additional information on terms for food not used for its intended purposes and managed in a variety of ways. Learn more: https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics

2.3 Determine Study Location, Timing and Costs

This handbook primarily focuses on conducting waste characterization studies at a transfer station or disposal site (i.e., post-primary collection activities).

However, cities might choose to conduct studies at the point of generation (e.g., curbside sorting). This might be advisable in instances where the waste arriving at the transfer station or disposal site is likely to be mixed from different sources (e.g., residential, commercial). For additional study designs, including curbside sorting techniques, refer to the UN Habitat WaCT [14].

- Location. Selecting the location to conduct a study is an important part of planning. These studies often occur at solid waste facilities, where it can be challenging to find the appropriate space. The study location should be:
  - Close to where the waste materials are being disposed to facilitate sample selection and reduce transportation requirements, while minimizing the study's impact on daily facility operations.
  - Safe and comfortable for staff conducting the study, which includes avoiding contact with truck and heavy equipment traffic, reducing exposure to dust, equipment fumes, sun exposure, and other health hazards, and eliminating the need for staff to walk around the site to access washrooms.
- Timing. Plan a waste characterization study during daylight hours in well-ventilated spaces during times when unusual conditions or events will not influence the waste materials targeted for the study (e.g., large festivals or holiday celebrations that generate significant amounts of waste could affect the study, significant rain events may cause waste materials to be heavier than normal due to excess water weight).
- Duration. The number of fieldwork days should allow enough time to obtain and sort the targeted number of waste samples. For example, if waste collection occurs in different sections of a city five days a week, it would be important to sample and sort the waste for the five-day period to capture waste characterization details for all the areas. Waste generated from households fluctuates depending on weekdays and weekends. It is important to collect waste throughout an entire week to account for this fluctuation.
- Staffing. The availability of staff who have been trained to support the project is critical for success. Individuals need to be committed to carry out their roles and responsibilities for the length of the study. The project manager should try to keep the same staff for the study's duration to provide consistency with the material being sorted and reduce the need to train new staff, which can lengthen a study's timeframe. As feasible, informal sector workers may be recruited to assist as staff if they are active at the facility location.
- Costs. Consider location, timing, and staffing, as these factors may influence the overall cost of the study. Costs vary widely, however if similar studies have been done in nearby cities or

[14] UN Habitat. 2021. Waste Wise Cities Tool (WaCT). Available online: https://unhabitat.org/wwc-tool

regions, these may provide a starting estimate for planning purposes. It is also important to understand how the study will be funded, such as obtaining a grant or utilizing city funds.

2.4 Additional Considerations and Interviews

Factors such as mixed wastes and informal sector recycling can result in additional considerations for the waste sampling process. Where study managers lack existing data, brief interviews with truck drivers can refine study assumptions and provide anecdotal data.

2.4.1 Interviews

Waste haulers often collect multiple sources of waste simultaneously to minimize the amount of time they spend on their route and their costs. This can result in loads containing a mix of waste materials from different sources, thereby posing a challenge for waste characterization studies that seek to separately examine waste from different waste-generating sectors (e.g., residential vs. commercial).

Sampling and sorting mixed waste loads provides limited value, as waste characterization studies often aim to inform solid waste planning and diversion programs that are tailored to waste-generating sectors or sources. The sampling of mixed waste should be avoided whenever possible. In cases where mixed waste cannot be avoided, care should be taken when selecting waste samples. It is important to talk to the truck driver to determine if the waste from the targeted generating sector is isolated and can be obtained for sampling. Interviews can be conducted with drivers or with hauling company managers:

- Informal on-site. An informal interview with the truck driver on-site.
- Hauling company inquiry. An estimate of contracts by sector from a hauling company, derived either via interviews with fleet or contracts managers, or from existing contract data.

If there is concern or confusion about whether the waste designated for sampling represents the targeted waste stream, the waste samples should be discarded, and another waste sample should be obtained. In the study design phase, waste managers should address how the possibility of mixed waste will be handled during the sorting process. Appendix B provides example interview guides for reference.

2.4.2 Informal and Formal Sector Workers

Formal and informal sector workers often collect recyclable materials at waste disposal sites for recycling and reclamation purposes. The removal of recyclable materials by these workers affects the composition of the waste stream and can alter results from a waste characterization study when materials are removed from the waste stream prior to sampling.

Although each facility is different, formal and informal sector workers are often an integral part of facility operations, and the recyclables that are removed from the waste constitute local recycling efforts. If the study facility involves collection via the informal sector, consider opportunities to

consult existing informal worker associations during the study planning process, which could potentially include hiring informal workers as study sorting staff.

To ensure accurate data collection, waste characterization studies should aim to either:

- Conduct sampling prior to access by informal workers. Ensure study access to waste from truck to sorting location and sort the entire waste sample prior to informal sector access. Once data has been collected and recorded, waste characterization study teams can give the sorted materials to informal workers.
- Conduct sampling after sorting by informal workers. Sample and sort waste that has been searched by informal sector workers, which will provide a more accurate representation of the materials that are destined for disposal at the site. Be sure to include both the chosen recyclables (obtained from informal workers) and the remaining waste to obtain a full sample. Waste characterization study teams can interview or speak with informal workers to estimate the volume of waste diverted or recycled, the types of waste removed, and the average number of informal workers at a site.

2.4.3 Unaccounted or Additional Waste Streams

There are often some waste streams that are generated but not disposed of at the study disposal site (where waste characterization is occurring). For example, a private composting service may collect organic waste from wealthier households on a voluntary, paid basis. Additionally, in some areas, especially informal settlements and isolated rural areas, waste collection may be non-existent or overly expensive, which often results in illegal dumping and open disposal sites.

It is important to understand how additional collection efforts prior to disposal impact the volume of waste that may not be part of the waste characterization. This could affect results if unaccounted for in the waste characterization. This waste commonly accounts for a small percentage of the total waste stream being handled and may not require additional calculation but could be noted in the study as a data gap or limitation.

Estimating unaccounted waste can allow decision makers to account for it when planning MSW services and facility capacity. While this waste may be unaccounted for currently, it may be introduced into the routine waste streams in the future. For more information on estimating unaccounted waste, refer to the UN Habitat WaCT[15].

2.5 Develop Sampling Plan

Developing a waste sampling plan is an important component for fieldwork planning. Sampling plans vary by study but should at a minimum include information on the study location, waste quantity and sources, targeted number of samples by generating sector and/or material stream, schedule, and major hauler information.

[15] UN Habitat. 2021. Waste Wise Cities Tool (WaCT). Available online: https://unhabitat.org/wwc-tool

The sampling plan is a guide for selecting waste samples and represents the best-case scenario for sampling. However, conditions at the solid waste facility may require deviation from the sampling plan. The final sampling plan will determine staffing needs, discussed below in Section 0, and ensure the study has the required capacity to achieve the desired goals.

2.5.1 Study Location and Waste Received by Haulers

The sampling plan identifies the name of the facility or site where the waste sampling will occur, commonly referred to as the "host" facility.

The sampling plan should then identify the major haulers that deliver waste to the study location and the quantity of waste hauled by waste-generating sector (e.g., residential, commercial, institutional, others). The waste generating sectors targeted for the study will depend on the goals and objectives of the study.

The number of waste samples should be representative and proportional to the quantity of waste received at the study location or a particular site, which can be implemented using the following approach to first identify the waste-generating sector and then by the hauler of each waste generating sectors:

- Select by Waste-Generating Sector(s). Aim to obtain a distribution of waste samples from each waste-generating sector that is proportional to the quantity of waste the facility receives.
    - For example, if a facility receives 60 percent of its waste from residential generators and 40 percent from commercial generators, the number of samples should be proportional. If a total of 50 waste samples are to be sorted in this example, 30 samples should be residential waste and 20 samples commercial waste.
- Select by Hauler. Waste samples can be obtained from specific waste haulers in proportion to the amount of waste they deliver to the site.

    Building off the above example, if 50 percent of the residential waste is collected by Hauler A, then 15 of the 30 residential waste samples should be obtained from Hauler A. Samples should be collected from all the major haulers for each waste-generating sector.

2.5.2 Number of Samples and Schedule.

When choosing sample size, consider that:

- Sample sizes which are too small introduce bias and can lead to poor data quality and limited usefulness of findings.
- Sample sizes which are too large are expensive, time consuming, and potentially unnecessary to achieve similar data quality and results.

Not all studies need to have a large sample size to be useful and answer the desired questions. As one example, the UN Habitat's WaCT[16] suggests taking samples from three trucks per low, medium, and high-income levels for a total of 9 samples (50 to 70 kilograms each).

The number of days the study will take place and the targeted number of samples to obtain and sort each day for each waste-generating sector should be determined in advance.

Exhibit 4. Example Waste Sampling Plan

This Exhibit provides an example waste characterization study sampling plan that records total waste received and the breakdown of waste samples to be sorted by waste-generating sector (e.g., residential, commercial, institutional). The template captures the total waste received at a study location and breaks down this information by waste-generating sector (residential and commercial are used as examples) and by how the waste is transported (i.e., direct haul, transferred, other) to the study location. In this example sampling plan, the study team can also record the public and private haulers and the representative number of samples to sort from each hauler. The Waste Characterization Excel Tool can support the data collection and recording of samples in the 'Sampling Plan & Pre-Sort Weight' tab according to the sampling plan, once determined.

Example Sampling Plan for Waste Characterization – Study Location Name						
		Total Waste Received at the Study Location (tons)				
		Residential and Commercial Waste Received (tons)				
		Other Waste Received – Construction and Demolition (C&D), bulky, demo/clean-out waste (tons)				
		Number of Samples to be Sorted				
RESIDENTIAL			**COMMERCIAL**			**TOTAL**
%	Tons	Transportation Method	%	Tons	Transportation Method	Tons
		Direct Haul			Direct Haul	
		Transferred			Transferred	
		Other			Other	
100%		**TOTAL RESIDENTIAL**	**100%**		**TOTAL COMMERCIAL**	
		% Total			% Total	100%
SAMPLING PLAN						
		# of samples			**# of samples**	
		Direct Haul			Direct Haul	

[16] UN Habitat. 2021. Waste Wise Cities Tool (WaCT). Available online: https://unhabitat.org/wwc-tool

		Transferred			Transferred	
# of Samples	%	Major Haulers	# of Samples	%	Major Haulers	
	100%	**TOTAL**		**100%**	**TOTAL**	

3. Field Activities

Once the details of a waste characterization study are planned and all project partners agree on their roles in executing the study, the field activities can commence.

3.1 Conduct Project Team Training

Training the project team is an important first step before the data collection begins. The study should be managed by a solid waste professional experienced in waste characterization who will be onsite during all field activities. This individual is responsible for training the project team in carrying out their roles and responsibilities to execute the study. Project team training should include the following information:

- Health and safety
- Purpose and objectives of the project
- How to identify, select, and obtain waste samples
- Proper sorting techniques
- Material categories and types
- Protocols for weighing materials
- Disposal of sorted materials

In addition to project team training before the start of field activities, the project manager should encourage team members to ask questions and receive clarifications on project-related items throughout the fieldwork. This may take the form of preparatory meetings before starting work each day.

3.2 Consider Health and Safety of Project Team

Maintaining and protecting the health and safety of workers is of utmost importance and should be the first priority of the project team. The site manager should have a first aid kit and contact numbers and locations for immediate medical attention. Waste characterization studies are inherently dangerous, as project team members are exposed to potential hazards, including:

- Heavy Equipment and Truck Traffic. Many waste characterization studies occur at solid waste facilities. Solid waste collection vehicles and heavy-duty trucks continually traverse these sites while transporting waste materials. Heavy equipment, including bulldozers, backhoes, dump trucks, and excavators, are often used at these sites to process waste materials and prepare the site for waste disposal. Vehicle and equipment operators are often focused on their own work and may not be aware of waste characterization study activities occurring in proximity. Project team members should always stay visible and remain in designated work areas. If a team member needs to leave the designated work area at any time, the project manager should be notified.

- **Waste Materials.** The components of solid waste pose a significant risk to project team members. Sharp objects such as broken glass, nails, needles, and scrap metal can injure workers. Workers should be trained to use caution when handling waste materials.
- **Chemical and Toxic Substances.** Workers may encounter a variety of chemicals and other substances while sorting waste (e.g., poisons, flammable materials, oxidizers, corrosives, and other toxic compounds that can affect human health and the environment). Project team members should be trained to keep chemicals or unknown substances in containers and minimize their handling to reduce exposure risk. If team members have concerns about a particular chemical or substance discovered in the waste stream, they should notify the project manager to receive guidance on the appropriate course of action.
- **Weather Conditions.** These studies often occur outdoors or in facilities that do not have climate control features. As a result, project team members can be exposed to extreme hot or cold conditions that may affect their health and safety. The impact can be magnified if workers are wearing personal protective equipment (PPE; discussed below) that interferes with the body's natural ability to cool or warm itself. Staff need to understand their limits working in hot and cold conditions. The project manager should continually observe workers, and immediately stop work to provide appropriate medical attention if unusual behavior or illness is detected.
- **Site Access.** In some locations, solid waste facilities have minimal site controls, which facilitates unrestricted access by informal sector workers. Informal sector workers that collect and sell recyclables and reusable materials from the waste stream may perceive the study as interfering with their livelihood or ability to earn money, which could create confusion if not properly explained. Project managers and facility representatives should meet with workers associations and individuals to explain the study and the potential for the informal sector to assist with data collection.
- **Animals.** Animals searching for food sources at a waste facility may become aggressive or pose health threats to workers. The project manager should discuss a plan with the facility representatives to address safety concerns. Site owners or representatives should provide a safe working environment.

Before the project team arrives in the field to conduct the waste characterization study, the project manager(s) or organizer(s) should develop a health and safety plan, which will be the basis for the training provided to the project team. This plan should identify all the potential hazards at the facility where field activities will occur and should include details on emergency response procedures and injury reporting. The plan should be reviewed by multiple individuals overseeing the study, as well as by solid waste facility staff. **Appendix A** provides a template for a waste characterization study health and safety plan.

Workers conducting waste characterization studies must also wear PPE. Exhibit 5 lists the PPE that should be required for all fieldwork where waste materials are hand-sorted. Depending on the facility where the fieldwork occurs, additional PPE may be required, which might include hard hats, hearing protection, coveralls, or dust masks. Project team members should be shown the proper

way to wear PPE and be required to always wear PPE while performing waste characterization study activities.

Exhibit 5. Required Personal Protective Equipment (PPE) for Waste Characterization Studies Where Materials are Hand-Sorted.

PPE	Purpose
Puncture-resistant gloves	Protects hands from cuts, abrasions, and punctures while handling waste materials; can be worn with rubber/latex gloves underneath to keep hands dry.
Safety glasses	Protects eyes from liquids and materials in the waste, as well as dust and other particles that may become airborne during sorting activities.
Head, body, and shoe covers	Protects body parts, hair, and clothing from cuts, abrasions, and punctures while handling waste materials; facilitates quick disposal of contaminated items should a spill occur. Keeps dust off of team members.
N95 and/or surgical masks	Protects team members from dust, fumes, and airborne contaminants contained in waste samples or occurring in broader work environment.
Reflective safety vests	Keeps project team members visible to facility staff and heavy-equipment operators.
Steel/composite toe boots or shoes	Protects feet from falling objects and provides additional support on uneven terrain.
Other	Insect repellent, hand sanitizers, soaps, etc.

3.3 Determine Staffing

Staffing needs for a waste characterization study will vary depending on the type and scale of study. The following staff are required:

- Project Manager. The project manager should be experienced with waste characterization studies and oversee the entire project's field activities, including quality assurance of the obtained data. This individual is the main point-of-contact for facility staff and handles emergency communication and first-aid needs.
- Sampling and Sorting Managers. This manager is responsible for selecting, obtaining, weighing, and transporting waste samples for sorting. This individual uses the sampling plan to obtain waste samples and is responsible for ensuring the correct waste is sorted. This manager is usually positioned near the entry point to the facility to oversee and select the trucks entering the facility whose waste will be sampled. This person oversees waste-sorting operations and must be familiar with the sorting protocol and the different material categories to be sorted. The manager is responsible for answering questions about material classification, providing quality

assurance for proper material sorting, recording weights of sorted materials, and keeping the datasheets in a secure place. Sampling and sorting managers are often two different people.

- Waste Sorters. Waste sorters physically handle the individual materials in the waste stream and place the materials into appropriate containers. The number of waste sorters needed depends on the scope of the project and the number of waste materials being segregated. Typical studies include four to six waste sorters. If feasible and desired, consider temporarily hiring informal sector waste workers from the area as waste sorters.
    - Note: Consider staffing two team members per waste sample per day, meaning that a team of six sorters can process three to four samples per day, depending on weather conditions and waste materials sorted. Therefore, a five-to-seven-day study with six sorters could likely achieve an estimated total of 15 to 28 samples (at 70 to 110 kg per sample, which results in approximately 1,000-3,000 kg total weight sorted).

It is important to ensure that at least one staff member (ideally both the project manager and sorting manager) speaks the primary local language(s) and dialect(s) fluently. At a minimum, it is crucial that all study team members can communicate effectively and respond to safety and sorting instructions.

3.4 Identify Equipment and Set Up Requirements

Proper equipment is necessary to safely and efficiently complete waste characterization study field activities, including:

- PPE. Protects workers from site- and waste-related hazards.
- Containers. Used to sort and weigh waste samples. Garbage cans or other containers of varying sizes (usually two or three different sizes) can be used. The quantity of containers needed depends on the number of waste materials to be sorted. Assign a unique identifier to each container, and record its tare (i.e., empty) weight before placing waste in it. Containers should be of high quality with no holes or cracks or handles missing.
- Sort Table. Provides a platform for carrying out the waste-sorting activities. This table should be approximately 1 x 2 meters in size or larger and capable of supporting at least 50 kilograms of waste, but ideally up to 100 kilograms. It can be made from several different types of materials, such as wood panels, plastic, or wire mesh screens.
- Supporting Structure or Barrels. Basic support structures can be used to elevate the sort table, which should be approximately 1 to 1.5 meters above the ground or floor to facilitate ease of sorting. Many objects (e.g., steel drums, garbage cans, wooden stands or 'sawhorses') can be used. Two to four sawhorses or barrels are needed to adequately support the sort table.
- Scales. Two scales, each with a capacity to weigh up to 110 kilograms, are recommended for a waste characterization study. Scales should be portable, heavy-duty or industrial, and calibrated according to the manufacturer's recommendations.
- Tools. Various tools such as shovels, sticks, brooms, and tarps are needed. Shovels and sticks can be used to obtain waste sample materials and minimize handling. Brooms are necessary to

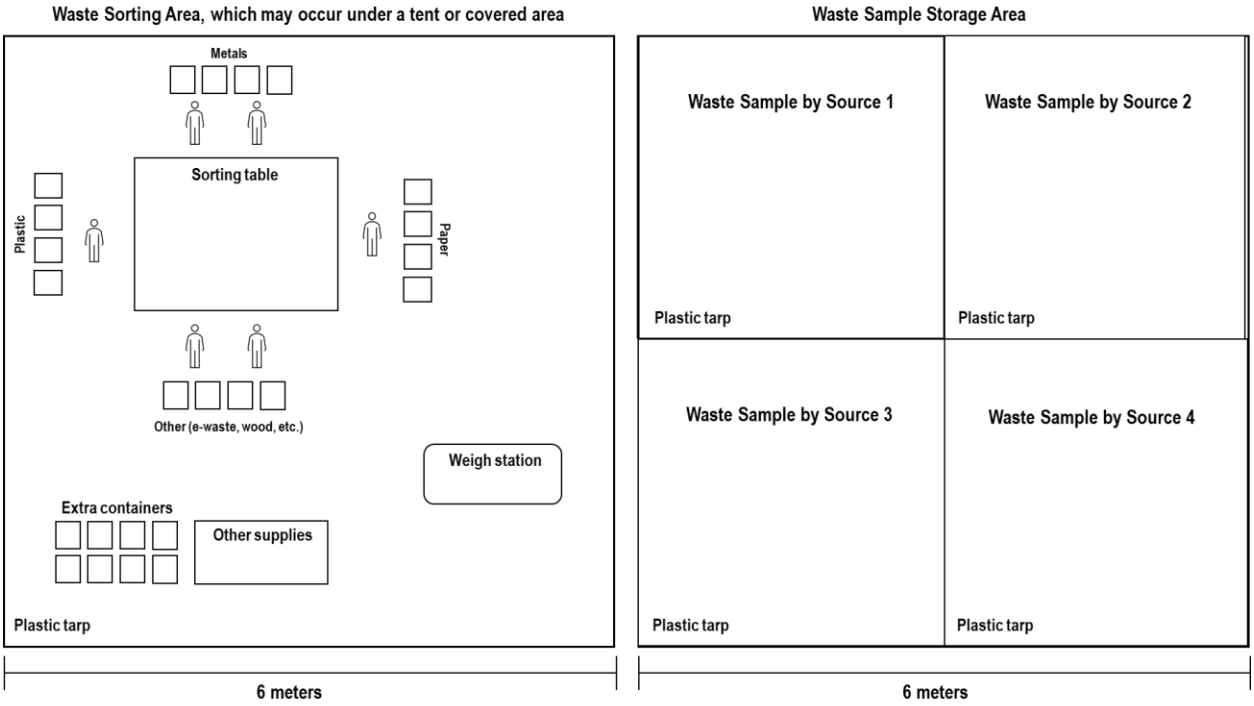
maintain a clean and clutter-free work area. Tarps are used to cover waste materials to prevent exposure to the elements. Other tools may also be required.

- Covering or Tent. A covering or tent is needed if the waste characterization study is not conducted in a building to protect project team members from weather elements and keep waste materials from getting wet during precipitation events. A tent or canopy that is fully or partially enclosed may be necessary if windy conditions are encountered.
- Fans or Lights. If the waste characterization is not conducted in a building, fans and/or lights might also be needed to make the workspace more comfortable for the team members.
- Waste Sample Records. Waste sample records are used to record and track field data. Typically, there is one waste sample record for each sample of waste sorted. It is important to keep the documents in a secure place until the data can be electronically uploaded. Alternatively, field data may be recorded directly on an electronic device.
- Access to Washroom. Project team members need safe access to a washroom with soap to wash their hands. In many cases the facility where the study is occurring provides access to a washroom. If access is not available, a portable toilet and washroom should be rented and brought to the study location.
- Photography equipment: Capture images of the sampling and sorting processes to document the project. These photographs serve as visual evidence depicting the waste samples and their distinctive features. They play a crucial role in effectively communicating findings to stakeholders, policymakers, and the general public.

Sorting Site Setup

Exhibit 6 contains a diagram of one potential waste characterization site layout with necessary equipment and space requirements. During the study, waste samples are organized by source (right side of the layout) and then sorted by material category and type. To sort the waste samples (left side of the layout), team members will open bags of waste on the sorting table and sort materials into their labeled bins (e.g., plastic, paper, organics). Team members can either sort for a specific material, pulling out all plastics from the bags, or each team member can sort a specific sample and put each material type into its respective bin.

Exhibit 6. Site Layout and Space Requirements



3.5 Select and Weigh Unsorted Waste Samples

Selecting the "correct" waste sample for sorting is the first step in preserving the data quality. The sampling manager is principally responsible for this portion of the study. This individual uses the sampling plan as the guide for selecting waste vehicles as they enter the facility. Additional information on using the waste characterization Excel tool for sample data collection is described in 4.1 The sample selection and weighing procedure includes the following steps:

- Identify Potential Trucks for Waste Sampling. Identify trucks carrying loads of waste entering the solid waste facility and note the name of the hauler, truck number, and type of truck. Using the sampling plan, the sampling manager will decide whether the truck may have waste that is appropriate for sampling.
- Interview Driver. In a safe location, motion for the truck driver to stop and conduct a brief interview to obtain details on the waste contained in the vehicle. If the truck has waste that is targeted for sampling, record the following information on a waste sample record: hauler name, truck number, type of waste, and collection location. Appendix B has a sample driver interview form for reference. Direct the truck driver to a safe location to unload the waste for further screening and sampling. Always ensure that the unloading and sampling location is completely clear prior to emptying the truck to avoid injury. It is advisable to select a sampling location that is both safe and in close proximity to the waste processing or disposal area of the facility. This facilitates the transfer of waste not intended for sampling and ensures efficient facility operations while minimizing waste handling.

- **Physically Inspect the Waste.** The sampling manager should request that the driver or facility workers unload the waste from the truck in an elongated pile to facilitate complete inspection of the waste. Once the waste is unloaded from the truck, observe the waste materials, and note any unusual characteristics. The sampling manager will determine whether a sample is pulled from the waste materials. If there is confusion or uncertainty about the waste and its source, it is best to avoid sampling the materials and select another truck.
- **Select and Obtain Sample.** Select a random location in the waste pile where the sample is to be obtained. The waste pile can be visually divided into quarters or sixths to randomly select which segment will be used as the sample. Shovel all waste materials into containers without screening the materials, except for large or bulky items. Large or bulky items should be avoided to prevent skewing the waste data. Information on other sampling methods, including the "Quartering Technique", where larger amounts of waste are mixed and reduced into one blended sample, is available in Section 6.2 of UN Habitat's WaCT[17], or the waste study standards developed by ASTM International.[18.]
- **Weigh Sample.** Weigh the containers holding the waste sample to confirm there is at least 90 to 110 kilograms of waste. Be sure to subtract the weight of the container when calculating the sample weight.
  - **Note:** Use the accompanying waste characterization Excel tool to record container tare weights and sample weights in the 'Tare Weights' tab before sorting. The tool allows study team members to record the source category and waste collection location or hauler with each waste sample.
- **Label Sample.** Label samples and containers to track which containers correspond to each waste sample. This can be done with tape, spray paint, or marker pens. Keep containers of waste for each sample source together, as shown in Exhibit 6.
- **Transport Sample.** Transport samples to the sorting location. If the sorting location is far from the sampling location, a vehicle will be necessary. Coordinate with facility manager for transportation, if possible.

Repeat this process until all waste samples have been obtained for the day. Additional waste samples for the following day may be obtained and held overnight, depending on the facility.

3.6 Sort and Weigh Waste Samples

Systematic instructions for hand-sorting waste materials include:

1. **Place Waste on the Sort Table.** Unload containers of waste samples on the sorting table. Take care to avoid spilling waste materials on the ground or overloading the sorting table.

[17] UN Habitat. 2021. Waste Wise Cities Tool (WaCT). Available online: https://unhabitat.org/wwc-tool

[18] The ASTM International, Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste, D5231-92 (2016) is available for purchase online: https://www.astm.org/Standards/D5231.htm.

2. **Identify and Separate Waste.** Open the bags of waste and separate the individual materials from one another. Separate composite items to the extent possible (e.g., food should be separated from its packaging).
3. **Sort Waste Materials.** Place segregated waste materials in a designated container; each different material should have a separate container. Use only one container for each material type. Waste sorters should pass materials among themselves as necessary to properly sort the waste. Workers should be discouraged from throwing materials across the sort table.
    a. **Note:** If the waste samples can be sorted into the sorting containers without needing to weigh containers during the sort, repeat Steps 1-3 until all waste from a sample has been sorted and characterized.
4. **Recover Fines.** Small amounts of materials are indistinguishable from one another and cannot be individually characterized for each sample; these materials can be characterized as "fines." Sweep these materials off the sort table and collect them for weighing. If using a fine wire mesh screen tabletop, ensure collection under the table. Weigh the collected fine materials separately, as they are still a part of the sample.
5. **Weigh Sorted Waste Materials.** Place containers of segregated materials near the scale for weighing. Separately weigh each individual container of materials and record the results on the waste sample record. Be sure to also record the unique container identifier so that the proper tare weight of the container can be subtracted from the recorded weight during the data analysis.
    a. **Note:** Use the accompanying waste characterization Excel tool to record container tare weights and material weights during the study ('Record Sort Data' tabs).
6. **Review Waste Sample Record.** After all segregated materials have been weighed and the results recorded on the waste sample record, review the form for completeness. This includes verifying that all weights are properly recorded and readable, and all waste sample identifiers (i.e., hauler name or source of the waste) are included.
7. **Dispose of Waste Materials.** Properly dispose of all sorted waste materials, which may include placing recyclable materials into a designated recycling container for recovery by informal or formal workers at the site. A suitable vehicle for transporting the waste will need to be borrowed from the site or otherwise obtained. The project manager should coordinate with site staff to request pickup, or schedule drop off, of waste materials as preferred and required by the site.

Repeat these steps for each waste sample sorted as part of the waste characterization study.

4. Data and Results

4.1 Data Analysis – GMI Waste Characterization Tool

Once the field data has been obtained and recorded, the waste sort records can be analyzed. If the study team used hand-written data collection forms, transcribe this data into an electronic format for further data analysis (e.g., Microsoft Excel). For example, hand-written waste sort records can be added into the accompanying waste characterization Excel tool for further analysis.

This section describes the data analysis process using the accompanying waste characterization Excel tool. In the Excel tool, the data are organized using consistent source and material categories to develop detailed waste characterization profiles of different waste streams. For example, if a study's objective is to develop waste characterization profiles for both residential and commercial waste streams, the data will be organized and analyzed accordingly. If the study characterized waste from high- and low-income areas, the team could write in this information in the section for notes during data collection.

The GMI waste characterization tool assists users with each phase of a study, and includes:

- Definitions: This tab defines terminology and abbreviations used in the tool, a table of units of measurement, and a table identifying waste types and example materials for each type.
- Site and Staff Requirements: This tab includes information on staffing and site requirements.
- Supplies: This tab includes a list of supplies necessary for the study.
- Tare Weights: This tab includes a table to enter the tare weight of each container used in the study.
- Sampling Plan & Pre-Sort Weight: This tab identifies and tracks the different waste haulers that will be engaged for the study.
- Record Sort Data: This tab includes the main table for recording waste sort data during the study. To accommodate multiple study days, this tab has been repeated for up to five days.
- Data Analysis: This tab provides a summary analysis of the waste sort data.

4.2 Essential Data Analysis Concepts

If using a different method or a blank Excel file to analyze data, the following metrics and methods describe how to calculate key data:

- Calculate the total weight of all samples weighed before sorting.
- Remove container weight (tare weight). For each container of waste weighed, subtract the container weight (tare weight) from the total amount. This amount will be the weight of the material sampled.
- Find total material weights. Sum the individual material weights to obtain the total weight of each waste sample.
- Find total weight of all samples. Sum all the total material weights to obtain the total weight of the sampled material.

- **Calculate percent composition.** Convert each material weight into a percentage by dividing the individual weight by the total weight. Complete this calculation for all waste samples in a waste-generating sector.
- **Calculate the average composition.** For each material in the waste stream, take the percent composition from each material type from all waste samples in a waste-generating sector and average them. The percentages from each material type should sum to 100 percent.
- **Develop an overall waste composition for a community**. Weight the waste composition for each generating sector. For example, if a landfill receives 60 percent of its waste from high-income neighborhoods and 40 percent from low-income neighborhoods, the waste composition percentages for each should be weighted (i.e., multiplied) by 60 percent and 40 percent, respectively, to develop an overall waste characterization profile for the landfill.
- A basic statistical analysis can also be performed, including calculating the standard deviation, and the upper and lower confidence intervals for each material type.

4.3 Example Data Analysis Using the Tool

The example charts below were generated using the GMI waste characterization Excel tool and illustrate the results of a five-day waste characterization study which collected 16 samples, primarily from household MSW containing large amounts of metals, glass, and organics. The analysis is designed to automatically create tables and charts of waste weight by material type and source, providing users with a quick overview of study results.

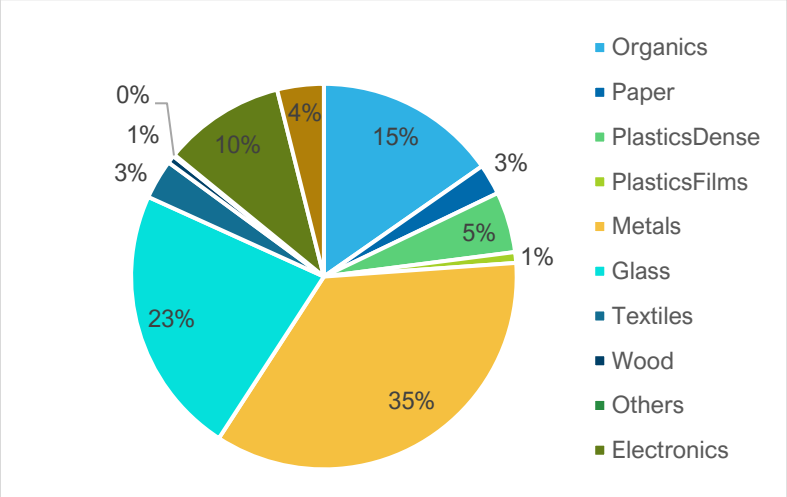


Figure 1: Sample Composition by Waste Type

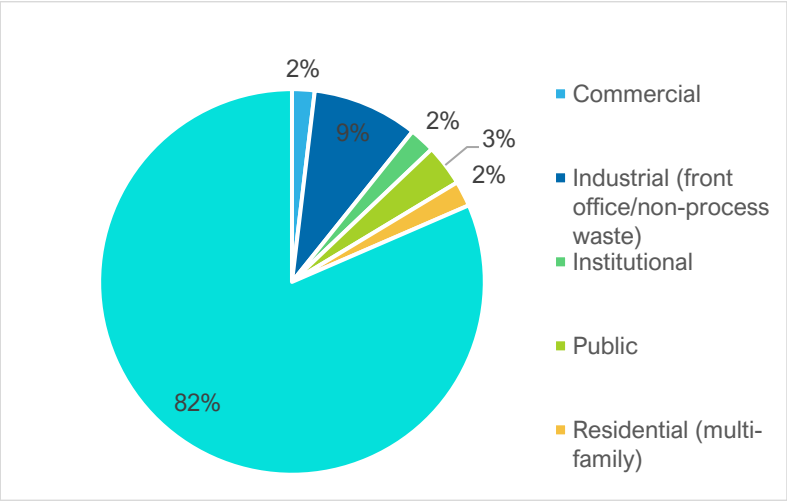


Figure 2: Sample Composition by Source

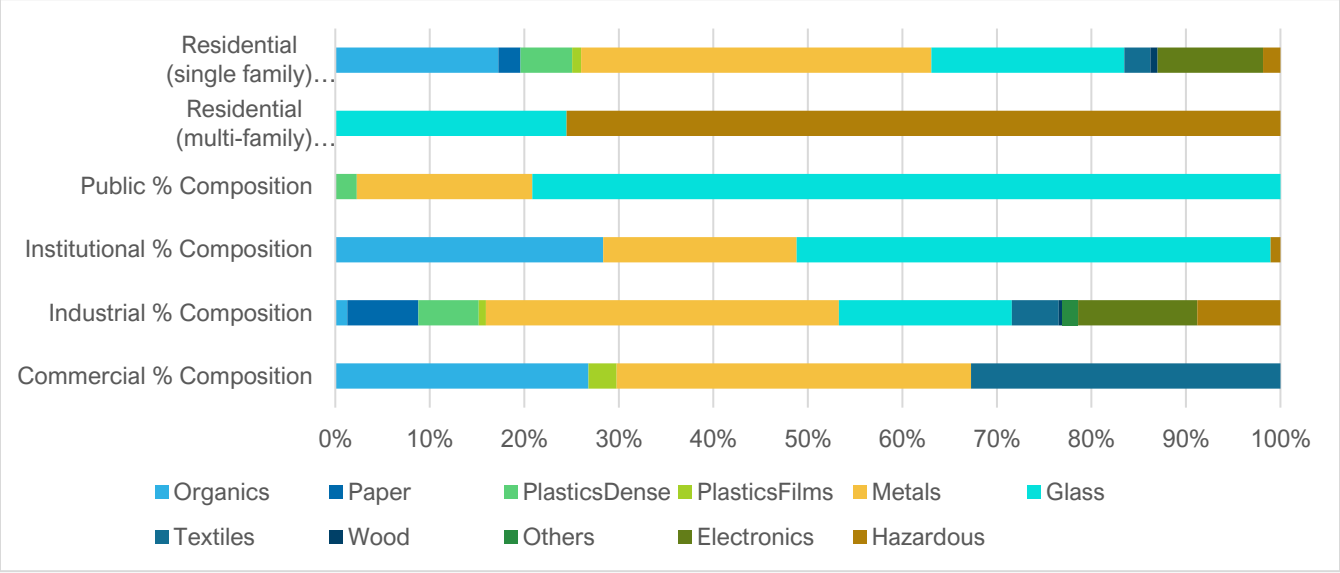


Figure 3: Sample Composition by Waste Type and Source

4.4 Data Use

Waste characterization data can be used in several ways, depending on the study's goal and objectives. In many cases, these studies are used to inform the design of programs and policies to divert waste materials from disposal.

The data can help identify what types and quantities of recyclable and compostable materials are being disposed, which can help evaluate the level of success of current programs or policies or identify the need for a new or expanded program to divert more materials.

As previously discussed, the main opportunities for using waste characterization include:

- Establishing baseline waste management conditions.
- Developing diversion strategies.
- Planning facilities and selecting waste processing and management technologies that offer greenhouse gas emission reductions.
- Understanding recyclable or compostable contamination.
- Evaluating and improving programs.

While data from a waste characterization study can provide valuable information to inform solid waste program and policy decisions, additional information and studies may be required to make a more informed decision. There are other GMI tools and resources that project teams and decision makers can use to provide further insight such as:

- The Solid Waste Emissions Estimation Tool (SWEET) to understand the potential emissions reductions from various waste management scenarios.
- The Anaerobic Digestion (AD) Screening Tool to understand if specific organic feedstock could support an AD project.
- The Landfill Gas (LFG) Screening Tool to estimate how much landfill gas a site may produce and if the supply could support landfill gas to energy projects.

5. Case Studies

5.1 Naucalpan, Mexico

In 2017, the United States Environmental Protection Agency – on behalf of the Climate and Clean Air Coalition Waste Initiative – conducted a waste characterization study in Naucalpan, a suburb of Mexico City. The study was designed to help the city find solutions to several solid waste management challenges it currently faces.

5.1.1 Study Objectives

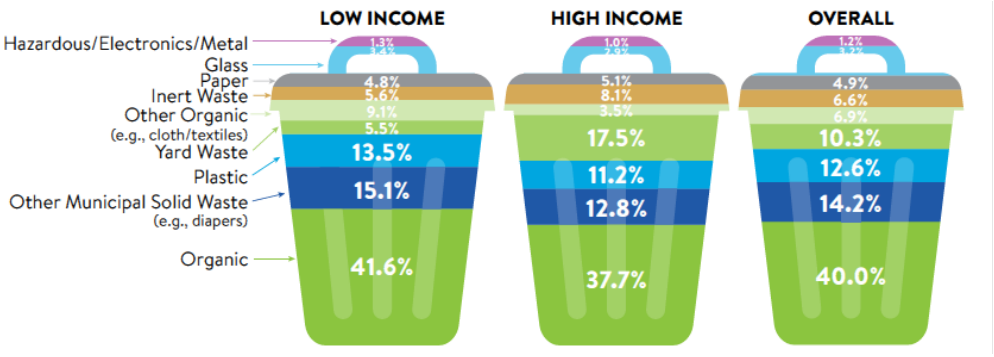
Naucalpan does not have its own disposal site and transports large quantities of waste to other localities, which consumes a significant amount of fuel and resources. In addition, Naucalpan does not have a systematic means of separating and treating organic waste, which accounts for a substantial fraction of the overall waste stream. This organic content, which could be recovered and used to benefit Naucalpan, is included in the waste that is transported to distant landfills. To help address these challenges, Naucalpan was considering constructing a mechanical and biological treatment facility, including an anaerobic digester to treat organic waste. The biogas recovered from the digester would be used to generate electricity. Before undertaking this venture, however, the city needed to obtain high-quality data about their waste stream to understand system viability.

5.1.2 Study Design and Results

The study was conducted in March 2017 at Naucalpan's transfer station. Waste samples were analyzed from high- and low-income areas of the city. The study indicated that approximately 69 percent of the waste handled at the transfer station could be recycled or otherwise diverted from the landfill, and that more than half of the waste could be used as feedstock in composting or anaerobic digestion projects. The city is using this study's results to inform decision-making about the mechanical and biological treatment project's design and procurement options.

Exhibit 7 shows the different compositions from waste streams collected from high-income neighborhoods compared to low-income neighborhoods. For more information, see the Climate and Clean Air Coalition's webpage on analyzing the waste stream in Naucalpan.

Exhibit 7. Composition of Waste from High- and Low-Income Neighborhoods in Naucalpan, Mexico



5.2 Gurugram, India

In 2019, the Municipal Corporation of Gurugram, India worked with a team of experts from the United States Environmental Protection Agency to conduct a waste characterization study. The study was designed to capture detailed information on the types of waste received at the Bhandwari landfill, which receives waste from the twin cities of Gurugram and Faridabad.

5.2.1 Study Objectives

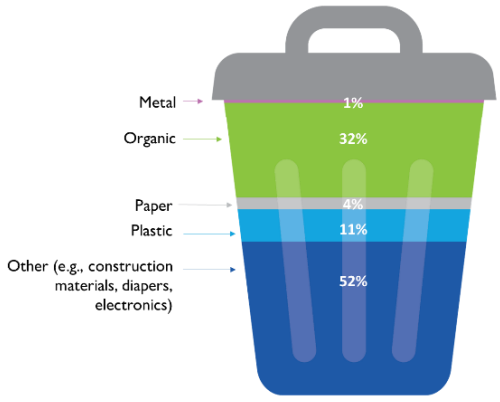
In addition to establishing a baseline of waste composition in Old and New Gurugram, the study had two other goals. While previous studies provided information on waste at the point of generation from cities around India, no information was available concerning the composition of waste that is ultimately disposed of. This is an important distinction in India (as in many countries), where the informal sector removes a considerable amount of recyclable material from the waste stream between the point of generation and the point of disposal. Because this study focused on waste at the landfill, the results showed the composition of waste after informal sector collection.

Moreover, the Municipal Corporation of Gurugram had plans to develop a waste-to-energy facility at the Bhandwari landfill. The waste characterization study was designed to help evaluate the energy potential of waste being delivered to the site.

5.2.2 Study Design and Results

The study was conducted over a five-day period in April 2019 and focused on sorting 30 samples from Old and New Gurugram into six broad categories of waste, shown in Exhibit 8. The six broad categories of waste included 35 sub-categories of waste which were recorded during the sort. The team hired science and engineering students interested in the solid waste sector from local universities to conduct the characterization. As such, the study served as a training opportunity for students who might lead waste characterization studies in the future. The urban local bodies (ULB) provided a sorting shed and collection vehicle used for transporting waste to the study site.

Exhibit 8. Composition of Waste at Point of Disposal in Gurugram, India



The study highlights the fact that Gurugram would benefit from implementing dedicated organic waste diversion strategies. At present, 32 percent of the waste disposed of at the landfill is organic. Currently, the city is asking bulk waste generators, including high-rise residential buildings, to manage their own organic waste, which has led to entrepreneurs approaching residential welfare associations throughout the city with solutions to help them manage their wet waste.

In addition, the study revealed that the fraction of waste disposed of that could be combusted in the proposed waste-to-energy facility is quite low. This will be an important piece of information for the city to consider when evaluating options for future waste-to-energy feedstocks.

Appendix A: Health and Safety Plan

Waste characterization is a process used to understand the types and amounts of waste in each waste stream. This understanding can help decision-makers plan effective waste management projects, programs, and policies, which in turn helps generate a range of environmental, health, and economic benefits.

Developing waste management projects, programs, and policies without a clear understanding of the waste stream can lead to numerous problems, ranging from sub-optimal operations to project failure. The following pages in the appendix serve as an outline for a health and safety plan adapted from an actual health and safety plan developed for a waste characterization study conducted by the U.S. Environmental Protection Agency with SCS Engineers.

The text in the following appendix is organized with **bolded text headings** that highlight the type of information a study team should include in a health and safety plan and *italicized text* that can be used as a basis for filling in the health and safety plan content.

- Bulleted text **Acknowledgement page** where staff should sign to confirm they have read and understand the health and safety plan
- **Introduction,** including project organization and scope of work
- **Site Description**
- **Emergency Response and Medical Treatment Procedures**
  - Emergency Contact and Notification Information
  - Accident or Incident Reporting System
  - Notification Procedures for Incidents
  - Methods to Summon Emergency Response Team
  - Rescue and Medical Treatment Requirements
- **General Field Safety Procedures**
  - Applicable Standard Operating Procedures (SOPs) and Programs
  - Job Task Safety Analysis (JTSA) and PPE Assessment
  - Site Control
  - Decontamination Procedures
  - Handling of Hazardous Waste Materials
  - Housekeeping Requirements
- **Site Hazards**
  - Chemical and Physical Agent Hazards
  - Physical Hazards
  - Biological Hazards

ACKNOWLEDGEMENT PAGE

"I have read the attached Health and Safety Plan for the Waste Characterization Study on _____<insert date(s)>. I have discussed any questions and/or concerns that I have regarding the contents of this document with the designated project safety representative, and I understand its requirements.

I understand that failure to comply with safety regulations, the Health and Safety Plan, failure to use safety equipment, or wandering outside of the area designated by the project manager shall be grounds for immediate dismissal.

I consent to the use of my image and likeness in photographs or communications materials, to be used for study purposes exclusively. I acknowledge that all information, data, and photographs are the intellectual property of this study and may not be divulged for any other purposes or to any other entity."

Name	Signature	Company	Date

1. INTRODUCTION

This Site-Specific Health and Safety Plan (SSHSP) provides information to identify hazards that may be present and/or introduced by project's activities on job sites, and details needed precautions that employees should follow to protect themselves. Tasks performed on site or during projects should be analyzed to determine if physical or chemical hazards requiring safeguards or additional personal protective equipment (PPE) exist. This plan will be modified as necessary if any new hazards are identified during the project that require that additional safeguards be put in place.

1.1. PROJECT ORGANIZATION AND CONTACT INFORMATION

Project Manager	*Name*	*Phone and email*
Sampling and Sorting Manager	*Name*	*Phone and email*

1.2. SCOPE OF WORK

Waste characterization involves collecting field samples and sorting municipal solid waste into designated categories. The data generated from the field activities will be compiled and presented in a report. There have been no reported serious or fatal incidents attributed specifically to the performance of waste characterization studies. However, accidents may occur due to the potential hazards associated with the presence of heavy equipment at the site, the components of the waste itself (e.g., potentially sharp objects, broken glass), and climatic conditions.

At landfills and transfer stations, combustion of the waste materials at the working face or in "hot loads" from refuse vehicles can present potential hazards. The presence of heavy equipment in operation at the site (end loaders, graders, transfer station compactors, garbage trucks, etc.) presents potential hazards, which can be avoided by increasing situational awareness and staying visible.

The equipment operators generally are involved in performing their tasks and may be unaware of the presence of other individuals within the immediate area. Personnel will be trained to be always aware of the movement and location of equipment. High-visibility safety vests must always be worn. The components of municipal solid waste present potential physical hazards. These include, but are not limited to, cuts from broken glass and sharp metal objects; splinters from pieces of wood; punctures from nails and other sharp objects; and scrapes and abrasions from the general handling of solid waste. There is also potential for exposure to household products, such as bleach, cleansers, and other toxic chemicals.

To alleviate the possibility of injury, caution should always be employed when physically handling the solid waste. Protective clothing, including gloves and safety glasses, should always be worn. If there is any question about the handling of a component of solid waste, the project manager should be notified. The waste characterization will be performed outdoors and not in a climate-controlled area. Caution should be

taken to avoid the possibility of heat stress due to protective clothing or weather, or frostbite in areas of extreme cold.

Refuse deposited at the transfer station can pose a potential fire hazard. Fires can be started through carelessness, sparks, or from "hot loads" handled at the refuse facilities. If fire or smoke is observed, transfer station personnel should be notified immediately, all personnel should leave the immediate area at once, and the local emergency fire department should be notified.

2. SITE DESCRIPTION

The facility is located at _____<insert address and location details>_ .

The project will be conducting fieldwork at the _____<insert instructions to the location within the facility where the sort will occur>.

3. EMERGENCY RESPONSE AND MEDICAL TREATMENT PROCEDURES

3.1. Emergency Contact and Notification Information

This section can include a screenshot of a map, route information, and contact information to the closest hospital or emergency response location.

3.2. Accident or Incident Reporting System. Sample language includes:

In the event of an emergency at the site, project personnel should call _____<insert contact> for emergency assistance. After the immediate emergency situation has been addressed by emergency personnel, project personnel should call the project manager and inform them of the situation. The project manager should evaluate the nature of the emergency and direct project personnel actions from that point.

3.3. Notification Procedures for Incidents

Site personnel should contact their supervisor immediately when an accident or injury occurs and provide any needed information so that additional notifications can be determined and completed as needed.

3.4. Methods to Reach Emergency Response Team

Emergency services can be reached through _____<insert emergency call information>, as this service is active in the area.

3.5. Rescue and Medical Treatment Requirements

Stop work authority should be exercised when an injury or accident occurs. The appropriate emergency agency should be contacted and first aid administered, if possible.

If the injury is not life threatening and does not require emergency response, contact _____< insert contact information for non-life-threatening emergencies>.

4. GENERAL FIELD SAFETY PROCEDURES

Project team members will conduct themselves in a safe and professional manner at all times. The following restrictions will also be observed by all project personnel.

- *Working while under the influence of intoxicants, narcotics, or controlled substances is prohibited.*
- *Smoking anywhere on site is prohibited.*
- *Loose clothing will not be worn on-site. Long hair will be worn up inside a hat.*
- *Eating, drinking, chewing gum, smoking, or any practice that increases the probability of hand-to-mouth transfer and ingestion of material is prohibited on-site, unless in designated break areas.*
- *No personnel will be admitted to the site without the proper safety equipment, clearance, or other approval.*
- *All personnel must comply with established safety procedures. Any staff member who does not comply with the safety policy, as established by the project manager, will be immediately dismissed from the site.*
- *No unapproved work clothes or equipment will be allowed on-site.*
- *Work areas will be established based on prevailing site conditions and are subject to change. Personnel should check with the project manager for current and appropriate procedures regularly.*
- *Contact with contaminated or potentially contaminated material should be avoided. Whenever possible, do not walk through puddles, mud, or any discolored ground surface. Do not kneel on the ground. Do not lean, sit, or place equipment on drums, containers, or vehicles.*
- *Due caution will be observed when proceeding on foot through open areas. Personnel will remain near the sorting area and avoid high-traffic areas, such as the working face of the facility.*
- *Any medical emergency supersedes routine safety requirements.*

4.1. Applicable Standard Operating Procedures (SOPs) and Program

Note: The study team may list references to the site or facility's existing SOPs, including but not limited to:

- General code of safe work practices
- Fire Extinguishers
- Materials Use and Handling
- Site Sanitation Procedures
- Safe Procedures for Biological Hazards (Snakes, Insects, Vegetation, Bacteria)
- Avoidance of Slips, Trips, and Falls

- Avoidance and Prevention of Heat and Cold Stress, and Other Weather-Related Hazards
- Hazard Communication
- Procedures for Proper PPE Use
- PPE Other Than Respiratory Protection
- Respiratory Protection
- Motor Vehicle and Fleet Safety
- Bloodborne Pathogens

4.2. Job Task Safety Analysis (JTSA) and PPE Assessment

A Job Task Safety Analysis (JTSA) helps project teams integrate known health and safety principles into job tasks. JTSAs for activities performed as part of a waste characterization project have been completed as indicated below and in the table. A completed JTSA is required for all waste characterization work tasks performed at the site. JTSAs are designed to identify steps which involve potential hazards to project staff and should be reviewed and understood (and signed providing evidence of understanding) before performing any task at the site. If additional steps or hazards are present, the JTSA should be revised (and the revision signed by all affected staff) to indicate that all items have been appropriately addressed and are understood before proceeding with the task.

Unless identified in an attached Job Task Safety Analysis (JTSA) form, all project tasks are anticipated to require certain listed personal protective equipment (PPE).

Project personnel will be informed about the use of safety equipment and will be required to wear protective clothing appropriate for the tasks in which they will be involved.

Extra equipment will be located on-site. This equipment will include the following items:

- *Protective Coverall Suits (e.g., high-density olefin fabric)*
- *Gloves*
- *High Visibility Safety Vests*
- *Eye Protection*
- *Ear Protection*
- *Hard Hats*
- *First Aid Kit*

Sufficient water for personal use will be brought on-site daily.

JOB TASK SAFETY ANALYSIS AND PPE ASSESSMENT FORM

Job Task Step	Potential Environmental and Personnel Hazards[1]	Critical Actions	PPE Required
1. Drive to site, set up sorting table and containers.	Heavy lifting Slips/trips/falls Vehicle traffic	• Check in with facility • Ensure work area is secured/isolated • Use safety partners • Use safe lifting • Stretch/warm-up	• Body: Safety vest, coveralls • Foot: Steel-toe ANSI boots • Hand: Nitrile + leather outer glove • Respiratory: None • Hearing: None • Eye/Face: Safety glasses
2. Collect solid waste samples.	Heavy lifting Vehicle/heavy equipment traffic Slips/trips/falls Medical/bio waste Sharps Chemical exposures	• Use safety partners • Stay visible • Use safe lifting • Set up away from traffic • Avoid heavy equipment traffic	• Body: Safety vest, coveralls • Foot: Steel-toe ANSI boots • Hand: Nitrile + puncture resistant gloves • Eye/Face: Safety glasses
3. Hand-sort solid waste materials on the sorting table.	Heavy lifting Vehicle/heavy equipment traffic Slips/trips/falls Medical/bio waste Sharps Chemical exposures Stress/hygiene concerns	• Use safety partners • Stay visible • Use safe lifting • Set up away from traffic • Brush trash (vs digging) • Wash hands freq. • Stay hydrated • Shift breaks	• Body: Safety vest, coveralls • Foot: Steel-toe ANSI boots • Hand: Nitrile + puncture resistant gloves • Respiratory: Dust mask (optional) • Hearing: Earplugs (optional) • Eye/Face: Safety glasses
4. Cleanup and decontaminate.	Heavy lifting Slips/trips/falls Vehicle traffic	• Ensure work area is secured/isolated • Use safety partners • Use safe lifting • Stretch/warm-up • Decontaminate PPE	• Body: Safety vest, coveralls • Foot: Steel-toe ANSI boots • Hand: Nitrile + leather outer glove • Respiratory: Dust mask (optional) • Hearing: None • Eye/Face: Safety glasses
5. Demobilize.	Vehicle/heavy equipment traffic	Check out w/facility	• Head: None • Body: High visibility vest • Foot: Steel-toe ANSI boots • Hand: None • Respiratory: None • Hearing: None • Eye/Face: None

4.3. Site Control

Project staff will be restricted in site usage to the area designated for sorting samples at the transfer station. A front-end loader will transport samples to the sorting area. Under no circumstances will project employees enter buildings and areas of the transfer station. Project employees will remain in the area designated for sorting samples.

Our facility partners are responsible for providing employees with safe site access, which includes sites that are free of threats from unauthorized access. If a project employee encounters an aggressive person or animal, they should withdraw from the site and contact the site representative and their supervisor. The site owner is responsible for removing the threats, and employees should not take any affirmative action of their own.

4.4. Decontamination Procedures

The risks of illness due to ingestion of diseased or decomposing materials from the work site are significant. To minimize these risks, all personnel should remove and store the outer layer of their protective clothing (i.e., coveralls, gloves, hard hat, etc.) on-site. Hands, face, and fingernails should be thoroughly washed, or scrubbed, with soap and water prior to engaging in any activity likely to transmit materials encountered on-site into the mouth. If waste materials come in contact with the skin, that crew member will be temporarily excused to thoroughly wash the affected area with soap and water.

4.5. Handling of Hazardous Waste Materials

Hazardous materials will be avoided during sample selection. If hazardous materials are encountered during the waste sorting activities, they will be segregated from the normal waste and recycling streams and put in separate containers. The contents of these containers will be reported to transfer station personnel for proper disposal.

Caution will be taken when handling mercury-containing wastes such as fluorescent light bulbs. Care will be taken to not break the glass bulb, and to avoid samples with excess amounts of fluorescent light bulbs. Gloves and protective coverall suits will provide skin protection from mercury compounds.

Extreme care will be taken when handling and disposing of hazardous materials. If personnel encounter any material that may be considered hazardous, they will be instructed to report it to the transfer station manager immediately.

4.6. Housekeeping Requirements

A portable toilet will be accessible near the sorting area. Hand sanitizer and soap will be made available to assist with decontamination. The designated break area will be located near the sorting area.

5. SITE HAZARDS

Note: This section should contain information on the identification of the following hazards. The examples provided should be tailored to the site conditions as identified by the study team.

5.1. Chemical and Physical Agent Hazards

The following chemical and physical hazards should be considered before performing any task or work at the site. The analysis will depend on a thorough understanding of the site's physical characteristics and the task(s) being performed.

Toxic Compounds: *Non-Methane Organic Compounds (NMOCs), as well as inorganic toxic contaminants such as mercury, and sometimes even radioactive contaminants such as tritium, may be present on a site. NMOCs include such toxic compounds as benzene, toluene, chloroform, vinyl chloride, carbon tetrachloride, and trichloroethane, which, although commonly less than 1 percent by weight, are hazardous. These potential hazards should be evaluated on a case-by-case basis. Additional precautions will be established as needed.*

Poisons: *Pesticides, cleaners, or other toxic materials of various types may be present in the waste stream. Avoid contact with these items. Pay close attention to where you walk and what you touch such that materials do not accidentally come into contact with skin, eyes, mouth, or clothing. Immediately remove any contaminated clothing, and wash with soapy water any skin that becomes contaminated. Avoid contact at all times.*

Flammables: *Fuel such as gasoline and diesel may be present in the waste stream. Additionally, paint thinners or other flammable materials may be present in the waste. The primary risk associated with these materials is fire. Keep all ignition sources away from flammable materials. Do not smoke. Pay close attention to where you walk and what you touch such that materials do not accidentally come into contact with skin, eyes, mouth, or clothing. Immediately remove any contaminated clothing, and wash with soapy water any skin that becomes contaminated. Avoid contact at all times.*

Oxidizers: *Fertilizers, pool chemicals, chlorine, or other oxidizers may be present in the waste stream. These materials may be in use at water treatment plants or in the waste at the site. The primary risk from oxidizers is an increased fire potential. Keep fire and fuel or oil away from oxidizers. Do not smoke. Pay close attention to where you walk and what you touch such that materials do not accidentally come into contact with skin, eyes, mouth, or clothing. Immediately remove any contaminated clothing, and wash with soapy water any skin that becomes contaminated. Avoid contact at all times.*

Corrosives: *Acidic and caustic materials may be present in the waste stream. These materials may be in use at water treatment plants or in the waste at the site. The primary risk from corrosives is damage to the skin or eyes. Pay close attention to where you walk and what you touch such that materials do not accidentally come into contact with skin, eyes, mouth, or clothing. Immediately remove any contaminated clothing, and wash with soapy water any skin that becomes contaminated. Avoid contact at all times.*

5.2. Physical Hazards

The following physical hazards should be considered before performing any task or work at the site. Depending on the task(s) being performed, any or all these hazards may be present.

Heavy Equipment: Compactors, bull dozers, loaders, track hoes, forklifts and large trucks, and other vehicles are present at the transfer station. Loud noise and limited visibility can increase the threat of being run over or crushed by these vehicles. Wear high-visibility vests (recommend Class III) and coordinate with vehicle operators when working in the vicinity of these pieces of equipment. Heavy equipment hazards are especially present at or near the working area. The project team will remain in the area designated for sorting samples and avoid high traffic areas and areas where heavy equipment operates.

Heat-Related Injuries: Elevated body temperatures can cause serious injury or death. Working outdoors or in the sun increases the chance of heat-related injuries. This hazard is especially critical when PPE (such as coveralls or rain gear) is worn since heat from the body becomes trapped inside clothing. Personnel should drink plenty of liquids and take breaks as needed. The following describes the various effects of heat-related injuries.

Heat Disorders and Health Effects:

Heat Stroke: This disorder occurs when the body's system of temperature regulation (e.g., sweating and evaporation) fails and body temperature rises to critical levels. The condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. Heat stroke is a serious hazard, however. Primary signs and symptoms are confusion, irrational behavior, loss of consciousness, convulsions, a lack of sweating (usually), hot, dry skin, and an abnormally high body temperature. If a worker shows signs of possible heat stroke, call emergency services to obtain immediate medical assistance. The worker should be placed in a shady area, and his or her outer clothing should be removed. The worker's skin should also be wetted and air movement around the body increased to improve evaporative cooling until professional methods of cooling are initiated and the seriousness of the condition can be assessed. Fluids should be replaced as soon as possible--by mouth only if the worker is conscious. The medical outcome of an episode of heat stroke depends on the victim's physical fitness and the timing and effectiveness of first aid treatment. Regardless of the worker's protests, no employee suspected of being ill from heat stroke should be sent home or left unattended unless a physician has specifically approved such an order.

Heat Exhaustion: The signs and symptoms of heat exhaustion include clammy skin, headache, nausea, vertigo, weakness, thirst, and giddiness. Fortunately, heat exhaustion responds readily to prompt treatment. This condition, however, should not be dismissed lightly, for several reasons. One is that fainting associated with heat exhaustion can be dangerous because the victim may be operating machinery or controlling an operation that should not be left unattended. The victim could also be injured when he or she faints. While the signs and symptoms associated with heat exhaustion are similar to those of heat stroke, the notable difference (with heat exhaustion) is clammy skin. Workers suffering from heat exhaustion should be removed from hot environments and given fluid replacement, by mouth only if the workers are conscious. They should also be encouraged to get adequate rest.

Heat Rashes: The most common problem occurring in hot work environments is heat rash. Prickly heat is manifested as red papules and usually appears in areas where the clothing is restrictive. As sweating increases, the papules give rise to a prickling sensation. Prickly heat occurs in skin that is persistently

wetted by unevaporated sweat, and papules may become infected if they are not treated. In most cases, heat rash will disappear when the affected individual returns to a cool environment.

Heat Fatigue: *One factor that predisposes individuals to heat fatigue is the lack of acclimatization. Use of a program of acclimatization and training for work in hot environments are advisable. The signs and symptoms of heat fatigue include impaired performance of skilled sensorimotor, high-concentration, or high-vigilance activities. The sole treatment available for heat fatigue is to remove heat stress and increase fluid replacement before a more serious heat-related condition develops.*

Inclement weather: Blizzards, flash floods, fog, tornadoes*, and other meteorological events may or may not be predictable and may require immediate response for survival. Personnel should use sound judgment concerning significant weather threats, including a stop work authority if necessary. Some weather events may restrict visibility which can present a driving hazard. Gusts of wind may physically knock a worker off a ledge or piece of equipment (e.g., ladder). The danger of lightning strike is increased when working on an elevated surface. Lightning can strike miles ahead of a storm when no rain is present. All field work should be stopped immediately when lightning is visible or thunder is audible. All personnel should seek shelter inside a building or vehicle. Do not take shelter near tall objects such as power lines, trees, antennas, or the flare stack. Work should not resume until lightning is no longer visible and thunder cannot be heard.*

5.3. Biological Hazards

Rodents, poisonous and venomous insects, snakes, other animals and/or plants are a natural part of any ecosystem. They are sometimes difficult to eliminate or avoid on some sites because of the location. Employees should be aware of the potential for encountering these types of animals and plants. Where possible, nesting places should be removed or access to them should be limited. If several infestations occur, remedies should be discussed with a supervisor and the facility partner.

The following could be encountered in performance of the operation, maintenance, and monitoring functions of a project:

Hantavirus: *Infection typically occurs by the inhalation of tiny airborne droplets of fresh or dried rodent excretions. Transmission to humans may also occur through direct contact with rodents or rodent-contaminated materials, and ingestion of contaminated food or water is also a possible route of transmission. Sweeping or "shaking out" rodent-contaminated materials should be avoided unless performed using respiratory protection. The early symptoms of hantavirus disease are flu-like (fever, chills, muscle aches). For a very short period, the infected person starts to feel better. Then, within 1 to 2 days, he or she may develop shortness of breath. The disease gets worse quickly and leads to respiratory failure, a condition known as Hantavirus Pulmonary Syndrome (HPS). About half of all HPS patients experience these symptoms, which usually occur 1 to 5 weeks from contracting the illness.*

Spiders: *The brown recluse spider, or violin spider, is usually not aggressive unless threatened. They are small and bites often go undetected. They are nocturnal animals and remain in undisturbed areas like footwear or drawers. Bite areas are initially red and stinging with pain that becomes more intense as time*

passes. Within 48 to 72 hours a blister forms, turns red and bursts. This area has a chance of infection because this area may not heal properly. Poison control and or a physician should be contacted.

Bloodborne Pathogens: *Human blood can contain harmful viruses such as the Human Immunodeficiency Virus (HIV) and Hepatitis B Virus (HBV). Contact with affected blood, as well as materials contaminated by this blood, can result in transmitting viruses and the life-threatening conditions they cause.*

When an employee is involved in an exposure incident, it must be reported in accordance with the Health and Safety Injury and Illness Prevention Plan. All employees involved in an exposure incident will be offered post-exposure evaluation and follow-up.

Follow-up will include:

Documentation of the route of exposure and the circumstances related to the incident.

If possible, identification of the source individual and, if possible, the status of the source individual. The blood of the source individual will be tested (after consent is obtained) for HIV/HBV infectivity.

Results of testing of the source individual will be made available to the exposed employee, along with applicable laws and regulations concerning disclosure of the identity and infectivity of the source individual.

The employee will be given appropriate counseling concerning precautions to take during the period after the exposure incident. The employee will also be given information regarding potential illnesses and procedures for reporting related symptoms to appropriate personnel.

Appendix B: Sample Interview Guides

As discussed in Section 2.5.1, waste haulers and collection services companies are a valuable source of information about the amount and type of waste collected in a city or region. Not only will they provide crucial access to waste, but if a study is lacking information or wants to verify assumptions, brief interviews with truck drivers and hauler employees are a tool to be considered.

- Interviews with truck drivers should be short, gather specific details about their route, and include identifying information such as their truck number and hauler name.
- Interviews with hauler fleet, operations, or contract managers should aim to gather specific data from the company's records and be comprehensive to avoid the need for follow-ups.
- All interviews should provide the subject with informed consent about the study, ensure that information gathered will be presented anonymously and only be used for research purposes. The informed consent letter template is discussed in Section 2.2.

TRUCK DRIVER SAMPLE INTERVIEW GUIDE

Hello, I am a researcher from _____ (organization) who is conducting a waste characterization study here at the _____ (landfill/disposal site) to help _____ (city/region) better manage its solid waste. Are you able to answer a few simple questions about your collection route today? It should take less than 5 minutes.

Before we begin, please know that participation in this interview is voluntary and we can pause or stop at any time without penalty to you. All responses will remain anonymous, and information will be used for research purposes only. Would you like to continue?

1. Date, time, location:
2. Truck driver name:
3. Truck number or identification:
4. Hauling company name:
5. Estimated weight of collected truckload:
6. Estimated number of collection stops:
7. Neighborhood(s) or area(s) collected from:
8. Estimated waste percentage, residential versus commercial:
   ____% residential, _____% commercial
9. Any hazardous or dangerous waste to be aware of?
   (Yes/No) If Yes, please describe _____
10. Any unusual or atypical waste collected?
    (Yes/No) If Yes, please describe _____

Thank you very much for taking the time to help with our study! Your efforts will help us to improve waste management and quality of life for residents.

- If truck meets criteria for taking a waste sample, direct driver to clear and safe area to dump load for inspection.
- If truck does not meet criteria for taking a waste sample, direct driver to continue with disposal.

HAULER MANAGER SAMPLE INTERVIEW GUIDE

Hello, I am a researcher from _____ (organization) who is conducting a waste characterization study at the _____ (landfill/disposal site) to help _____ (city/region) better manage its solid waste. Are you able to answer a few simple questions about your company's waste hauling operations? It should take less than 5 minutes.

Before we begin, please know that participation in this interview is voluntary and we can pause or stop at any time without penalty to you. All responses will remain anonymous, and information will be used for research purposes only. Would you like to continue?

1. Employee name and position:
2. Hauling company name:
3. Number of waste collection trucks in service:
4. Estimated weight of average truckload:
5. Neighborhood(s) or area(s) collected from:
6. Estimated waste percentage, residential versus commercial:
   ____% residential, _____% commercial
7. Are you able to estimate the percentage of contracts or collection for each source? (An educated guess is OK).
   - Residential (single family): ____%
   - Residential (multi-family): ____%
   - Public: ____%
   - Institutional: ____%
   - Industrial (front office/non-process waste): ____%
   - Commercial: ____%

Thank you very much for taking the time to help with our study. Your efforts will help improve waste management and quality of life for residents.

Appendix C: Sample Letter of Introduction

A local government commissioning a waste characterization study may need to approach the entity controlling the waste material (e.g., waste collector or landfill owner) to request support. Waste characterization teams can send a letter of introduction to provide project background and informed consent information when project teams request access to waste material for a characterization study. This letter should be adapted for the waste characterization study's needs and presented to the relevant waste management authority or facility operator prior to the study at that site.

Letter of Introduction

Dear [*Waste Facility/Collections Operator*],

We are writing to inform you that [*Name of organization/local government*] is conducting a survey of solid waste in [*region/city name*]. This survey, known as a waste characterization study, will assist [*region/city name*] in providing sustainable and efficient solid waste management services and improving environmental and health conditions for residents. To conduct the study, our trained staff will manually collect and sort waste samples to understand their composition.

We would appreciate your collaboration in allowing [*name of organization/local government]* staff access to waste materials from incoming collection vehicles and the permission to briefly interview collection vehicle drivers. Employee confidentiality will be maintained and participation is voluntary.

[*Insert any additional requests – transportation of waste samples, sorting/study area, etc.].*

Please do not hesitate to contact me with any questions or concerns. I can be reached at [*contact phone number and/or email address].*

We thank you for your assistance,

Sincerely,

[Name of Signatory]

[Position/Title]

[Name of organization/local government]

[Phone Number and/or Email Address]