METHODOLOGICAL GUIDE

PREPARATION OF WASTE COMPOSITION STUDIES

October 2020

TRANSPARENCY AND ACTIVE LISTENING GROUP

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CHAPTER I. Introduction

This **METHODOLOGICAL GUIDE FOR PREPARING MUNICIPAL WASTE COMPOSITION STUDIES** (hereinafter, the **Guide**) is provided as a working reference document for municipal waste composition studies commissioned by both public and private entities.

Mindful of how important it is to know the composition of the waste generated in an environment and how it evolves over time, and in order to set up prevention targets based on the reducing and properly managing waste, the Transparency and Active Listening Group (forum for the exchange of know-how, for debate and reflection, created as an Ecoembes initiative and featuring professionals from most of Spain's regional governments, the Spanish Federation of Municipalities and Provinces (FEMP) and the National Association of State-Run Environmental Companies (ANEPMA)) set out to develop this Guide. To this end, a specific Working Group coordinated by ANEPMA was organised that, through meetings and the constant exchange of information, has been laying the foundations and validating the different issues discussed.

Although this type of study had been conducted previously in different areas of Spain, both within the framework of the Pilot Plan[1] promoted by the *Ministry of Agriculture, Food and the Environment* (currently the *Ministry for the Ecological Transition*), and in works promoted by various entities tasked with waste management, there is no agreed general work methodology that can be used as a reference for conducting composition studies. This Guide thus tries to answer those questions that may arise when planning a waste composition study, considering everything from the goals of the study to the interpretation of its results.

The Guide is intended to provide a user-friendly manual. Accordingly, it consists of a concise and synthetic main body (Procedure) and a set of Annexes that supplement and enhance the information presented. In summary, it consists of:

- **Procedure for preparing Waste Composition Studies:** this is the reference document, which describes the main guidelines to use when carrying out this type of work. It describes the goals and scope of a composition study, defines the sampling plan, how to conduct the characterisation itself, and how to analyse and interpret the results.
- **ANNEX I. Glossary of terms**: includes a compilation with definitions of the terms used in this Guide.

- **ANNEX II. Statistical methodology for preparing the sampling plan:** details the statistical methodology proposed for segmenting territories and calculating the sample size (it also includes any applicable statistical concepts).

[1]“Pilot Plan for characterising urban waste from households”, commissioned by the Ministry of Agriculture, Food and the Environment (currently the Ministry for the Ecological Transition), the results of which were published in 2012.

- **ANNEX III. Sampling procedure:** describes step by step the method to carry out the characterisation, from the time the sample arrives at the work site until the results are collected in the Characterisation Sheet.
- **ANNEX IV. Guide for differentiating materials in a characterisation:** provides a description and examples of each of the materials included in the Characterisation Sheet, as well as, in some cases, characteristics and recommendations for differentiating them.
- **ANNEX V. Procedure for determining the adhered moisture/dirt and volatile matter**: describes the methodologies for determining the moisture, dirt and volatile compound contents, based primarily on UNE Standards.
- **ANNEX VI. Recommendations for avoiding biases and issues to consider when interpreting the results:** provides recommendations to avoid bias as much as possible and issues to consider both during the selection and characterisation processes involving samples and when interpreting the results**.**
- **ANNEX VII. Reference documentation**: list of the documentation that was consulted related to the purpose of this Guide.
- **ANNEX VIII. Proposed technical guidelines for government agencies to consider in the Bidding Specifications of contracts for characterisation services**: contains a proposal of the fundamental technical issues for government agencies to consider when contracting Characterisation Services.

CHAPTER II. Preparing the Guide

As indicated in the INTRODUCTION, the development of this Guide is part of an initiative of the **Transparency and Active Listening Group**, whose members include most of Spain's regional governments, the Spanish Federation of Municipalities and Provinces (FEMP), the National Association of State-Run Environmental Companies (ANEPMA) and Ecoembes.

To create this guide, a specific Working Group was set up within the Transparency Group consisting of ANEPMA (which also coordinated the work), the Ministry for the Ecological Transition (MITECO), ECOEMBES and various regional governments[2]. The Working Group met periodically both to define the scope of the work and to discuss and validate its contents.

This Guide was developed between July 2019 and February 2020.

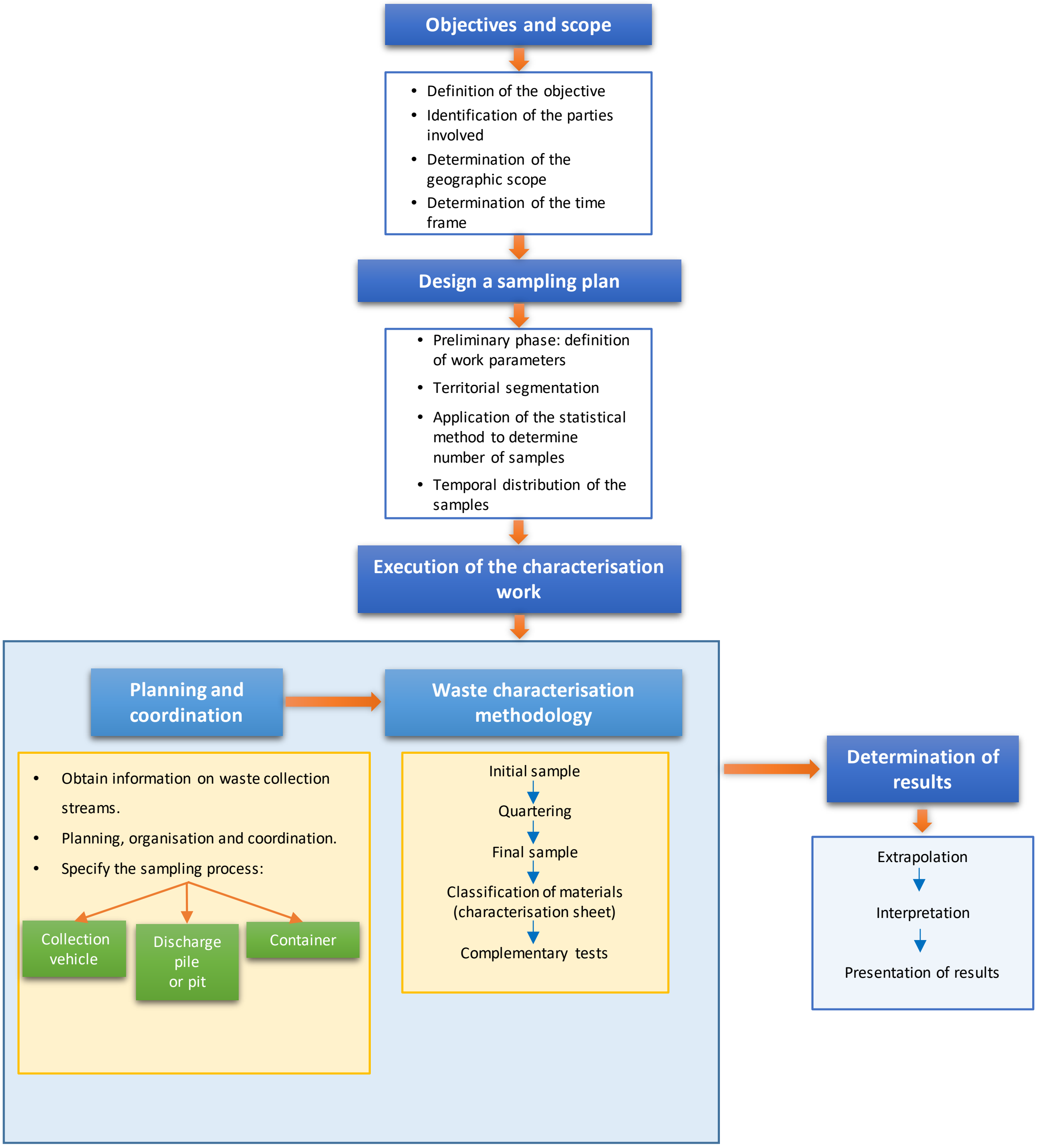
In addition, when preparing the Guide, various related documents were consulted that ended up serving as a reference in its development. They were also used to learn about different approaches and cases involved in the main aspects to be addressed in this Guide. The types of documents considered include:

- Pilot plan to characterise urban waste of household origin. Ministry of Agriculture, Food, and the Environment. 2012
- Municipal waste composition studies carried out in different regions of Spain.
- International waste composition methodologies.
- Specific guides and manuals related to aspects of waste composition.
- Standards published by standardisation and certification bodies.
- Other documents, reports and studies of interest.

[2]Catalonia, La Rioja, Community of Navarre and the Basque Country

CHAPTER III. Procedure for preparing waste composition studies.

The Guide is structured into different sections that define each of the phases that make up a waste composition study. An outline of the issues discussed herein is presented below:



Source: Working group

Figure 1. Outline of the waste composition study

The Guide is applicable to municipal collections of normal waste deposited in collection systems that rely on containers, pneumatics, buckets or bags, that is, the light packaging, paper/cardboard, glass, “other” and inorganic fractions.

This Guide is not mandatory, and is presented as a working reference document for studies of the composition of municipal waste.

Collections from recycling centres and other specific collections like the door-to-door pick-up of bulky waste, collection of textiles, WEEE, oils, batteries, etc., are beyond the scope of this Guide.

Over the course of this document, a practical example is provided as a guide on how to perform a waste composition study.

1 Objectives and scope

1.1 Objectives

Defining the goals of a waste composition study is key to determining how to carry out:

- The design of the sampling plan
- The sample characterisation
- The analysis and evaluation of results

The goals can be very different, the most common being the following (or a combination of them):

- Sizing, design and commissioning of waste treatment facilities.
- Knowledge of the composition of municipal waste in a specific area (region, province, group of municipalities, municipality, neighbourhood, etc.), so as to define strategies and/or prepare waste prevention and management plans, as well as to monitor regulatory targets.
- Identify errors in sorting the fractions that are collected separately.

1.2 Parties involved

Different agents or actors are involved when conducting a waste composition study, depending on the specific activity to be carried out (planning, field work, interpretation of results, etc.). Their coordination is crucial to the successful completion of all the tasks. Sometimes, one party may have several responsibilities (for example, the project promoter may also be the entity that collects and/or manages the waste).

Depending on the types of works described in this Guide, we can, at a minimum, single out the following parties:

- **Promoter:** agent that identifies the need to perform the work to ensure compliance with a specific goal. It can belong to either public or private entities. In many cases, the promoter may also be responsible for designing the sampling campaign and interpreting the results, or it may decide that a third party is needed to carry out these tasks. It also determines whether it is feasible to do the characterisations in the field with internal or subcontracted personnel.

- **Coordinator**: agent who tracks the overall scope of the work, the deadlines and the goals. It is responsible for ensuring that all the necessary information is available at the start of each phase and that the planned goals are achieved. It will act as a link between all the agents involved. It may be the same party as the promoter and/or a member of the technical design team.
- **Technical team to design the sampling campaign and to analyse and evaluate the results:** responsible for collecting data and performing the specific tasks to determine the size and distribution of the samples to be taken, as well as for evaluating the results. It may be the promoter itself or be an independent entity that is only used for the theoretical work involving the composition study.
- **Entity tasked with collecting the waste**: entity responsible for collecting the fractions analysed in the study (local entity that owns the service and/or the service operator). Depending on the territorial scope of the composition study, there may be several Entities that are responsible for collecting the different fractions.
- **Manager or owner of the facility where the characterisation will be done:** entity in charge of the facilities, whether for the transfer or final treatment of the waste, where the characterisation work will be carried out (it will ensure that the conditions required to do the work are met).
- **Field work team:** in charge of carrying out the on-site characterisation of the waste (based on the guidelines set by the technical design team), that is, selecting the sample to be characterised, processing it, sorting it manually, weighing it and entering the data in the Characterisation Sheet. This team will also fill in the Field Sampling Form.
- **Laboratory**: entity tasked with doing the physical/chemical analyses (complementary samples) needed to complement the studies.

1.3 DETERMINATION OF THE GEOGRAPHIC AREA OF THE ACTIVITY

The scope of the sampling involves the geographic area or territory that is going to be the object of the study, which can be national, regional (autonomous community, province, grouping of municipalities, such as community, consortium, etc.) or local (municipality, neighbourhood or district).

1.4 DEFINITION OF THE TARGET WASTE

When preparing a composition study, the target waste of said study has to be defined. For example, when the study involves the composition of municipal waste in a given territory, the target waste will be all the "ordinary" fractions handled by municipalities, namely, any waste that is collected, whether separately or not, by public waste collection services. In the case of a composition study to design a treatment plant, the target waste will be the fraction or fractions to be processed at said plant, whether it is the "other" fraction, light packaging, etc. In the case of a study to identify mistakes in the separation at the point of origin, the target waste will be the fraction to be monitored, for example the "other" fraction, to determine which waste fractions are not being separated properly when deposited.

1.5 DETERMINATION OF THE TIME FRAME

The time frame of waste composition studies refers to their duration, which should be, in general and for all purposes, one year, so that seasonal variations can be adequately documented.

1.6 DEFINITION OF THE CASE STUDY

Over the course of this document, a practical example is provided as a guide on how to perform a waste composition study.

Practical example: The practical example proposed involves determining the composition of waste in a geographic area made up of several municipalities, all of them inland, with the following characteristics:

- There is a main urban area with a commercial zone. There are several neighbouring towns near the urban centre that have small populations and are mainly residential. Other populations, further away, engage in predominantly agricultural activity.

The goals and time frame of the study are as follows:

- The goal of the study is to determine the composition of the waste in the geographic area in question.
- The target waste will be the "other" fraction and the light packaging fraction. In the case of paper/cardboard and glass, they will not be characterised due to their mono-material nature, but the amount collected will be taken into account to determine the aggregate composition.
- The time frame of the study is one year.

2 Sampling procedure

The design of the sampling plan will determine when, where and how many samples will be collected in order to obtain a representative quantity within the geographic and operational scope that is both manageable and allows meeting the stated goals.

A sampling plan consists of the following phases:

- Preliminary phase: definition of work parameters
- Choice of sampling method
- Territorial segmentation
- Sample size
- Sampling system

Each of the phases of a sampling plan that are needed to successfully complete the work are detailed below:

2.1 PRELIMINARY PHASE: DEFINITION OF WORK PARAMETERS

As a preliminary or research phase when designing the sampling plan, it is important to collect certain information, as well as to have reference data, mainly obtained from historical studies or data related to the composition of waste in the geographic area in question.

In this regard, below are a series of guidelines and instructions to take into account for gathering and processing this baseline information:

BASELINE INFORMATION	DEFINITION	INSTRUCTIONS
Historical data on the composition and generation of waste	This refers to the historical data relative to both the generation of waste and its composition. In addition to providing knowledge of the waste composition of the territory, it can be used to conduct the statistical analysis necessary to determine the number of representative samples.	When processing previous studies, both the reliability of the information (in terms of who carried out the study and whether it comes from official and reliable sources) and the similarity of the study (in terms of how its goals compare with those of our study and with the characteristics of the territory) have to be considered. The annual waste generation data needed are the tonnes collected and the generation rate.
Data necessary to segment the territories.	This refers to the compiling of demographic and socioeconomic data in the area of activity.	Section 2.2 contains a series of recommendations and sources of information to help segment the territories.

BASELINE INFORMATION	DEFINITION	INSTRUCTIONS
Data on the waste management model.	This refers to obtaining data on the waste management model in the area of activity. This information will allow for better stratification of the geographic area in question.	Section 3.1.1 details how to collect information on the territory's waste management model.
Data on the facilities available and other data needed to carry out the characterisation work.	This refers to the number of facilities available in the territory, as well as to their characteristics.	Section 3.1.2 sets out the characteristics that the facilities must meet to do the characterisation work.

Source: Compiled internally

Table 1. Preliminary information needed to design a sampling plan

Practical example: Based on the example proposed in the previous section, the information needed to carry out the study must be gathered. The information obtained and the sources of the data are as follows:

- o Waste generation data provided by Local Entities, as indicated in the table below.
- o Population data obtained from the INE (National Statistics Institute).

It is assumed that no waste composition study was conducted previously in the area.

The resulting figures are as follows:

	Urban Mun.*	Rural Municipalities 1 to 15	Rural Municipalities 16 to 25
Light packaging (kg/yr)	897,000	480,525	277,992
Paper/Cardboard (kg/yr)	994,500	506,325	222,750
Glass (kg/yr)	858,000	457,950	235,224
Other waste (kg/yr)	17,875,000	8,385,375	4,187,350
Nº of inhabitants	65,000	32,250	17,820

*Includes waste generated in the commercial area, for which data on the routes associated with that area are available.

2.2 CHOICE OF SAMPLING METHOD

To carry out the sampling plan, it is first necessary to decide what type of sampling to use.

According to the *UNE-EN 14899:2007 standard,* two sampling types are applicable, namely:

- **Probabilistic sampling,** which relies on the fact that each element within the population to be evaluated has the same probability of being selected in the sample.
- **Expert sampling**, which is a type of sampling in which, unlike the previous one, samples are taken in the best of cases using a probabilistic approach and in the worst of cases using a non-probabilistic approach.

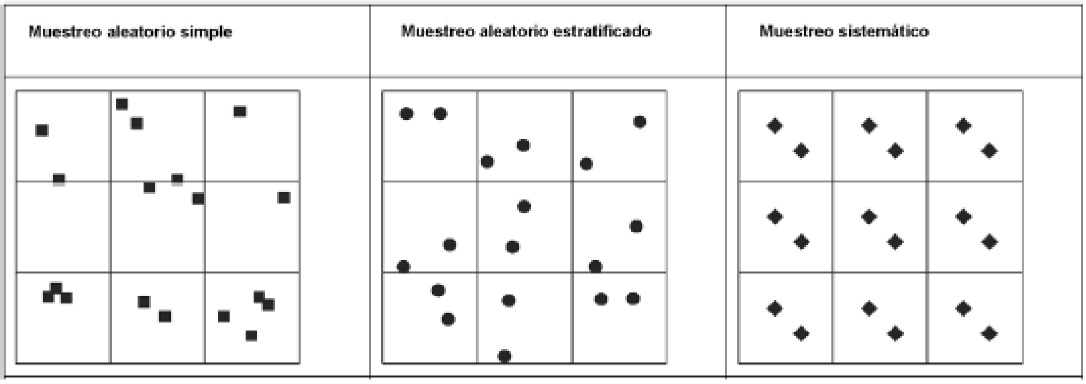
In expert sampling, the sample selected is not guaranteed to be representative, since not every element of the population has the same likelihood of being chosen, a circumstance that does not occur in probabilistic sampling. Expert sampling is only recommended when the population is not accessible or if no prior information is available.

As a result of the above, and considering that it is the sampling method normally used in characterisation studies, the use of **probabilistic sampling** is recommended for waste composition studies.

In turn, probabilistic sampling provides the following options:

- Simple random sampling: in this type of sampling, the samples are taken at random independently.
- Systematic sampling: a first sample is taken at random and then, at constant intervals, all the other samples are chosen.
- Stratified random sampling: after segmenting the population into homogeneous groups, called strata, as indicated in the previous section, the samples are selected by a simple random method or by a systematic method in each stratum.

The diagram below shows the different sampling methods:



Source: Technical report UNE-CEN/TR 15310-1 IN (standard UNE-EN 14899:2007)

Table 2. Types of probabilistic sampling

The table below analyses the pros and cons of each type of probabilistic sampling:

SAMPLE TYPE	ADVANTAGES	DISADVANTAGES
Simple random	It is the simplest type of sampling method.	By leaving everything to chance, the sample may not be sufficiently representative of the population being analysed.
Systematic	Easy to apply. When the population is arranged following a known trend, the resulting sample accounts for all the variability in the population.	It depends on how the population is arranged. It can cause problems if the population exhibits cyclical behaviour.
Stratified random	Each stratum can be studied as a subpopulation by itself, yielding conclusions about the behaviour of the characteristic in question in said stratum. It provides more accurate estimates.	If we rely on incorrect assumptions when creating the strata, this can lead to faulty conclusions in the study.

Source: Working group

Table 3. Pros and cons of probabilistic sampling methods

The choice of one probabilistic method or another will depend on the stated objective and the resources (time and/or economic) available. The **stratified random method** is recommended in those cases in which the territories are segmented. This method, although it requires more effort when planning the work, yields more accurate and reliable results and reduces the sample size needed to achieve the desired level of confidence.

2.3 SEGMENTING THE SCOPE OF THE STUDY

Due to the operational difficulty and the cost involved, in many cases, to expand the sampling to the entire territorial scope of the study, it is common to segment said scope into homogeneous strata/zones, such that by taking representative samples from each stratum, its complete representativeness can be guaranteed. This section presents a method to conduct this segmentation that can be applied in composition studies of a supra-municipal nature (national, regional, provincial, association, consortium ...) or of urban municipalities of a certain size.

Thus, we propose segmenting a territory by dividing the geographic work area into homogeneous sectors (strata), meaning they have similar characteristics, such that the results obtained in each stratum are representative of the whole.

If we consider the *UNE EN 14899:2007 Standard*, stratification is defined as the division of a population into mutually exclusive and exhaustive subpopulations (called strata), which are considered more homogeneous in terms of the characteristics being analysed than the total population.

To do this stratification, it is important to identify common characteristics in each stratum based on factors that affect the generation rate and composition of the waste. These characteristics can be of different natures (environmental, geographical, socio-cultural and economic). Documentary sources can be checked to identify them (some are proposed below), and the stakeholders in the geographic area can also be involved in the process. The important thing is to ensure that the segmentation reflects a similarity in the generation and composition of the waste, and, as in any analysis with a statistical component, it will be necessary to balance the complexity and cost involved in conducting the study against any gains in the representativeness of the samples.

As an example of the diversity of the existing segmentation types, the following table shows the classification used in different studies in Spain (see below in alphabetical order), as well as the different variables used to determine them:

EXAMPLE	SEGMENTATIONS	VARIABLES USED
Example 1 *(Balearic Islands)*	• Urban areas • Coastal/tourist areas • Inland/rural areas	1. Types of municipalities: urban, coastal and rural. 2. Tourism: municipalities with a strong tourist influence and a broad service sector.
Example 2 *(Castilla-La Mancha)*	• Urban • Semiurban • Rural • Isolated rural • Residential • Industrial/Commercial • Agricultural	1. Types of municipalities: urban, semiurban, rural and isolated rural. 2. Economic activities: agricultural, industrial/commercial.

EXAMPLE	SEGMENTATIONS	VARIABLES USED
Example 3 *(Catalonia)*	• Construction • Rural agricultural • Rural residential • Rural residential young • Rural tourism • Camping tourism • Hotel tourism • Urban active • Urban industrial • Urban services	1. Types of municipalities: rural and urban. 2. Economic activities: construction, agricultural, industrial, services. 3. Tourism: camping tourism, hotel tourism.
Example 4 *(Galicia)*	• Urban • Semiurban • Rural • Primary sector • Secondary sector • Tertiary sector inland • Tertiary sector coastal • Organic/Inorganic	1. Types of municipalities: rural, urban and semiurban. 2. Economic activities: primary, secondary and tertiary sectors. 3. Geographic location: coast and inland. 4. Waste management model: organic/inorganic.
Example 5 *(Madrid)*	The waste is segmented by stratum: a total of 6, plus the city of Madrid.	1. Demographics: Nº of inhabitants, population density, age, etc. 2. Socioeconomic: income, number of houses, property value, personal income tax, GDP, employment rate, etc. 3. Tourism: beds in hotel establishments. 4. Geographic location: elevation, distance to the city of Madrid, etc. 5. Waste: tonnes generated and generation rate. 6. Economic activities (commercial): percentage of urban structures for leisure and hospitality; urban land for services and commercial use.

Source: Working group

Table 4. Examples of segmentation of supra-municipal scope

As we can see, the strata were defined using common characteristics based on different variables: types of municipalities, weight of different economic activities, tourism, etc. The characteristics have been applied to the specifics of each territory. There does not seem to be a single solution, but it seems possible to identify elements or references in order to adapt the best solution to each study area.

Taking into account experiences from past studies and the most commonly used variables, a methodology is proposed below for segmenting the supra-municipal area or municipal areas where different strata can be defined. This is proposed from the point of view of segmentation by levels, such that there is an initial segmentation that can be complemented by additional elements (mainly due to the tourist factor) and elements associated with the collection service.

Level 1. BASIC SEGMENTATION

This is the initial level of segmentation, which is done by municipality type and by economic and/or socio-demographic activity, according to the following criteria:

- Segmentation by **type of municipality or degree of urbanisation**, based on their demographics. The following types will be considered:

  - Metropolitan area. Continuous urban area with residential, industrial, commercial and service activities, with a higher estimated population than an urban area.
  - Urban. Population between 50,000 and 175,000 inhabitants.
  - Semiurban. Population between 5,000 and 50,000 inhabitants.
  - Rural. Population below 5,000 inhabitants.

  Source of information:

  - National Statistics Institute (INE) (www.ine.es).
  - Statistics institutes or other official bodies of the regional governments and of Ceuta and Melilla.

- In light of the above segmentation, and as a complement to it, criteria involving **economic and/or sociodemographic activity** in the study area will be taken into account, provided they are clearly defined. The following are proposed:

  - Agricultural/Fishing (predominant activity in the agricultural or fishing sector).
  - Commercial/Services (main activity focused on services or commerce).
  - Industrial (mainly that in industrial areas).
  - Residential (areas generally far away from urban areas, or located in a place with little traffic containing a group of houses).
  - Tourist (areas where most of the activity involves tourism. They tend to be highly seasonal).

  Each criterion may be applicable to the segmentation, as long as it represents at least 10% of the total waste generated, or failing that, if it involves a priority goal of the waste composition study.

  In the particular case of segmentation by tourism, the additional elements indicated in Level 2 should be taken into account.

  Source of information:

  - National Statistics Institute (INE) (www.ine.es).
  - E-Office of the Property Register. Revenue Ministry (www.sedecatastro.gob.es).
  - SIGPAC viewer. Spanish Agricultural Guarantee Fund (sigpac.mapa.es).
  - Statistics institutes or other official bodies of the regional governments and of Ceuta and Melilla.

The following cases are proposed as examples of the basic segmentation procedure indicated.

- Example 1.1: We want to conduct a waste composition study in a municipal association made up of 17 municipalities, whose classification based on the municipality type is as follows:

    - 2 urban municipalities
    - 5 semiurban municipalities
    - 10 rural municipalities

  These are non-tourist municipalities where the activity in one of the urban municipalities is mainly commercial and/or services. In contrast, two of the semiurban municipalities are basically residential. The 10 rural municipalities are similar, so no additional segmentation is required. In this case, the proposed segmentation is as follows:

    - Urban
    - Urban commercial
    - Semiurban
    - Semiurban residential
    - Rural

- Example 1.2: We want to conduct a waste composition study in an area made up of several municipalities, some coastal and tourist, and others agricultural. There is also a main urban municipality away from the coast, with a tourist area, an important commercial area and a small industrial park. The classification by municipality type is as follows:

    - Urban
    - Rural

  The rural municipalities are either entirely tourist (coastal municipalities), with a high seasonality, or merely agricultural (inland municipalities, far from the coast). In the case of the urban municipality, there is a tourist area, a commercial area that accounts for 12% of the total waste generated, while the small industrial park generates 2% of the total waste. The scope of this study thus considers a rural agricultural area, a tourist area, the commercial urban area and the rest of the urban population. The final segmentation for the study would be as follows:

    - Urban
    - Urban commercial
    - Rural agricultural
    - Tourist

Level 2. TOURISM ELEMENTS IN ADDITION TO THE BASIC SEGMENTATION

In the case of those segmentations whose economic activity is related to tourism, there may be different characteristics that affect waste composition and generation, which will be assessed to determine whether to include them in the tourism segmentation done as part of the basic segmentation.

The following cases are proposed:

- By location: Inland/Coast.
- By type of accommodation: Hotel/Large Hotel/Small Hotel/Campground

Source of information:

- National Statistics Institute (INE) (www.ine.es).
- Statistics institutes or other official bodies of the regional governments and of Ceuta and Melilla.
- Local agencies

As an example of elements in addition to the basic segmentation, the following case is proposed, based on example 1.2 indicated above.

- Example: As indicated in example 1.2 above, there is a tourist zone located in rural areas situated on the coast, and a tourist zone inland. To differentiate them, they are segmented as follows to complement the previous segmentation:
    - Urban
    - Urban commercial
    - Rural agricultural
    - Tourist inland
    - Tourist coast

Level 3. ELEMENTS ASSOCIATED WITH THE COLLECTION SERVICE

This third level takes into account the characteristics associated with differences in the waste collection model or service. If the differences are small or affect a small population, there would be no need to incorporate another new level of segmentation, and the process should avoid selecting, within the sample, the municipality or area whose service is characterised by a feature that is not applicable to the majority of the stratum of which it is a part.

Two groups of elements would have to be assessed:

- o Elements associated with the Segregation Model: those cases in which there is a difference in the number and/or types of waste fractions, such as organic waste, textile waste, organic/inorganic model, etc.
- o Elements associated with the level of service, such as containerisation, distances between containers, collection frequencies, etc.

As we can see, there may be many scenarios and cases involved in level 3. In general, previous studies have not resorted to segmentations based on the characteristics of the collection service.

Source of information:

- Local agencies.

An example of level 3 is provided below, which builds on example 1.2.

- Example: Within the urban municipality, there is an area with a waste separation model that differs from the rest, in that it includes a container for organic waste. To account for it, a new type of segmentation for this area is added that results in the final segmentation shown below for the area studied in example 1.2:
  - o Urban
  - o Urban commercial
  - o Urban organic container
  - o Rural agricultural
  - o Tourist inland
  - o Tourist coast

As we have been stating in the segmentation procedure proposed, there are various types of data sources. This list summarises the main ones that can yield the data needed to conduct the segmentation:

- National Statistics Institute (INE).
- Directorate General of the Property Registry. Ministry of Finance.
- Statistics institutes of the regional governments and of Ceuta and Melilla.
- Ministry of Agriculture, Fisheries and Food.
- www.fichassocioeconomicas.com (Economic Council).
- Municipal websites.
- SIGPAC viewer. Spanish Agricultural Guarantee Fund.
- Iberpix viewer. National Geographic Institute.
- Ministry for Ecological Transition
- Local agencies and city councils.
- Others that can be identified.

Regardless of the methodology indicated above, another option is to do the segmentation using mathematical models, such as "**cluster analysis**", based on the K-means algorithm (MacQueen, 1967). The method involves a grouping method that seeks to partition a set of n observations into k groups.

In our context, this analysis can, based on demographic and socioeconomic variables defined for each population area, be used to segment these data variables into groups that have not been predefined, meaning the model itself is responsible for creating homogeneous groups (clusters or strata) based on the initial data.

Annex II presents the methodology for the aforementioned "cluster analysis" that is applicable to the segmentation of territories, and discusses the pros and cons of this particular method.

Practical example: We propose segmenting the practical example following the methodology set out in this section, and dismiss doing so based on mathematical models (cluster analysis).

The first classification by municipality (based on its inhabitants) is as follows:

- Urban
- Rural

Because there is a commercial area, which accounts for more than 11% of the total waste generated, this area is considered in the segmentation. Also taken into account are the rural areas of a residential nature (municipalities 1 to 15 indicated above) and those where the predominant activity is agriculture (municipalities 16 to 25). The final segmentation would be as follows:

- Urban
- Urban commercial
- Rural residential
- Rural agricultural

2.4 SAMPLE SIZE

Next, we will proceed to calculate the sample size, that is, to determine the number of samples necessary for the study to be representative of the total population, taking into account the segmentation carried out in section 2.3, since the samples must represent each stratum before subsequently proceeding to extrapolate the results to the total population.

This is done by considering the stratified random sample indicated above, although the way to calculate the sample size indicated in this section may be valid if the simple random sample method is used instead.

To calculate the sample, we will use the following assumptions (they are explained in detail in Annex II):

- That the population distribution is normal.
- That two possibilities exist to calculate standard deviation (σ), which measures how the values of a sample variable are dispersed:
  1) Existing information is available from other, similar waste characterisations: if so, the available data will be used to establish the dispersion of the sample through the standard deviation (σ), as well as the arithmetic mean of the sample population ($\bar{x}$)[3], which is needed to calculate the standard deviation.
  2) If no existing information is available from similar characterisations, the following alternatives are proposed:
     - Use the information available from other waste characterisations carried out in areas that have similar characteristics, so as to determine the value of the standard deviation (σ) and mean ($\bar{x}$).
     - In the absence of the above information from similar studies, consider the information provided in the Pilot Plan for Characterising Household Urban Waste of the Ministry of Agriculture, Food and Environment (now the Ministry for the Ecological Transition), to establish the value of the standard deviation (σ) and mean ($\bar{x}$). These values are as follows for each waste fraction:

	Light packaging	Glass (kg)	Paper/Cardboard (kg)	FORM (kg)	Other waste (kg)
Standard deviation (σ)	35.93	17.17	16.09	42.26	21.68
Arithmetic mean ($\bar{x}$)	185	211	180	196	190
Sample size	250	200	200	250	250

Table 5. Standard deviation and arithmetic mean. Pilot Plan to Characterise Urban Waste

The quantities indicated in the table above correspond to the material in each of the fractions.

The equation used to calculate the sample size, taking into account the assumptions listed above, is given below:

$$n \geq \frac{N \cdot Z^2 \cdot \sigma^2}{(N-1) \cdot e^2 + Z^2 \cdot \sigma^2} \qquad (1)$$

[3]See Annex II (Statistical methodology for preparing the Sampling Plan)

Where:

n = the size of the sample to be calculated (number of samples)

N = population size (kg of urban waste generated in the strata to be sampled, divided by the amount of waste characterised per sample).

Z = confidence value (confidence level).

σ^2 = variance we expect to find in the population. This figure is obtained beforehand from the standard deviation.

e = maximum allowed margin of error, as a percentage of the arithmetic mean ($\bar{x}$).

To apply the formula, the values of the following parameters have to be set:

Confidence level (*Z*): This is the probability that the true value of the parameter estimated in the population lies within the confidence interval obtained, so a different value is used depending on the confidence level. The most frequent values are:

- 90% confidence level, $Z = 1.645$
- 95% confidence level, Z = 1.96
- 99% confidence level, Z = 2.575

The confidence level is usually set to 95%, meaning Z = 1.96.

It should be noted that if the confidence level is increased, so does the sample size.

Margin of error (*e*): This is the interval within which we expect to find the parameter being measured. The studies consulted typically use a value of 5%; in any case, it should normally be less than 10%.

Keep in mind that if the error is reduced, the sample size increases.

For practical purposes, the equation given above has to be applied to each stratum (as indicated in section 2.2) and for each of the waste fractions to be studied. This will yield the number of samples to be characterised by stratum and by fraction.

Example:

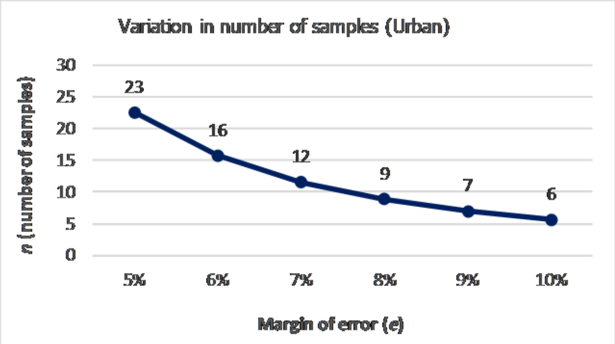
The minimum number of samples needed (n) for an (urban) stratum is calculated using the statistical formula (1).

The values of the confidence level (Z) and margin of error (e) used are the recommended 1.96 and 5% respectively, while the values of the standard deviation (σ) and mean ($\bar{x}$) were taken from previous studies. Each sample will contain 250 kg to be characterised.

The following values are plugged into fomula (1):

	N	Z	σ^2*	$\bar{x}$*	E	n
Urban	3,566	1.96	495	183	5%	$n \geq \frac{3.566 \cdot 1{,}96^2 \cdot 495}{(3.566\text{-}1)\cdot(0{,}05\cdot 183)^2+1{,}96^2\cdot 495} \geq \mathbf{23}$

If we increase the margin of error gradually up to a maximum of 10%, we see that the smaller the margin of error, the larger the sample size.



Practical example:

As indicated in the previous example, the minimum number of samples of each segmentation and fraction was calculated for the practical example, yielding the following results:

n (minimum nº of samples)	Urban	Urban commercial	Rural residential	Rural agricultural
Light packaging	15	6	11	10
Other waste	23	11	17	15

The calculation of the samples takes into account the values for standard deviation (σ) and mean ($\bar{x}$) obtained from similar studies, which are as follows:

	Urbano		Urbano comercial		Rural residencial		Rural agrícola	
	Media	D. típica	Media	D. típica	Media	D. típica	Media	D. típica
Envases ligeros	183	18,0	180	11,6	189	15,8	178	14,1
Fracción resto	186	22,5	190	16,4	189	19,6	183	18,0

2.5 GEOGRAPHIC SELECTION OF SAMPLES AND TEMPORAL DISTRIBUTION

Based on the number of samples determined using formula (1) in the previous section, for each stratum and fraction, the municipalities or areas where said samples will be taken are chosen at random.

As for the temporal distribution, depending on the goal of the study, the samples can be taken over a short period or distributed throughout the year.

In the case of studies of the composition of municipal waste in a territory, and to take into account the seasonal effect (due to differing consumption depending on the time of year due to tourist activity, etc.), an annual distribution is recommended that can be adapted to a **four-month distribution**[4] over the calendar year (periods: January-April, May-August and September-December), as well as to a quarterly distribution adjusted to the seasons. In other specific cases, such as when identifying segregation errors, it may be more convenient to cluster the samples in a short period.

Practical example:

Once the minimum number of samples to be characterised is obtained, certain municipalities are selected at random (random sampling) for each of the segmentations considered.

As an example, in the Rural Residential segmentation (stratum), samples will be taken in municipalities 1, 8 and 13 every four months.

[4] For localities with a high variability in waste generation per quadrimester, the number of samples may be distributed based on the quantities generated in each quadrimester.

2.6 SAMPLING SYSTEM

Once the study territory has been segmented and the sample size calculated, various sampling systems or procedures can be used to carry out the waste composition study. Which one is selected will basically depend on the goals set, the features of the characterisation campaign, the resources available and other variables involving aspects like the economy, the availability of information, etc.

When choosing the sampling system, it is important to realize that the result obtained in the characterisation campaign will be extrapolated to all the waste. This means that small deviations in the results can cause the estimates for the total population to be over or under the actual values.

Because of this, as indicated above, it is important that the baseline data for the characterisations be highly reliable so as to avoid deviations in the final results.

There are three main sampling systems:

- Through representative **routes** of each stratum/segment.
- In **pit** - discharge pile at the plant.
- Through **containers**.

The characteristics of each sampling system mentioned are indicated below:

1) Through representative **routes** of each stratum/segment.

This sampling system is most commonly used for waste composition studies in territorial areas of a supra-municipal nature.

It basically involves taking samples of materials from waste collection routes for each of the strata previously defined when segmenting the study area. The samples to be characterised are taken from the collection vehicles for the selected routes. Annex III of this Guide details the procedure.

The route sampling system is mainly intended for composition studies of wide geographic areas of a supra-municipal nature, such as studies in autonomous communities, provinces or groupings of municipalities, where the geographic area being studied has to be segmented into strata or segments, as indicated in section 2.3 above.

For this procedure to yield representative samples, two conditions must be met: first, each collection route from which the sample is taken has to correspond to a single stratum or segment (that is, if the collection route usually services municipalities that belong to different strata/segments, when a sample has to be taken, the usual collection route must be modified so that only the waste from the municipality(ies) belonging to the corresponding stratum is collected); and second, generation information is available for each collection route so that the characterisations can be correctly assigned to the amount generated.

Due to the stratification process, all the strata or segments are considered homogeneous, meaning that any selected route will be representative of the sampling, as long as the conditions specified above are met.

The main advantages of sampling using routes are the ease of the process and that it does not require arranging for specific collection/movement of containers, and thus it is also less costly.

The main drawback of this system is that, unless there are separate collection routes for waste of commercial/services origin, there would be no way to differentiate between household and commercial waste. Another important point to consider is the need to properly homogenise the material collected by the vehicle so that the sample selected is as representative as possible.

2) In **pit** - discharge pile at the plant.

Sampling a pit or discharge pile at a facility consists of obtaining the sample to be characterised directly from the pit or intake pile at a waste treatment plant. As in the previous case, Annex III of this Guide presents the procedure in detail.

Since this is the point where the waste generated throughout the territory served by the plant is received, the samples selected will not be representative of a municipality type or of a specific area.

Bearing this limitation in mind, this procedure is intended for studies in which it is not necessary to know the origin of the waste, such as studies to size or modify a waste treatment plant.

The main advantage of the pit-pile sampling system is that the collection process is entirely unaffected. And the main limitations are that it is not suitable for obtaining the composition of a specific territory, and that biases in the composition may occur, since heavier materials will shift to the bottom of the waste pile.

3) Through **containers**.

The container sampling system basically consists of obtaining samples for characterisation directly from pre-selected containers. This procedure is explained in more detail in Annex III of this Guide.

The image below shows a typical container sampling process:

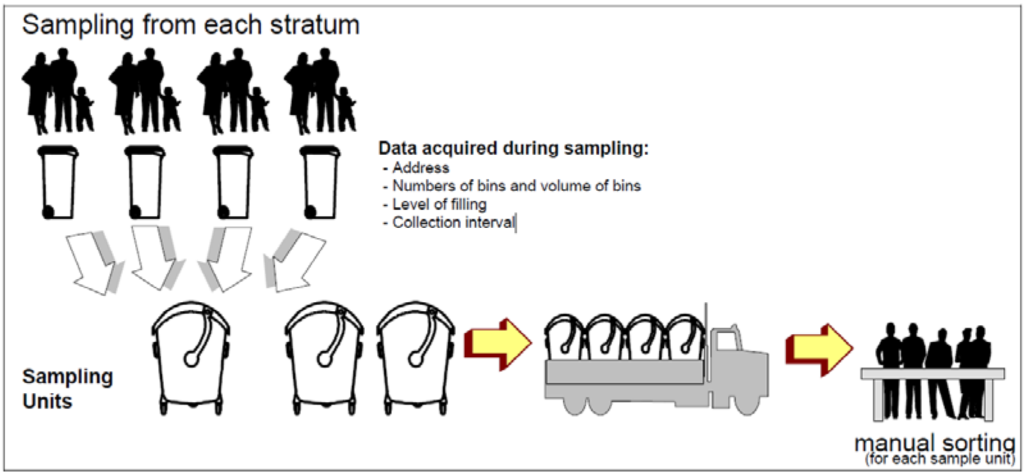


Figure 2. Typical container sampling process. Source: Methodology for the Analysis of Solid Waste (SWA-Tool)

The container sampling system can be used both in studies of the composition of supra-municipal areas, as well as in other geographically smaller areas, such as municipalities, neighbourhoods, etc.

Compared to the route sampling procedure, container sampling is more complex, mainly due to the work that has to be done before the characterisation (the precise location of each container has to be known using a computer system that associates them with a specific area, specific users, etc.), and to the process of moving the containers to the place where the characterisation will be carried out. On the plus side, this sampling system yields results with the highest granularity at the point of origin (it can, for example, differentiate between household and commercial waste).

The main advantage of the container sampling system is that the composition and specific generation can be determined by the type of waste generator, by neighbourhood, by street, and can thus be used to make improvements to the service provided in these areas. Possible drawbacks include the greater complexity of the process, especially if it is a composition study in a supra-municipal territory, and its limited utility if rubbish is collected in bags, door to door.

3 Execution of the characterisation work

This section describes the procedure for doing the characterisations, from compiling the information needed to plan them, to selecting and preparing the sample, processing it and filling in the Characterisation Sheet, where the resulting data are documented

When selecting the sample, it is important to note whether it comes from a collection vehicle or directly from a container.

3.1 Planning and coordination

3.1.1 Obtaining information on waste generation and collection

If a system is used that relies on representative **routes** for each stratum/segment, the following information is needed to choose the routes from which the samples will be taken:

- Collection routes: municipalities or areas that are included in the collection. This information is necessary to plan the sampling process.
- Generators of the waste collected on the route: household, commercial, industrial and others.
- Route information: containers to be collected, type, number and itinerary.
- Collection frequency and times.
- Collection vehicle.
- Amount of waste collected on each route.
- Additional information.

The information collected will be used to determine the number of different routes, by sample population and stratum, that are selected based on the goals of the study in question.

Below is a series of recommendations to consider when choosing the routes:

- Bear in mind the variability of the territory being studied to ensure that the different segments are adequately represented. However, the diversity of waste generation will be reconciled with the greater proportion of waste that is generated in certain areas.
- When possible, take into account the type of collection (door to door/container), as well as the container types and their capacity, when determining the routes. This can influence the presence of improper waste (containers with more capacity and a larger opening allow the public to dispose of unsorted waste, making it more likely to find improper waste).

- To the extent possible, samples will not be taken on dates that may influence the variability of the waste composition, such as Mondays, weekends, holidays, days after holidays, etc., unless this is necessary to achieve an adequate level of representativeness (in which case the sample must be weighted with the generation). Likewise, the samples must be distributed between the days of the week, in keeping with the weekly collection schedule. Seasonal changes to the frequency in areas with a high population variability due to seasonality should be taken into consideration.

Once the representative routes are identified, those that are necessary to cover the total allocation of characterisations will be selected at random (since there are likely to be more routes than the number of characterisations to be carried out).

If the sample is taken from the **intake pit** at the plant, the following information should be collected in advance:

- Days the waste is received.
- Peak and off-peak reception hours.
- Operating schedule of the plant.
- Average amount of waste entering the plant daily.
- Stay time of the waste in the pit.
- Service outages of the plant.

If the sample is taken from the **container**, based on the defined stratification and the information collected, the representative containers needed to complete the sample will be selected. To this end, the following information should be compiled for the selected containers:

- Location of the containers.
- Container type and volume.
- Visual estimate of the fill level percentage.

WASTE COLLECTION INFORMATION FORMS (1)

LIGHT PACKAGING											
ROUTES	Municipalities or areas	Generators (household/commercial and services/industrial, other)	Container type	Nº of containers	Description of itinerary	Frequency	Schedule	Licence plate	Destination	Amounts collected annually (kg)	Remarks
Route 1											
Route 2											
Route 3											
Route 4											
Route 5											
Route 6											
Route 7											
Ruta 8											
Route 9											
Route 10											

PAPER/CARDBOARD											
ROUTES	Municipalities or areas	Generators (household/commercial and services/industrial, other)	Container type	Nº of containers	Description of itinerary	Frequency	Schedule	Licence plate	Destination	Amounts collected annually (kg)	Remarks
Route 1											
Route 2											
Route 3											
Route 4											
Route 5											
Route 6											
Route 7											
Ruta 8											
Route 9											
Route 10											

GLASS											
ROUTES	Municipalities or areas	Generators (household/commercial and services/industrial, other)	Container type	Nº of containers	Description of itinerary	Frequency	Schedule	Licence plate	Destination	Amounts collected annually (kg)	Remarks
Route 1											
Route 2											
Route 3											
Route 4											
Route 5											
Route 6											
Route 7											
Ruta 8											
Route 9											
Route 10											

"OTHER" FRACTION											
ROUTES	Municipalities or areas	Generators (household/street cleaning/parks and gardens/markets/other)	Container type	Nº of containers	Description of itinerary	Frequency	Schedule	Licence plate	Destination	Amounts collected annually (kg)	Remarks
Route 1											
Route 2											
Route 3											
Route 4											
Route 5											
Route 6											
Route 7											
Ruta 8											
Route 9											
Route 10											

ORGANIC FRACTION											
ROUTES	Municipalities or areas	Types of waste (household/food services/other)	Container type	Nº of containers	Description of itinerary	Frequency	Schedule	Licence plate	Destination	Amounts collected annually (kg)	Remarks
Route 1											
Route 2											
Route 3											
Route 4											
Route 5											
Route 6											
Route 7											
Ruta 8											
Route 9											
Route 10											

Source: Working group

Figure 3. Waste collection information form (1)

WASTE COLLECTION INFORMATION FORMS (2)

LIGHT PACKAGING

ROUTES	Amounts collected (t)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual total (t)
Route 1													
Route 2													
Route 3													
Route 4													
Route 5													
Route 6													
Route 7													
Ruta 8													
Route 9													
Route 10													
Total (t)													

PAPER/CARDBOARD

ROUTES	Amounts collected (t)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual total (t)
Route 1													
Route 2													
Route 3													
Route 4													
Route 5													
Route 6													
Route 7													
Ruta 8													
Route 9													
Route 10													
Total (t)													

GLASS

ROUTES	Amounts collected (t)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual total (t)
Route 1													
Route 2													
Route 3													
Route 4													
Route 5													
Route 6													
Route 7													
Ruta 8													
Route 9													
Route 10													
Total (t)													

"OTHER" FRACTION

ROUTES	Amounts collected (t)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual total (t)
Route 1													
Route 2													
Route 3													
Route 4													
Route 5													
Route 6													
Route 7													
Ruta 8													
Route 9													
Route 10													
Total (t)													

ORGANIC FRACTION

ROUTES	Amounts collected (t)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual total (t)
Route 1													
Route 2													
Route 3													
Route 4													
Route 5													
Route 6													
Route 7													
Ruta 8													
Route 9													
Route 10													
Total (t)													

Source: Working group

Figure 4. Waste collection information form (2)

3.1.2 PLANNING, ORGANISATION AND COORDINATION

In order for the characterisation to have the least possible impact on the normal waste collection and treatment process, a work plan must be devised to coordinate the parties involved, specifically, the manager/owner of the facility where the work is to be carried out and the person in charge of the field team. The work should also be coordinated with the collection company from whose vehicle the sample is to be taken to ensure it is received properly, or, if the samples are taken from containers, the collection times should be coordinated so the containers with the most waste can be emptied.

It is important that both the manager/owner of the facility and the person in charge of the field work know what work is to be done, the methodology to be followed and the resources needed to ensure the process goes smoothly. For proper coordination, it is important to make sure:

- That the place where the sample is to be taken and the work is to be carried out satisfies the necessary conditions.
- That the sample to be analysed will be available at the correct date and time.
- That all the technical resources needed to carry out the work are available.
- That the field staff have adequate training and the proper equipment.
- That the Occupational Risks associated with the work to be done have been evaluated and that the appropriate measures have been taken for both the field team and the rest of the facility personnel to do the work safely.

As for the requirements applicable to the area used for the characterisation, the following should be considered:

- Large area that allows working with the sample, installing the necessary equipment (screening, sorting and weighing), and the movement of both people and machinery. In order to minimise risks, the work area should be closed off and kept in an orderly condition.
- Flat area, paved, protected and sheltered from the weather (wind, rain, etc.), as well as from birds and insects. It should also be well lit and ventilated.

The sections that follow describe the most relevant considerations involving the remaining aspects to take into account.

3.2 WASTE CHARACTERISATION METHODOLOGY

3.2.1 PERSONNEL

As previously indicated, the characterisation work (also called field work) requires the personnel assigned to it to have been trained beforehand on the tasks and to be provided with all the resources needed to do so.

Under normal conditions (assuming that the characterisations are done using the methodology that is described later), the field team doing the characterisation would have to be composed of at least two people.

As concerns the training, the following minimum training should be given to the field team:

- Training on the procedure to be used in the field, as well as on how to fill in the Sampling Sheet and the Characterisation Sheet, as well as familiarisation training on the *Material Differentiation Guide* (the one shown in Annex III or similar).
- Proper training on Occupational Hazard Prevention, that is, knowing the risks associated with the work to done, the Personal Protective Equipment (PPE) to be used and how to use it.

Machinery is typically needed to homogenise and quarter the sample. This machinery is normally operated by personnel from the facility where the characterisations are done. If this is not possible, the person on the work team who operates the machinery must be properly qualified to do so (backhoe, grapple) if necessary, and have the permits specified in Royal Decree 818/2009 of 8 May, which approves the General Regulations for Drivers[5].

Before the work is authorised to start, the training records should be checked and the relevant PPE should be verified to be available. While specific requirements may apply to certain studies, in general, the field team should be equipped with:

- Safety footwear, with non-slip sole and anti-perforation insoles.
- Helmet.
- Safety glasses (not required if wearing a helmet with an eye shield).
- Puncture resistant safety gloves.
- Mask to filter organic vapours, dust particles, etc.

[5]A class-B permit allows the holder to drive vehicles that weigh between 3500 and 4250 kg after passing a test of skills and behaviour. This test may be replaced by completing specific training, under the terms specified by Order of the Minister of the Interior.

- Hearing protection.
- Safety clothing/uniform, ideally, high visibility. At a minimum, a high-visibility vest will be worn over the uniform.

3.2.2 MATERIAL RESOURCES

Regarding the material resources to be provided, a distinction must be made between field work and laboratory work (described later).

In relation to the **field work**, the following considerations apply:

- Sampling resources: the material will vary depending on its origin (pit, discharge pile), and specific machinery (backhoe, grapple) may be required. In the case of container sampling, these types of resources are usually not necessary.
- Means for homogenising and quartering the sample: loader.
- Means for doing the characterisation proper:
  - ✓ Electronic or mechanical scale with a calibration certificate, with a sensitivity of at least 10 g and a maximum tare of 60 kg.
  - ✓ Electronic or mechanical scale with a calibration certificate, with a sensitivity of 1 g and a maximum tare of 3 kg, for smaller size/weight fractions or fines.
  - ✓ 50 mm mesh screens.
  - ✓ High-resistance plastic canvas.
  - ✓ Sorting table large enough to do the work properly.
  - ✓ Shovels, rakes and brooms.
  - ✓ Miscellaneous materials: magnets, gauge, cutting utensils, can opener, labels, indelible markers, etc.
  - ✓ Containers for sorting the different waste fractions.

Materials will also be needed to assist in the field work:

- Digital camera.
- Other consumables (computer equipment, wiring for the equipment, calculator, etc.).

In general, the following considerations should be taken into account:

- Before beginning the characterisation, the containers used to separate the fractions should be tared.
- For waste with a moisture content (e.g., organic matter), the use of metal or plastic containers is recommended in order to prevent the container from absorbing any moisture.

The **laboratory work** needed for the complementary tests (determination of moisture, dirt and volatile solid content, as specified in another section of the Guide) requires:

- Hermetically sealable plastic bags for transporting the sample.
- Precision scale (accurate to at least 0.05% of the mass to be weighed).
- Oven that is capable of holding a uniform temperature while the moisture is extracted from the sample.
- Containers for transport and analysis (test tubes) impervious to water vapour and made of a material that is impervious to any change in the testing conditions.

3.2.3 CHARACTERISATION PROCEDURE

The characterisation procedure consists of determining the composition of a waste sample by quantifying the amounts and proportions of the different fractions that comprise it.

The process begins with receiving or collecting the sample, which will be obtained from:

- The collection vehicle upon its arrival at the waste treatment facility (route sampling system).
- The pit at the facility.
- Pre-selected waste containers.

The waste will be characterised, depending on its source, using different methodologies, as detailed in Annex III. The most representative method for each case is recommended below.

1) Taken from **collection vehicle** (route sampling system):

   This method is applicable to all the fractions covered by the Guide: light packaging, paper/cardboard, glass, other and organic matter.

   Various methodologies employed nationally were used to identify a commonly accepted and widely used work procedure that we recommend adopting for the purposes of this Guide.

The procedure consists of the following steps:

- Once the lorry is weighed, the sample is dumped from the vehicle and deposited on the surface set up to do the characterisation.
- The sample is homogenised using mechanical means (with the help of a loader or similar).
- Waste weighing approximately 1,000 kg is selected.
- The sample is homogenised and divided into four parts.
- Material is taken from two diametrically opposite quarters chosen at random. This material, weighing about 500 kg, is spread out, any bags still closed are opened, and a second homogenisation and quartering process is done.
- About 125 kg is taken from two opposite quarters chosen at random. This will yield a 250-kg sample, the contents of which will be separated into different fractions. While this quantity is the usual sample size, some experiments have been conducted to assess whether reducing the size results in a loss of representativeness, as noted in point 3 of this section.
- Separate the materials manually and weigh them.
- Document the results in the Characterisation Sheet.

2) Taken from **intake pit**:

This procedure is done in those cases in which knowing the source of the waste is not necessary, such as when the goal of the study is to size or redesign a waste plant. This procedure is not recommended for all fractions, and should be used, depending on the methodologies consulted, for the light packaging and "other" fractions.

This procedure has the same steps as when the waste is taken from collection vehicles, with the exception of the sample taken from the pit, which is described below:

- The sample will be homogenised inside the pit, using the claw.
- The claw will be used to obtain approximately 1,000 kg of material. These waste samples will be taken from various points and at different heights in the pit.
- These 1,000 kg of material will be deposited on a clean and paved surface (or atop a waterproof canvas), where it will be mechanically spread out and homogenised.
- The same procedure as that carried out when the waste is taken from a collecting vehicle is then used.

3) Taken directly from the **container**

This procedure is applicable to all the fractions covered by this Guide. It consists of the following steps:

- The pre-selected containers are tagged with their place of origin.
- Upon arrival at the plant/facility, each container is weighed and the volume of waste from each is recorded to ensure that the different characterisations are comparable.
- The entire content of each container is dumped on a clean, paved surface.
- This procedure does not involve dividing the waste into quarters; instead, the material in all of the containers is manually separated, one by one.
- The same procedure as that carried out when the waste is taken from a collecting vehicle is then used.

The recommendations below are provided in an effort to standardise criteria and address certain aspects that could hamper the interpretation of the characterisation results:

- **Treatment of bulky materials**: given the large size of this fraction compared to the other fractions and how their presence could affect the characterisation, these materials have to be processed differently by separating them before quartering in order to determine their total weight and distribute them proportionally with the kg from the vehicle.
  A criterion for defining bulky waste is an item whose three sides add up to more than 1 meter. Examples include furniture (chairs, tables, etc.), construction waste (masonry, pipes, etc.), automotive waste (wheels, seats, bumpers, etc.) and mattresses.
  The information will be entered in the field log so that the sample results can be adjusted as necessary afterward.
  The smaller bulky items will be entered in the corresponding section of the characterisation sheet.

- **Treatment of unclassifiable waste**:
  Once all the fractions have been separated, the result is a mixture of materials that, due to their small size, will be very difficult to classify as a whole.
  To facilitate this process, a volumetric sieve should be used during the characterisation, in keeping with a defined granulometry criterion. A 50-mm mesh size should be used, as this is the size that is being used in some studies.

Once this material mixture is sifted:

- Any material that does not pass through the sieve should be fully characterised.
- The material that does pass through the sieve is what we will call "fines". The following characterisation procedure applies to this fraction:
    - If it is ≤ 20 kg, a 2-kg representative sample is taken.
    - If it is > 20 kg, a representative sample weighing 10% of the total mass is taken.

  A new separation process will be carried out involving that sample to try to separate the materials as much as possible and assign them to their corresponding fraction. The rest of the fraction will be unclassifiable.

According to the waste composition studies consulted, the percentage of "other" waste not associated with any category should be at most 10% of the total waste, while the unclassifiable material should be at most 7%.

- **Granulometric separation:**
  In addition to what was previously established for treating the "fines", for specific goals, such as sizing the trommels when designing a treatment plant, sieves of different sizes should be used (e.g., <90 mm, 90-200 mm and >200 mm).

- **Reduced sample size:** as described in the characterisation procedure in this Guide, the sample size normally used in Spain is 250 kg for all fractions, which may vary in the case of paper/cardboard or glass, although experiments have been conducted to analyse the impact that working with smaller sample sizes could have on the results.

  As an example, we note the studies carried out by ECOEMBES on samples of light packaging. Specifically studies conducted over successive periods (2014-2017) considered the impact on the variability of the proportion of the requested material (the material that should be deposited in the yellow container) in samples of light packaging when reducing the characterisation sample size to 150 kg, without changing the homogenisation, quartering and separation procedures and keeping the error margin within acceptable values that must not be exceeded, 5% in this case, with a 95% confidence level.

  The analyses carried out found that a similar accuracy can be obtained, at a lower cost than the usual method, by reducing the sample size from 250 kg to 150 kg.

  It was also observed that reducing the amount of material analysed increased the variability between characterisations, which could require increasing the number of samples taken. This would not affect the accuracy of the estimate of the desired material, since the more samples, the more information that is available on the waste, which could enhance the collection procedure.

If the goal is to modify the sample size with respect to other fractions for samples taken directly from the collection vehicle, we recommend that, as was done for the light packaging fraction, the characterisation of a full load be contrasted to verify that the variability of the samples from the same vehicle is much lower than the variability of samples from different vehicles.

3.2.4 SAMPLING AND CHARACTERISATION SHEETS

During the characterisation work, it is important to document both the procedure carried out and to record the composition data for each fraction.

To do this, two sheets are used:

- Sample Sheet: used to document the field work.
- Characterisation Sheet: used to identify the different materials or fractions into which the waste is classified, as well as their weight and percentage.

The Sample Sheet proposed is based on the *UNE EN 14899:2007 Standard*. It consists of the following parts:

- General information: contains the information involving the parties involved in the characterisation work.
- Waste: documents and identifies the fraction in question and its origin.
- Characterisation methodology: collects the information related to the characterisation work itself (place, date and time, equipment used, etc.).
- Methodology for taking samples for analysis: refers to the information involving the samples that will be taken for laboratory analysis (date and time, equipment used, types of analysis, laboratory identification, etc.).

The sheet proposed for collecting this information is provided below:

SAMPLING SHEET	
Reference:	Date:
GENERAL INFORMATION	
Promoter:	Waste collection and/or management entity:
Facility:	Manager/Owner of the facility:
Other parties involved:	
Characterisation work done by:	
WASTE	
Fraction:	
Source of the waste (Vehicle/Pit/Container):	
Vehicle registration/Route:	
CHARACTERISATION DATA	
Date and time of the work:	
Equipment used:	
Sample size (kg):	
Observations during the work:	
COMPLEMENTARY TESTS	
Date and time of sample:	
Equipment used:	
Size of analysis sample (kg):	
Type of analysis (Moisture/Dirt/Volatile solids):	
Classification of the sample(s):	
TESTING LABORATORY	
Name and address	Sample shipment date:

Source: Prepared internally based on the UNE EN 14899 Standard

Figure 5. Example Sample Sheet

As for the Characterisation Sheet, in order to adapt it to different studies, it features a modular design, offering initial levels (level 0 and level 1) whose categories can be broken down in more detail, depending on the desired goal.

As a result, levels can be added to these large groups to offer more detailed sub-categories and less grouping of materials. It is important to bear in mind that greater differentiation will entail a higher error margin and have a greater impact on the biases inherent to the sampling process (see Annex VI):

The proposed sheets are based on the sheet of the Ministry's Pilot Plan, supplemented with the sheets used in the waste composition studies carried out in different Autonomous Communities.

A sample Characterisation Sheet is shown below:

CATEGORIES			
Level 0	Level 1	KG	%
ORGANIC AND SIMILAR MATTER	ORGANIC MATTER		
	GARDENING WASTE		
CELLULOSE	CELLULOSE		
PAPER/CARDBOARD	PAPER/CARDBOARD PACKAGING		
	NON-PACKAGING PAPER/CARDBOARD		
	FOOD/BEVERAGE CARTON		
PLASTIC	PLASTIC PACKAGING		
	PLASTIC PACKAGING (except garbage bags)		
	NON-PACKAGING PLASTIC (garbage bags)		
GLASS	GLASS PACKAGING		
	NON-PACKAGING GLASS		
METALS	METAL PACKAGING		
	NON-PACKAGING METALS		
WOOD	WOOD PACKAGING		
	NON-PACKAGING WOOD		
TEXTILES	TEXTILES		
BATTERIES	BATTERIES AND ACCUMULATORS		
OTHER WASTE	BULKY		
	WEEE		
	SCRAP FROM MINOR CONSTRUCTION		
	OTHER WASTE		
	UNCLASSIFIABLE MATERIAL		
Remarks:			

NOTE 1: Depending on the goal of the study, some "Level 1" categories could be broken down in greater detail as per the attached tables
NOTE 2: In some studies, the "Other Cellulose (Tissue)" fraction has been added to the organic matter fraction

SUB-CATEGORIES OF ORGANIC MATTER
FOOD WASTE
GARDENING WASTE
OTHER ORGANIC MATTER

SUB-CATEGORIES OF CELLULOSE
SANITARY TEXTILES
OTHER CELLULOSE (Tissue)

SUB-CATEGORIES OF PAPER-CARDBOARD
PAPER-CARDBOARD PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
PAPER-CARDBOARD COMMERCIAL-INDUSTRIAL PACKAGING
NON-PACKAGING PAPER/CARDBOARD
FOOD/BEVERAGE CARTON

SUB-CATEGORIES OF PLASTIC PACKAGING
PET PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
NATURAL HDPE PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
COLOURED HDPE PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
PVC PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
FILM (except single-use bags) PROCESSABLE WITH HOUSEHOLD WASTE
COMMERCIAL/INDUSTRIAL FILM
FILM (single-use bags)
PET COMMERCIAL/INDUSTRIAL PACKAGING
NATURAL HDPE COMMERCIAL/INDUSTRIAL PACKAGING
Coloured HDPE COMMERCIAL/INDUSTRIAL PACKAGING
OTHER PLASTIC PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
OTHER COMMERCIAL/INDUSTRIAL PLASTIC PACKAGING

SUB-CATEGORIES OF NON-PACKAGING PLASTIC
PLASTIC PACKAGING (except garbage bags)
NON-PACKAGING PLASTIC (garbage bags)

SUB-CATEGORIES OF GLASS
WHITE GLASS PACKAGING
COLOURED GLASS PACKAGING
NON-PACKAGING GLASS

SUB-CATEGORIES OF METALS
STEEL PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
STEEL COMMERCIAL/INDUSTRIAL PACKAGING
ALUMINIUM PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
COMMERCIAL/INDUSTRIAL ALUMINIUM PACKAGING
NON-PACKAGING FERROUS METALS
NON-PACKAGING NON-FERROUS METALS

SUB-CATEGORIES OF WOOD
WOOD PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE
WOOD COMMERCIAL/INDUSTRIAL PACKAGING
NON-PACKAGING WOOD

SUB-CATEGORIES OF TEXTILES
TEXTILE PACKAGING
NON-PACKAGING TEXTILES

SUB-CATEGORIES OF WEEE
WEEE (Cat. 1 RD 110/2015)
WEEE (Cat. 2 RD 110/2015)
WEEE (Cat. 3 RD 110/2015)
WEEE (Cat. 4 RD 110/2015)
WEEE (Cat. 5 RD 110/2015)
WEEE (Cat. 6 RD 110/2015)
WEEE (Cat. 7 RD 110/2015)

SUB-CATEGORIES OF OTHER WASTE
BULKY
UNCLASSIFIABLE MATERIAL
DIRT AND RUBBLE
CERAMICS
QUANTITY OF PRODUCT IN PACKAGING (SOLID)
QUANTITY OF PRODUCT IN PACKAGING (LIQUID)
VEHICLE BATTERIES
OILS
CHEMICAL PRODUCTS: VARNISHES, PAINTS, GLUES, SOLVENTS,
MEDICINES
OTHER (materials not included in any of the above categories)

Source: Working group

Table 6. Sample Characterisation Sheet

There are fractions that are currently not being routinely taken into consideration in the characterisations, but that, because they will be included in the laws that will soon come into force or due to their special characteristics, may become significant in the medium term, so they are listed below:

- **Food waste**: in some regions of Spain, organic waste is being characterised depending on whether it is food waste or not.

  Directive 2018/851 of 30 May 2018, amending *Directive 2008/98/EC* on waste, contains the requirement to collect bio-waste separately, although the need to take measures in order to reduce food loss and waste is still being studied.

  Regarding the consideration of this flow, at this time there are no defined or accepted criteria for separating it during a characterisation process.

- **Hazardous household waste**: defined as waste that has any of the dangerous characteristics listed in *Annex III of Law 22/2011*, on waste and contaminated soils; however, the European Union law on household hazardous waste is currently under development and there are no established criteria for segregating this type of waste that are applicable to Member States.

  The Waste Directive also includes the requirement to collect hazardous household waste separately by 1 January 2025.

- **Others:**

  - Butts: there is some concern about this material and the large amounts that are present in municipal waste. There are small initiatives that employ recovery and recycling projects to reuse the filter and make other products or materials.
    Research conducted in this area has proposed producer responsibility measures that require these companies to manage the waste generated by their products.
  - Mattresses: another topic that causes debate is that of the mattresses that are deposited in municipal collection containers. Given their volume, it is proposed that these items be treated as bulky waste as per the instructions provided in the previous section.

3.2.5 COMPLEMENTARY TESTS

Complementary tests consist of a set of physical-chemical determinations or analyses that can be carried out to round out the results of a characterisation campaign. The most common tests are:

- Attached moisture/dirt
- Volatile solids

Annex V details the procedure for conducting the complementary tests indicated.

Attached moisture/dirt:

Moisture/dirt is part of the normal waste stream, but even so, it is important to realise that its weight can be significant[6], as is the case, for example, in less dense materials such as paper and plastics.

The moisture/dirt content is determined mainly for the paper/cardboard, plastics, metals and textiles fractions. It is important to note that there is a wide variability in the data associated with the type of material analysed. According to the characterisation studies consulted, plastic film for bags and cellulose are waste types that exhibit a large amount of moisture/dirt, while the waste with the lowest moisture content is metals, and specifically steel.

The moisture/dirt content is calculated as follows:

$$\% \text{ Moisture/dirt} = 100 - \left(\frac{\text{Gross sample weight x 100}}{\text{Gross sample weight)}} \right)$$

The percent of moisture/dirt content is applied to the entire fraction of the associated characterised material, and subtracted from the total gross weight of that material, thus yielding the net weight of each fraction. The result is represented together (moisture/dirt) as one more fraction in the final results.

Volatile solids:

In addition to the moisture/dirt analyses, another of the parameters measured in the laboratory is the volatile solids, although this measurement is not widely done in characterisation studies.

[6]Article 5 of the Commission Decision of 22 March 2005 establishing the formats relating to the database system pursuant to Directive 94/62/EC of the European Parliament and of the Council on packaging and packaging waste.

The calculation is based on including as organic matter the average percentage of volatile solids obtained in the physical-chemical analyses, and then eliminating said percentage from the initial unclassifiable material fraction. This process assumes that all the volatile solids identified in the analyses are organic matter.

Volatile solids are determined as follows:

$$\% \text{ volatile matter} = 100 * \frac{\text{(Gross weight)-(Weight after heating)}}{\text{Gross weight)}} - \% \text{ moisture}$$

The sample is taken mainly from the "other" fraction, although in studies in which the percentage of unclassifiable material from other waste fractions is considered significant, they could be analysed as well.

According to the waste composition studies analysed, the main methods for determining the moisture/dirt and volatile solid contents are as follows:

ANALYSIS	ANALYSIS PROTOCOLS	RESULTS
Moisture/dirt	Determination of moisture/dirt as per the methodology indicated in Annex V. In the case of paper/cardboard, procedure as per the *UNE-EN ISO 287:2018 standard*.	Moisture/dirt (%)
Volatile solids	*EN UNE-15402:2011 Standard, Solid recovered fuels. Determination of volatile matter content*. The samples are collected and prepared as per *UNE-EN 15442:2012, Solid recovered fuels. Sampling methods and UNE-EN 15443:2011, Solid recovered fuels. Methods for preparing the laboratory sample.*	Volatile matter (%)

Table 7. Methodologies for determining moisture/dirt and volatile solids

As indicated earlier, the methodology for carrying out these complementary tests is described in detail in Annex V. Their goal is to standardise how these data are obtained so that the results are comparable, regardless of the scope of the characterisation study.

However, in order to establish some reference values to use if no laboratory analyses are done, a comparative study was conducted of the complementary tests considered in the characterisation studies carried out in various Autonomous Communities. Based on this, the parameter that is analysed the most due to the large effect it has on the results is moisture.

The reference values provided below are based on the moisture-dirt values included in the studies carried out in the Community of Madrid and Galicia in 2015 and 2016, as well as in Catalonia in 2013.

It should be noted that the values are for the "other" fraction, which, once the waste is picked up in the collection vehicles, can lead to the transfer of moisture/dirt between different elements. These values would not be applicable to fractions collected separately.

		RESULTS (*)		
		Arithmetic mean (%)	Minimum (%)	Maximum (%)
Packaging				
	PET	20.41	7.2	38.33
	HDPE	21.77	8.06	58.1
	PVC	23.07	12.43	35.28
	Film	31.37	16.45	49.85
	Single-use bag (film)	48.62	31.28	61.77
	Other plastic	28.45	12.43	44.25
	Steel	17.65	5.41	28.6
	Aluminium	26.17	9.98	46.98
	Drinks carton	28.13	16.05	40.59
Cellulose		42.88	21.27	63.05
Textiles		22.52	8.53	46.43
Non-packaging plastic		13.02	1.85	35.8
Garbage bag film		46.45	25.3	65.7
Commercial/industrial plastic packaging		8.93	4.48	21.45
Commercial/Industrial film		18.24	5.67	28.4
Paper/cardboard		20.38	6.198	34.4

(*) The calculations considered the moisture/dirt values for all the samples from the waste composition studies in Madrid, Galicia and Catalonia.

Source: Working group

Table 8. Reference values for moisture for waste composition studies

Therefore, the values shown in the table above can be used as a reference if the complementary tests related to moisture/dirt are not performed, although the data provided in the table are only intended as a guideline, since the value for a given zone is conditioned by several factors, especially by the weather. The maximum values indicated in the table are for areas with the highest annual rainfall, and the minimum values are for dry areas.

3.2.6 CONSIDERATIONS ON THE RESULTS OF THE CHARACTERISATIONS

It is important to note that there are aspects related to the information obtained on the generation, the selection of the sample, and the performance of the sampling process, that can produce certain biases in the results in relation to the desired objective.

Some of the most commonly identified issues to take into account are discussed below, grouped by study phase, as well as guidelines on how to proceed (note that in some cases, they are interrelated).

1. <u>The aspects involving the aggregation of information to take into account in the segmentation and in choosing the origin of the sample to be characterised</u>: in this regard, we point out certain issues that could give rise to the results being interpreted in a way that does not correspond to reality if disaggregated or detailed information is not available.

- **Issue 1:** Waste generation streams are not segregated by local entities.

  The generation data provided by the entities involved in the process often include within the "other" fraction municipal waste such as bulky waste, waste from cleaning streets, parks, gardens and beaches, waste from minor construction, waste generated by economic activity (markets, shopping centres, hotels and restaurants, industrial parks, etc.). These streams, unless they are part of the collection route, are normally not characterised.

  Taking them into consideration can lead to considering streams with very different compositions in the generation aggregate, and to characterise these streams in a way that does not reflect reality. As a consequence of this, in later phases of the work, when the results are extrapolated to determine the results of the composition study, some streams could be over or underestimated. Depending on the goal of the study, this could entail significant errors.

  To keep this from happening as much as possible, we recommend:

  ✓ Working with the stakeholders (local entities, collection operators or treatment facility managers) to identify the routes within the stream of the "other" fraction where the situation described may occur (that is, identify the trucks that can transport the types of waste mentioned within the "other" fraction) and that may alter the results of the characterisations, and thus of the composition study.

  ✓ Trying to obtain generation and composition references for these less common streams and using them to complement and compare the information, so as to analyse the effects of said streams on the results of composition studies.

- **Issue 2:** Need for specific composition studies in municipalities that are part of a municipal association or some other type of grouping, when the waste from these municipalities is collected jointly.

When these joint waste collections occur, most entities do not have weighing systems in the collection vehicles, which makes it impossible to assign separate generation totals to each municipality. As a result, it is normal to allocate this generation to each municipality based on its population, without taking into account the characteristics of each. This may lead to assigning the same generation per inhabitant to municipalities that may be very different from each other, affecting the results of the composition study when the data are extrapolated.

In order to keep this from happening as much as possible, municipalities should be chosen in the segmentation process whose generation can be estimated independently, either because a different collection system is used or because the entity has a weighing system in the collection vehicles, or such a system can be implemented during the characterisation study, the results of which will be used as a reference and extrapolated for the composition study.

2. Aspects related to the selection of the routes to characterise.

- **Issue 1:** Characterisation of municipalities that do not have independent collection. This issue comes up often, especially in small municipalities that combine waste collection routes with other municipalities, which can be a problem when it comes to characterising the waste that is generated only by that municipality, and therefore may lead to errors in composition studies.

  To keep this from happening as much as possible, we recommend:

  ✓ When planning the characterisation work, consider changing the route by diverting the truck so that it collects the waste from the selected area/municipality, goes to the plant to unload, and then continues with the route for the remaining areas or municipalities. This is the best option, as it would yield specific data for the municipality.

  ✓ That the lorry cover the route as usual and then applying the same composition to the municipalities in the study that are part of the route. However, this is the least desirable option.

- **Issue 2:** Characterisation of municipalities that do not discharge directly to the sorting plant. This situation is quite common since there are many entities that unload their waste at transfer stations, where it is impossible to carry out the characterisation process.

  In order to keep this from happening as much as possible, routes or municipalities should be chosen that unload directly at the sorting plant. This avoids the need to alter the routine collection service, the increase in costs, and the complication of doing characterisations in sites not suited to this work (lack of technical resources in most cases).

3. Aspects related to the performance of the sampling process, that is, criteria adopted during the characterisation process in the field that can affect the results of the composition study when they are extrapolated:

- **Issue 1:** Differentiating between household and commercial packaging (when this separation is relevant to the study and is included in the Characterisation Sheet)

  There are many container types and formats, which makes it impossible to completely differentiate, during manual sorting, between household and commercial/industrial packaging. In general, using a size or volume criterion is not enough, and since there is no other indicator that is simple to apply, the end result is that packaging that is generated in the commercial/HORECA/industrial sector is assigned to household waste.

  In order to keep this from happening as much as possible, and so that the results can be used to determine how much to put on the market, the final considerations should take into account the fact that the figures for waste fractions with this level of disaggregation have a certain bias. The results should be checked against other sources of information, such as waste generation studies that are specific to the commercial sector, so as to validate the order of magnitude of the study results and its effect on the composition study.

- **Issue 2**: Impossibility of completely differentiating packaging and non-packaging streams.

  The difficulty of separating packaging and non-packaging materials for certain fractions, especially for plastics and to a lesser extent for aluminium, either due to a misconception or because they are fragmented or broken, could cause them to be incorrectly assigned.

  In order to keep this from happening as much as possible, and so that the results can be used to determine how much to put on the market, the final considerations should take into account the fact that certain materials could be over or underrepresented in the final result.

- **Issue 3:** Including excessive amounts of materials in the "other" category.

  Sometimes, the fines fraction includes many materials that could be assigned to other fractions, making the final percentage attributed to this category too high.

  In order to keep this from happening as much as possible, a maximum recommended reference percentage for this fraction should be established that, if exceeded, would trigger a specific review of the sample to verify that it does not have an impact on the result, and if it does, reject it.

- **Issue 4**: Multi-material waste.

  Some products/objects present in the waste to be characterised - such as toys or office parts, kitchenware, decoration - are made up of various materials, like metal and plastic pieces. This can also apply to packaging (for example, a PET bottle with a paper label and an HDPE cap, or a steel can with a paper label). When sampling, it is not feasible to sort each component, so it is all assigned to the majority material.

  In order to keep this from happening as much as possible, and so that the results can be used to determine how much to put on the market, the final considerations should take into account the fact that the results for certain materials can be skewed.

- **Issue 5:** Classification of packaging containing a liquid or solid product.

  Packaging that contains product must have this product removed in order to correctly differentiate the materials.

  In order to keep this from happening as much as possible, this information should be documented in the Characterisation Sheet.

- **Issue 6:** Presence of organic matter in the fines fraction.

  The fines fraction consists primarily of sand and organic remains that, due to their granulometry, cannot be completely disaggregated and therefore cannot be computed in the organic matter fraction, causing it to be underestimated.

  Recommendations: Conduct an analysis of the volatiles or use the results from other studies (See section 3.2.5. Complementary Tests).

4. General considerations: In general, before the resulting composition is validated, a comparison should be done using data from past characterisations or information from similar geographic areas, due to the presence of factors that may influence the results and lead to biases. These factors include:

   - Differences arising from the increase of certain fractions due to specific seasonal issues, such as taking samples when trees are being pruned or when their leaves are falling.

   - Differences caused by external conditions, such as the weather. For example, atypically wet or dry conditions can lead to variations in the weights of the different fractions, which must be corrected with a moisture analysis.

3.3 DETERMINATION OF RESULTS

Once all the sections described above have been completed, the final phase of a waste composition study is to determine the results.

This requires extrapolating the values obtained from the samples to the full geographic area of the study. The following working procedure is recommended (it assumes a supra-municipal area, but it would also be valid for a smaller geographic area):

Calculation of the composition by **municipality/area and fraction**:

First, the composition is obtained for each selected municipality/area, for each fraction and for each four-month period, by means of the **arithmetic mean** of the characterisations done in each four-month period. If differentiated information on waste generation is available by routes, the composition could be calculated by using a kilo-weighted characterisations of each route for each fraction.

To obtain the **net composition**, the corrections from the complementary tests (moisture/dirt) are applied using the following formula:

Net weight = Gross weight * (1-percent correction)

Next, the **annual composition** of each **municipality** and fraction is calculated using the **kilo-weighted average** for each quadrimester.

This process is done for each of the municipalities/zones selected in each stratum

Calculation of the composition by **stratum and fraction:**

Secondly, to obtain the composition of each stratum, the results obtained for each of the municipalities/areas that are part of the stratum are weighted using the kilos of generation associated with each of them.

This process must be done for each stratum and fraction.

Calculation of the composition of the **geographic study area and fraction:**

Third, to obtain the composition of each fraction in the entire geographic study area, the results of each stratum are extrapolated by weighting by the kilos of generation in each stratum.

If generation data are not available for all the municipalities/areas of a stratum, the average generation of the selected municipalities/areas is applied to carry out the characterisations.

This process is repeated for each fraction included in the study.

Calculation of the **total aggregate composition of the study area**

The composition of each fraction is used to obtain the total composition by adding the results, taking into account the generation of each.

Below is a diagram of the working procedure described to determine the results for a supra-municipal area.

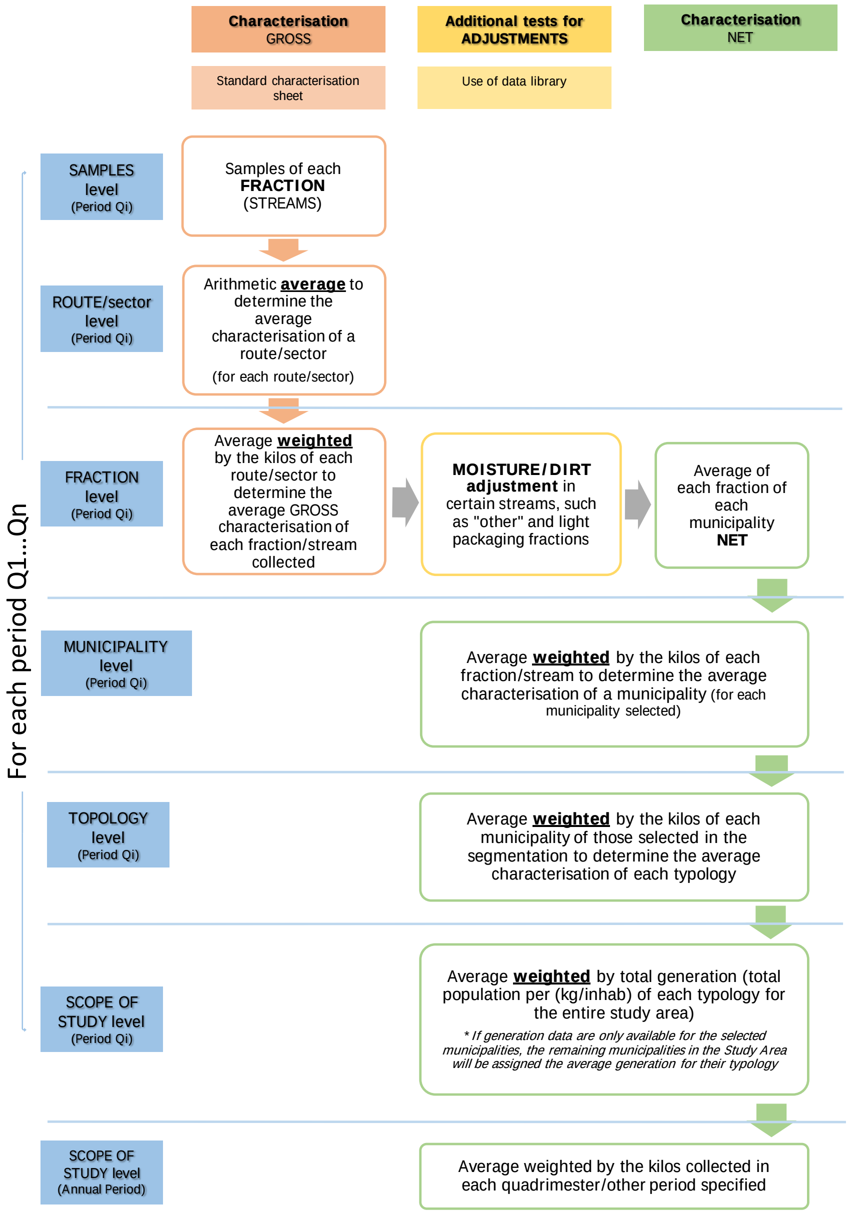


Figure 6. Aggregate composition for a supra-municipal study

Practical example:

In order to simplify the practical example, the results for a stratum and fraction are calculated below, specifically for the **Rural residential** stratum and the **"other" fraction**. It should be noted that the same process would have to be done for the remaining fractions and strata in question.

- **Sample points.**

  The following unit characterisations are carried out in the selected municipalities of the Rural residential stratum for the "other" fraction:

Stratum	Minimum nº of characterisations	Municipality	Unit characterisations	Annual campaigns	Nº of characterisations per campaign
Rural residential	17	Municipality 1	6	Quadrimester 1	2
		Municipality 8	6	Quadrimester 2	2
		Municipality 13	6	Quadrimester 3	2

Practical example (continued):

- **Gross results by municipality.**

The following gross results of the characterisations done for each quadrimester are obtained for each of the selected municipalities.

Since two characterisations are done in each campaign, their arithmetic average was calculated in each municipality. If generation data by route are available, the arithmetic mean of the characterisations of each route should first be calculated and then weighted based on the kilos associated with each route.

The results obtained, by municipality, are as follows:

Municipality 1:

Caracterización		Peso bruto - Q1	Peso bruto - Q2	Peso bruto - Q3	Población de estudio
Nivel 0	Nivel 1	%	%	%	
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	57,12%	56,74%	57,55%	2.040
PLÁSTICO	PET	1,82%	1,45%	1,98%	
	PEAD	0,89%	1,02%	0,49%	
METALES	ACERO ENVASE	5,93%	6,14%	7,89%	
TEXTILES	TEXTILES NO ENVASE	4,89%	4,74%	5,04%	
OTROS RESIDUOS	OTROS	12,30%	13,94%	11,13%	
Toral generación (kg)		180.012	164.582	169.726	

*The percentages do not add up to 100% since only certain materials are shown in this example.

Municipality 8:

Caracterización		Peso bruto - Q1	Peso bruto - Q2	Peso bruto - Q3	Población de estudio
Nivel 0	Nivel 1	%	%	%	
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	56,92%	55,98%	60,05%	1.870
PLÁSTICO	PET	0,99%	2,08%	1,93%	
	PEAD	0,85%	1,20%	1,05%	
METALES	ACERO ENVASE	6,10%	5,78%	5,78%	
TEXTILES	TEXTILES NO ENVASE	4,17%	4,97%	3,25%	
OTROS RESIDUOS	OTROS	14,30%	15,10%	13,14%	
Toral generación (kg)		137.939	171.234	166.477	

*The percentages do not add up to 100% since only certain materials are shown in this example.

Municipality 13:

Caracterización		Peso bruto - Q1	Peso bruto - Q2	Peso bruto - Q3	Población de estudio
Nivel 0	Nivel 1	%	%	%	
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	57,12%	58,19%	54,95%	2.370
PLÁSTICO	PET	1,15%	1,58%	1,77%	
	PEAD	0,63%	0,86%	0,99%	
METALES	ACERO ENVASE	5,20%	5,40%	6,15%	
TEXTILES	TEXTILES NO ENVASE	4,55%	4,71%	4,95%	
OTROS RESIDUOS	OTROS	15,66%	12,30%	13,85%	
Toral generación (kg)		205.969	187.245	230.936	

*The percentages do not add up to 100% since only certain materials are shown in this example.

Practical example (continued):

- **Net and annual composition by municipality.**

To obtain the **net composition**, the laboratory tests (in this case moisture/dirt) were taken into account, with the results being calculated as per the following formula (more examples of complementary tests are provided in Annex V):

*Net weight = Gross weight * (1-percent correction)*

The net composition calculations for Municipality 1 and the first quadrimester (Q1) are provided by way of example:

Caracterización		Peso bruto - Q1	Corrección	Peso neto - Q1
Nivel 0	Nivel 1	%	%	%
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	57,12%	-	57,12%
PLÁSTICO	PET	1,82%	12,00%	1,60%
	PEAD	0,89%	14,00%	0,77%
METALES	ACERO ENVASE	5,93%	11,00%	5,28%
TEXTILES	TEXTILES NO ENVASE	4,89%	13,00%	4,25%
OTROS RESIDUOS	OTROS	12,30%	-	12,30%

Calculation of the **annual composition** in each municipality:

The calculation relies on the weighted average of the generation results obtained in each quadrimester. The results are as follows:

Municipality 1:

Caracterización		Peso neto - Q1	Peso neto - Q2	Peso neto - Q3	Total anual Mun. 1	Población de estudio
Nivel 0	Nivel 1	%	%	%	%	
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	57,12%	56,74%	57,55%	57,14%	2.040
PLÁSTICO	PET	1,60%	1,28%	1,71%	1,54%	
	PEAD	0,77%	0,88%	0,43%	0,69%	
METALES	ACERO ENVASE	5,28%	5,50%	7,05%	5,93%	
TEXTILES	TEXTILES NO ENVASE	4,25%	4,08%	4,36%	4,23%	
OTROS RESIDUOS	OTROS	12,30%	13,94%	11,13%	12,44%	
Toral generación (kg)		180.012	164.582	169.726	514.320	

*The percentages do not add up to 100% since only certain materials are shown in this example.

Municipality 8:

Caracterización		Peso neto - Q1	Peso neto - Q2	Peso neto - Q3	Total anual Mun. 8	Población de estudio
Nivel 0	Nivel 1	%	%	%	%	
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	56,92%	55,98%	60,05%	57,68%	1.870
PLÁSTICO	PET	0,86%	1,83%	1,71%	1,51%	
	PEAD	0,75%	1,03%	0,91%	0,91%	
METALES	ACERO ENVASE	5,45%	5,14%	5,17%	5,24%	
TEXTILES	TEXTILES NO ENVASE	3,61%	4,32%	2,80%	3,58%	
OTROS RESIDUOS	OTROS	14,30%	15,10%	13,14%	14,18%	
Toral generación (kg)		137.939	171.234	166.477	475.650	

*The percentages do not add up to 100% since only certain materials are shown in this example.

Municipality 13:

Caracterización		Peso neto - Q1	Peso neto - Q2	Peso neto - Q3	Total anual Mun. 13	Población de estudio
Nivel 0	Nivel 1	%	%	%	%	
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	57,12%	58,19%	54,95%	56,64%	2.370
PLÁSTICO	PET	1,02%	1,37%	1,56%	1,32%	
	PEAD	0,54%	0,76%	0,85%	0,72%	
METALES	ACERO ENVASE	4,65%	4,82%	5,47%	5,01%	
TEXTILES	TEXTILES NO ENVASE	3,91%	4,07%	4,31%	4,11%	
OTROS RESIDUOS	OTROS	15,66%	12,30%	13,85%	13,98%	
Toral generación (kg)		205.969	187.245	230.936	624.150	

*The percentages do not add up to 100% since only certain materials are shown in this example.

Practical example (continued):

- **Composition by stratum and fraction.**

The composition by stratum and fraction is calculated for the various municipalities for each quadrimester, using the weighted average based on the kilos generated by the municipality.

By way of example, the results obtained for the first quadrimester (Q1) are provided below. The same procedure would be used for the remaining quadrimester and for each stratum.

Caracterización		Q1 - Municipio 1	Q1 - Municipio 8	Q1 - Municipio 13	Q1- Total estrato
Nivel 0	Nivel 1	%	%	%	%
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	57,12%	56,92%	57,12%	57,07%
PLÁSTICO	PET	1,60%	0,86%	1,02%	1,18%
	PEAD	0,77%	0,75%	0,54%	0,67%
METALES	ACERO ENVASE	5,28%	5,45%	4,65%	5,08%
TEXTILES	TEXTILES NO ENVASE	4,25%	3,61%	3,91%	3,95%
OTROS RESIDUOS	OTROS	12,30%	14,30%	15,66%	14,15%
Toral generación (kg)		180.012	137.939	205.969	

*The percentages do not add up to 100% since only certain materials are shown in this example.

The results obtained for each quadrimester and for the **Rural residential stratum as a whole** are as follows:

Caracterización		Q1- Total estrato	Q2- Total estrato	Q3- Total estrato	Total estrato Rural residencial
Nivel 0	Nivel 1	%	%	%	%
MATERIA ORGÁNICA Y ASIMILABLE	RESTOS DE ALIMENTOS	57,07%	57,01%	57,23%	57,10%
PLÁSTICO	PET	1,18%	1,49%	1,65%	1,44%
	PEAD	0,67%	0,89%	0,74%	0,77%
METALES	ACERO ENVASE	5,08%	5,14%	5,86%	5,37%
TEXTILES	TEXTILES NO ENVASE	3,95%	4,16%	3,88%	3,99%
OTROS RESIDUOS	OTROS	14,15%	13,73%	12,83%	13,55%
Toral generación (kg)		523.920	523.061	567.139	

*The percentages do not add up to 100% since only certain materials are shown in this example.

The relevant calculations would be done using the same process for **all the strata** of the fraction in question, yielding the following results:

	Urbano	Urbano comercial	Rural residencial	Rural agrícola
RESTOS DE ALIMENTOS	58,12%	56,75%	57,10%	59,25%
PET	1,65%	1,72%	1,44%	1,48%
PEAD	0,71%	0,85%	0,77%	0,68%
ACERO ENVASE	4,25%	4,95%	5,37%	5,12%
TEXTILES NO ENVASE	3,85%	4,65%	3,99%	4,15%
OTROS	13,15%	12,90%	13,55%	13,95%
Generación (kg)	15.908.750	1.966.250	8.385.375	4.187.350

*The percentages do not add up to 100% since only certain materials are shown in this example.

Practical example (continued):

- **Calculating the composition for the geographic study area.**

  Once the composition by stratum is known, the generation is weighted by kilo and by the population of each stratum to calculate the overall composition of the fraction in question.

	Urbano	Urbano comercial	Rural residencial	Rural agrícola	Total zona estudio
RESTOS DE ALIMENTOS	58,12%	56,75%	57,10%	59,25%	57,91%
PET	1,65%	1,72%	1,44%	1,48%	1,57%
PEAD	0,71%	0,85%	0,77%	0,68%	0,73%
ACERO ENVASE	4,25%	4,95%	5,37%	5,12%	4,72%
TEXTILES NO ENVASE	3,85%	4,65%	3,99%	4,15%	3,98%
OTROS	13,15%	12,90%	13,55%	13,95%	13,35%
Generación (kg/hab)	276,67	262,17	260,01	234,98	264,60
Población total estrato	57.500	7.500	32.250	17.820	115.070

*The percentages do not add up to 100% since only certain materials are shown in this example.

Note that if no generation data are available for all the municipalities in the geographic area, the generation associated with the municipality type, as determined by the study, will be assigned.

The entire process has to be carried out for each fraction (packaging, paper/cardboard, glass and other).

The **final calculation of the composition** of the waste in the geographic study area takes into account all the fractions, and uses the calculation methodology indicated above to yield the final composition result.

Presentation of results

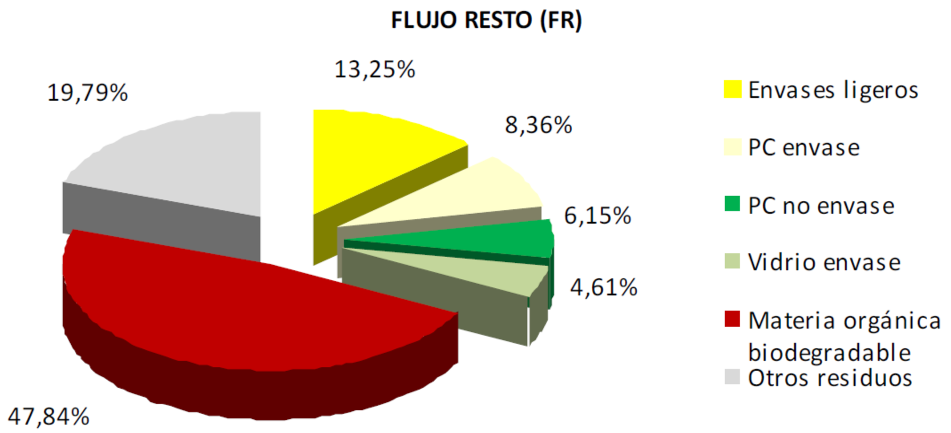
The way in which the results of a waste composition study are presented may differ, depending on the recipients of the study or how it will be disseminated. In any case, it is always advisable to prepare a summary document that provides traceability and proof of the methodology used and the results. In general, there are two different situations:

- Internal use of results, that is, the data obtained will not be published, but will instead be used as a work tool by the entity that commissioned the work. In this case, a simple report can be issued that, at a minimum, presents the basics of the sampling plan, the traceability of the field work and its results, the data processing method and an analysis of the conclusions.

- External use of the results, that is, their dissemination. In this case, in order to facilitate the interpretation of any decisions that are made, a more detailed document is recommended, one that contains at least:

1. The goals and scope of the study
2. Background
3. Work performed
    a. Selection and distribution of samples
    b. Characterisation procedure
    c. Complementary tests
4. Results
5. Conclusions and interpretation of results
6. Annexes (Results of the characterisations and complementary tests, calculations for the sample size, photographic documentation, calibration certificates, etc.)

In either situation, the documents should be as explanatory as possible, presenting numerical data and easy-to-interpret diagrams, such as the one proposed below:



Source: Pilot Plan for characterising household waste: Results report. July 2012

Figure 7. Sample representation using a pie chart

ANNEXES

ANNEX I. GLOSSARY OF TERMS

Cluster analysis: multivariate statistical technique used to group elements in such a way as to achieve maximum homogeneity in each group and differentiation between groups. It involves a grouping method that seeks to partition a set of n observations into k groups.

Characterisation: determining the composition of a waste sample by quantifying the amounts and proportions of the different fractions that comprise it.

Water content (ww)[1]: mass percent of water in a sample, determined by Karl-Fischer titration as specified in the 14346:2007 standard.

Moisture content[1]: the amount of water contained in a material. In practice, it is estimated as the ratio between the mass after drying and its mass when it is sampled. It is typically expressed as a percentage (ISO 287:1985).

Volumetric sieve: a device used to separate materials into fractions based on volume.

Crucible: ceramic container used in the laboratory for gravimetric analyses that require high temperatures

Quartering: dividing the waste sample into four parts.

Seasonality: the periodic and predictable variation in a time series lasting less than or equal to one year.

Strata[2]: mutually exclusive and exhaustive parts of a population. They are identified either because they are thought to be different from one another, or because of the purpose of the sampling.

Stratification (segmentation)[3]: division of the geographic study area into homogeneous sectors (strata), that is, sectors with similar characteristics, such that they are representative of the global population.

Reliability[2]: collective term to denote the degree of accuracy and confidence achieved by a given sampling scheme.

Fraction[4]: part of the total waste with similar characteristics.

Packaging fraction[4]: municipal waste fraction consisting of packaging. It includes paper-cardboard packaging, glass containers and light packaging.

Inorganic fraction[4]: term used to refer to the dry fraction of waste.

Organic Fraction[4]: when collected separately, the term FORS (SCOW, separate collection of organic waste or separately collected organic waste) is used. It consists of:

- Remains of food preparation or handling and processing of food products, leftover food, spoiled food and surplus food that is unsold or not consumed (separated from its container or packaging),
- Plant fraction in the form of small, non-woody plant debris from gardening and pruning (wilted flower bouquets, weeds, grass, small pruned branches, leaves, etc.).

Paper-cardboard fraction[4]: municipal waste fraction made up of paper and cardboard.

Other fraction[4]: waste fraction that remains after the sorting at source of fractions collected separately and that may still contain recoverable materials.

Plant fraction[4]: municipal waste fraction made up of plant remains from gardening or pruning and that can degrade biologically by composting.

Glass fraction[4]: municipal waste fraction made up of glass containers.

Improper waste[4]**:** element that is inconsistent with the other content in a certain fraction of municipal waste.

Constant mass[1]**:** masses obtained in two consecutive weighings that are within 0.1% of each other (ISO 287:1985).

Dry matter (wdm)[1]**:** mass fraction of a sample, excluding water, expressed as a mass percentage and calculated by determining the dry residue or water content as per the 14346:20067 standard.

Arithmetic mean[2]: sum of the values divided by the number of values.

Weighted mean: a measure of central tendency that is given by assigning each class a weight and calculating an average of the weights, each of which has a different value.

Sample[2]: portion of a material selected from a larger quantity of that material.

Representative sample[5]: sample in which the characteristic(s) of interest is (are) present and suitably reliable for the purposes of the test programme.

Goal[5]**:** underlying motivation for investigating a (potential) kind of waste.

Stakeholders[2]: parties involved in the (iterative) process involving the exchange of information regarding the material to be sampled.

Sampling plan[5]: predetermined procedure for selecting, withdrawing, preserving, transporting and preparing the portions to be collected from a population for sampling purposes.

Discharge pit or pile: waste reception area.

Population[3]: all the elements that are taken into account.

Waste[6]: any substance or object which the holder discards or intends to or is required to discard. (Art. 3a of Law 22/2011 of 28 July, on waste and contaminated soil).

Household waste[6]: waste generated in households as a result of domestic activities. Waste similar to the above that is generated in the service industry is also considered household waste.

This category also includes waste generated in homes from electrical and electronic equipment, clothing, batteries, accumulators, furniture and fixtures, as well as waste and debris from minor construction and home repair works.

Household waste includes waste from cleaning public roads, green areas, recreational areas and beaches, dead pets and abandoned vehicles. (Art. 3b of Law 22/2011 of 28 July, on waste and contaminated soil).

Commercial waste[6]: waste generated by wholesale and retail commercial activity, by restaurants and bars, by offices and markets, as well as by the rest of the service sector. (Art. 3c of Law 22/2011 of 28 July, on waste and contaminated soil).

Industrial waste[6]: waste resulting from manufacturing, transformation, use, consumption, cleaning or maintenance processes employed in industrial activity, excluding atmospheric emissions regulated by Law 34/2007, of 15 November. (Art. 3d of Law 22/2011 of 28 July, on waste and contaminated soil).

Hazardous waste[6]: waste that exhibits one or more of the dangerous characteristics listed in Annex III, and that which may be approved by the Government in accordance with the provisions of European regulations or international conventions to which Spain is a party, as well as any packaging and containers used to hold them. (Art. 3e of Law 22/2011 of 28 July, on waste and contaminated soil).

Dry residue (w_{dr})[6]: mass fraction of a sample that remains after a drying process at 105 ºC, as specified in Standard 14346:2007.

Bulky waste[7]: large waste that, due to its size, can distort the ordinary management of household waste (Ministry for the Ecological Transition)**.**

Segregation: process by which the different waste types in the sample are separated.

Bias (or systematic error)[2]: difference between expected test results and an accepted reference value.

Subpopulation[2]: defined part of the population to be identified for sampling purposes.

Sample size[2]: number of items or quantity of material that constitutes a sample.

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[1]Definition based on Standard UNE-EN 14346:2007 Characterization of waste. Calculation of dry matter by determining the dry residue or water content.
[2]Definition based on the UNE-EN 14899:2007 Standard. Waste characterisation Taking of waste samples. Outline for preparing and applying a sampling plan.
[3]Definition based on the Technical Report of Standard UNE-EN 14899:2007 (Report UNE-CEN/TR 15310-1 IN. Waste characterisation Waste sampling. Part 1: Guidelines for selecting and applying sampling criteria under various conditions).
[4]Based on the definitions used in the Guide for implementing the separate collection and management of bio-waste within municipal jurisdiction. Ministry of Agriculture, Food, and the Environment. 2013.
[5]Definition based on the Technical Report of Standard UNE-EN 14899:2007 (Report UNE-CEN/TR 15310-5 IN. Waste characterisation Waste sampling. Part 5: Guidelines for the process of defining the sampling plan).
[6]According to the definitions contained in Law 22/2011, of 28 July, on waste and contaminated soils (Art. 3).
[7]Definition of the Ministry for the Ecological Transition (https://www.miteco.gob.es/).

ANNEX II. STATISTICAL METHODOLOGY FOR PREPARING THE SAMPLING PLAN.

This Annex details the information referred to in Section 2 of the Sampling Plan, on segmenting the territory using mathematical models (cluster analysis), as well as on calculating the sample size, including the statistical concepts that are applicable in both cases.

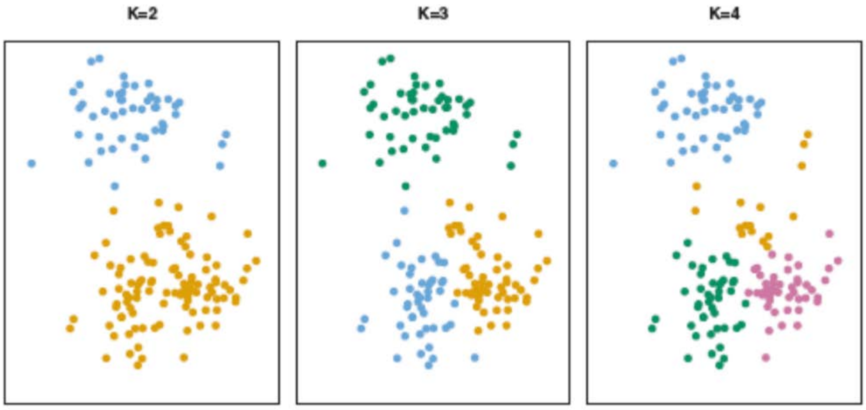
1) Segmentation using mathematical models (cluster analysis).

Section 2.2 of the main document in the Guide details the importance of segmenting territories such that they comprise homogeneous areas that ensure global representativeness. This section presents several procedures for segmenting a territory using the knowledge and/or data available in the field of study.

There are some cases in which the data available for doing the segmentation do not, a priori, provide a clear method for determining which type of segmentation to use. As a result, this section provides another segmentation option using mathematical models; specifically, **cluster analysis**, based on the K-means algorithm (MacQueen, *1967*)[1]. The analysis relies on a set of techniques that use multiple variables to sort a set of individuals into homogeneous groups.

When analysing the composition of waste, these techniques analyse the factors that foreseeably affect the rates of waste generation and its composition and, based on them, sectorises the study area, that is, it divides it into homogeneous sectors (clusters).

Cluster analysis is therefore a technique whose basic idea is to group a set of observations into a given number of clusters or groups (segmentations, in the case at hand). The following image shows a graphical example of segmentation:



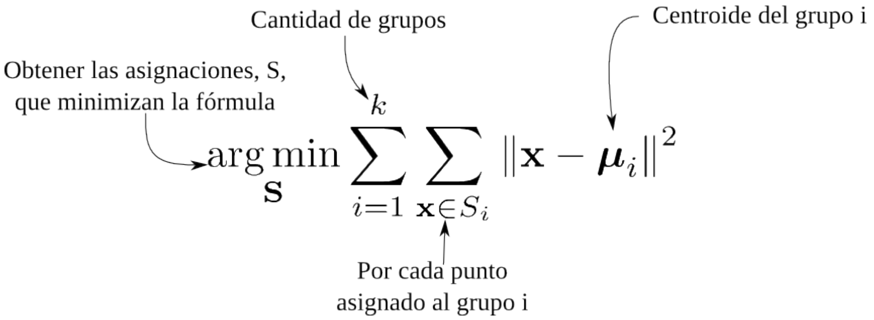
Source: Computer Science Dept. UNLP. 2016.

Image 1: Example of segmentation based on different groups (k)

From a mathematical point of view, cluster analysis, based on the K-means algorithm, entails grouping observations such that all those that are in the same group are the most similar to one another and those in different groups are most unlike one another. Distance measurements, like the Euclidean, are used to measure similarity and dissimilarity. One measure to indicate how well the centroids represent the members of their group is the sum of the squared errors.

[1]MacQueen, J. Some methods for classification and analysis of multivariate observations. Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability, Volume 1: Statistics, 281--297, University of California Press, Berkeley, Calif., 1967.

With each iteration, the K-means algorithm tries to reduce the value of the sum of the squared errors. The measure consists of summing the squared distances of each observation from the centroid of its group:



Source: Computer Science Dept. UNLP. 2016.

Image 2: K-means algorithm

K-means algorithm procedure.

The process to follow to carry out the cluster analysis based on the K-means algorithm consists of the following phases:

1) Selection of variables:

There is a set of factors that affect the generation rate and composition of MSW, whose value can vary within the same country, region or city. These can be of a different natures - environmental, geographic, socio-cultural, economic and political - and must be taken into account when studying the generation and composition of MSW in a given area.

This first phase thus involves selecting the variables that are expected to characterise the objects that are being grouped and for which information is available. If the number of variables is very large, a Principal Component Analysis may be done first to reduce the number of variables.

Some of the variables that may be considered include:

- The season of the year.
- Climate.
- Geographic area.
- Population density.
- Population age.
- Level of education.
- Percentage of foreign population.
- Income level.
- Lifestyle of the population.

- Population type.
- Degree of urbanisation.
- Types of homes.
- Number of members per household.
- Waste management habits in households.
- Seasonality of the population.
- Employment rate.
- Distribution of employees in the different sectors (primary, secondary, tertiary)

2) <u>Definition of centroids:</u>

Certain initial points (K points) have to be selected where the data to be grouped are located. These points will initially represent the initial centroids of the sectors or clusters. Therefore, K will be a positive integer that defines the number of sectors that, a priori, we wish to obtain.

3) <u>Data mapping:</u>

Each data point (elements of the set) must be assigned to the group that has the closest centroid to it.

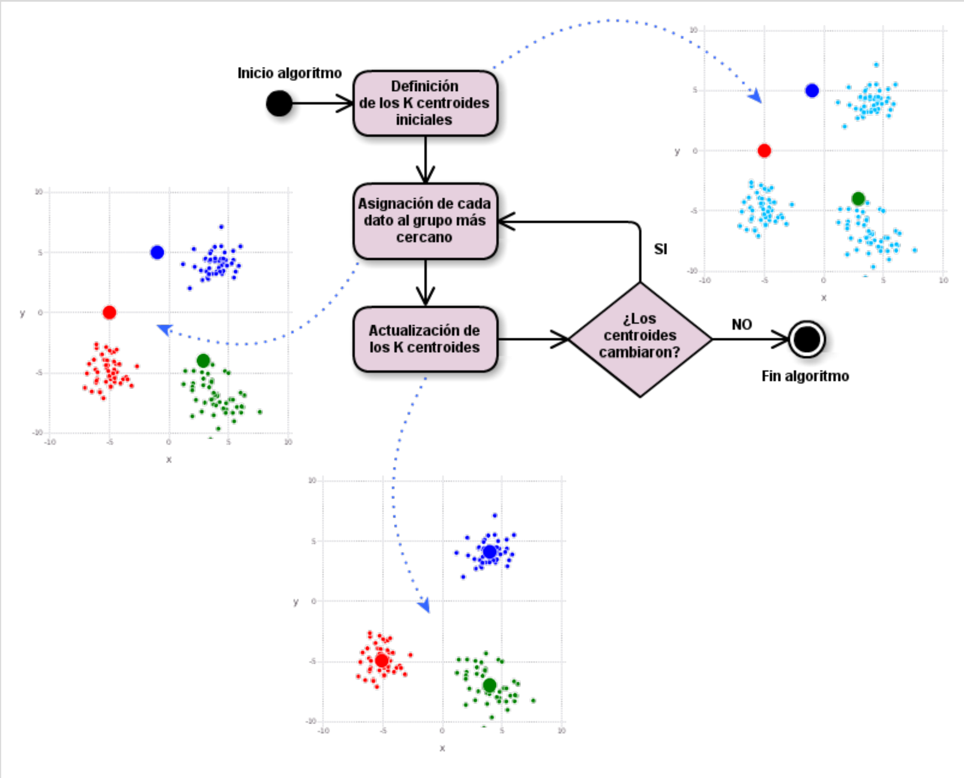
To do this, the Euclidean distance between each observation and the centroids of the clusters is calculated and each observation is reassigned to the closest group, forming the new clusters, which provide a better approximation than the initial ones.

4) <u>Recalculation of centroids:</u>

Once all the data points are assigned, all the centroid positions are recalculated. If these centroids have changed position, step 3 of the data mapping is repeated and recalculated until the value of the centroids remains constant.

Once all the steps are repeated until the values of the centroids remain constant, the different sectors or homogeneous clusters are obtained, depending on the selected variables.

The image below shows an outline of the procedure for executing the K-means Algorithm.



Source: Computer Science Dept. UNLP. 2016.

Image 3: Process for executing the K-means Algorithm

Aspects to note when using the K-means algorithm.

The following recommendations and/or observations are worth noting when using the **cluster analysis** based on the K-means **algorithm**:

- It is the most commonly used mathematical method for determining homogeneous groups, yielding reasonable results. The mathematical process requires a specialised study of each individual case, which implies a significant effort when defining a segmentation in the field of study of waste composition.
- It is a very useful method when the goal is to classify a large number of data points from different variables.
- The number of groups (clusters) to be created must be decided in advance. Depending on the results, the analysis can be repeated using a different number of clusters.
- The type of scale of the variables is important: if the variables have different scales (for example, one variable is expressed in kg and another in years), the results could be wrong. The variables must also be quantitative.

2) Calculating the sample size.

The main document of the Guide provides the formula proposed for calculating the sample size in a waste composition study; that is, the number of samples necessary for said study to be representative of the total population, taking into account the previous segmentation determined in the study area.

On a statistical level, the sample size refers to the number of observations that make up the sample drawn from a population and that, as a minimum, are necessary for the results to be representative of that population. The sample size is calculated for each stratum and fraction to be characterised.

Baseline hypothesis.

Certain hypotheses must be taken into account to determine the formula for calculating the sample size:

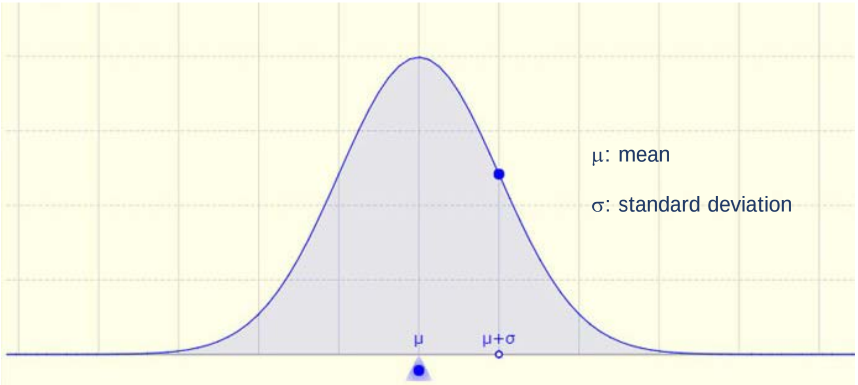
- **Type of sampling:**

Stratified random sampling will be used if strata (segmentations) were previously defined for the study area.

A simple random sampling will be applied to each stratum to choose the elements that will be part of the sample. Distributing the sample into the various strata is called allocation. Of the different existing types, we will use a proportional allocation, that is, the distribution that is made according to the weight (size) of the population in each stratum.

- **Population distribution:**

The data distribution is assumed to follow a Normal Distribution. In this type of distribution, the data points are concentrated around the mean and drop off quickly as we move away from the centre to either side ('tails' of the distribution), so the further away the value is from the centre of the function, the less likely we are to observe that value.



Source: www.matematicasvisuales.com

Image 4: Example of a Normal Distribution

If, once the study is complete, the results do not exhibit a Normal Distribution due to their deviation from the mean, they should be verified. This can be done using several methods:

1) Graphical methods:

   - Histogram and normal curve: consists of representing the data by means of a histogram and superimposing the curve of a normal distribution with the same mean and standard deviation exhibited by the data.

- Q-Q plot: consists of comparing the quantiles of the observed distribution with the theoretical quantiles of a normal distribution with the same mean and standard deviation as the data. The closer the data are to a normal, the more aligned the points are around the straight line.

2) Analytical methods:

- Asymmetry and kurtosis: a kurtosis and/or asymmetry coefficient value between -1 and 1 is generally considered a slight deviation from normal (Bulmer, 1979), (Brown, n.d.). Between -2 and 2, there is an obvious, but not extreme, deviation from normal.

3) Hypothesis testing:

- Shapiro-Wilk test: this test is used to contrast normality when the sample size is less than 50. The equivalent for large samples is the Kolmogorov-Smirnov test.

- Kolmogorov-Smirnov test and Lilliefors test: the Kolmogorov-Smirnov test is used to determine if a sample comes from a population with a certain distribution (mean and standard deviation), it is not limited strictly to normal distributions.

- **Standard deviation (σ) and mean ($\bar{x}$):**

To calculate the standard deviation (σ), which measures the dispersion of the values of a variable in a sample, we need prior information on said value from other characterisations.

As indicated in this Guide's main document, the following cases can be established:

1) Existing information is available from other, similar waste characterisations: if so, the available data will be used to establish the dispersion of the sample through the standard deviation (σ), as well as the arithmetic mean of the sample population ($\bar{x}$), which is needed to calculate the standard deviation.

2) There is no information on other waste characterisations in the area in question.

   In this case, the following alternatives are proposed:

   - Use the information available from other waste characterisations carried out in areas that have similar characteristics, so as to determine the value of the standard deviation (σ) and mean ($\bar{x}$).

   - In the absence of the above information from similar studies, consider the information provided in the *Pilot Plan for Characterising Household Urban Waste of the Ministry of Agriculture, Food and the Environment* (now the *Ministry for the Ecological Transition*), to establish the value of the standard deviation (σ) and mean ($\bar{x}$). These values are as follows for each waste fraction:

	Light Packaging	Glass	Paper and Cardboard	Organic waste	Other waste
Standard deviation (σ)	35.93	17.17	16.09	42.26	21.68
Arithmetic mean ($\bar{x}$)	185	211	180	196	190

Table 1: Standard deviation and arithmetic mean. Pilot Plan to Characterise Urban Waste.

To obtain the arithmetic mean of the sample population ($\bar{x}$) for each fraction, the sum of the "correct" waste that is deposited in each container must be considered, except for the "other" fraction, which is the sum of the waste types other than those that should go in the remaining containers.

Equation for calculating the sample size

The equation used to calculate the size of the samples by adapting the formulas for the normal distribution is shown below:

$$n \geq \frac{N \cdot Z^2 \cdot \sigma^2}{(N-1) \cdot e^2 + Z^2 \cdot \sigma^2} \qquad (1)$$

Where:

n = the size of the sample to be calculated (number of samples)

N = population size (kg of urban waste generated in the sectors or strata to be sampled, divided by the amount of waste characterised per sample).

Z = confidence value (confidence level).

$\sigma 2$ = variance we expect to find in the population. This figure is obtained beforehand from the standard deviation.

e = maximum allowed margin of error, as a percentage of the arithmetic mean ($\bar{x}$).

To apply the formula, the values of the following parameters have to be set:

Margin of error (*e*): This is the interval within which we expect to find the parameter being measured. Usually, for the studies consulted, it takes on a value of 5%, recommending that the value of the relative accuracy of the total result be less than 10%. It should be applied to the arithmetic mean of the sample population ($\bar{x}$).

Confidence level (Z): This is the probability that the true value of the parameter estimated in the population lies within the confidence interval obtained, so a different value is used depending on the confidence level. The most frequent values are:

- 90% confidence level, *Z* = 1.645
- 95% confidence level, *Z* = 1.96
- 99% confidence level, *Z* = 2.575

The confidence level set is usually 95%, meaning Z = 1.96.

The sample size, therefore, is closely related to these two factors, so modifying either of them entails the following:

- Reducing the margin of error requires increasing the sample size.
- Increasing the confidence level requires increasing the sample size.
- Increasing the sample size can reduce the margin of error or increase the confidence level.
- Decreasing the sample size increases the margin of error or decreases the confidence level.

For practical purposes, the equation given above should be applied to each stratum and to each waste fraction to be studied. This will yield the number of samples to be characterised by stratum and by fraction.

In addition to the sample size, when interpreting the results, we must consider the error assumed for each fraction and the fractions the statistical error has been limited to.

The estimation error or absolute error is the deviation of the mean of the fraction samples to be estimated, with respect to the real value of the variable.

An example of sample size calculation is given below, which also shows the influence of considering different margins of error and confidence levels.

Let us consider the following data for a stratum in an area of study for the case of Light Packaging:

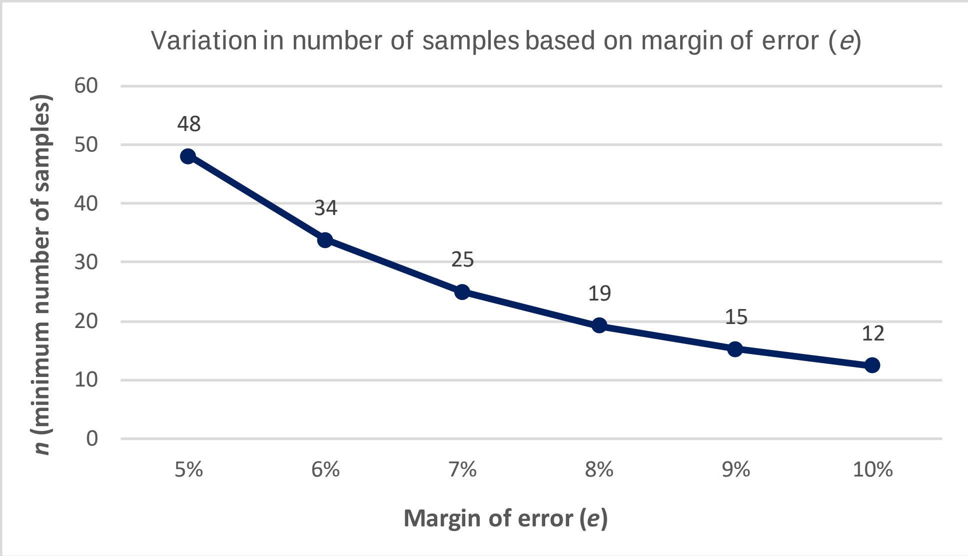
- Urban waste generated: 320,000 kg.
- Kg in each characterisation: 250 kg.
- N = 320,000 kg/250 kg = 1,280 (sample maximum).
- Z = 1.96 corresponding to a confidence level of 95%.
- σ2 =1,100 (the variance obtained from a previous study).
- $\bar{x}$ = 184 kg (mean obtained from a previous study).
- e = 5%

Substituting the values in equation (1), we have:

$$n \geq \frac{1{,}280 \cdot 1.96^2 \cdot 1{,}100}{(1{,}280-1)\cdot(0.05\cdot 184)^2 + 1.96^2\cdot 1{,}100} \geq 48\ samples$$

The value of n, applying equation (1) is **48 samples**, which is the minimum number of samples to characterise that are considered representative of the stratum in question for a 5% margin of error and a confidence level of 95%.

If we gradually increase the margin of error up to a maximum of 10%, we obtain the minimum samples shown in the following graph:

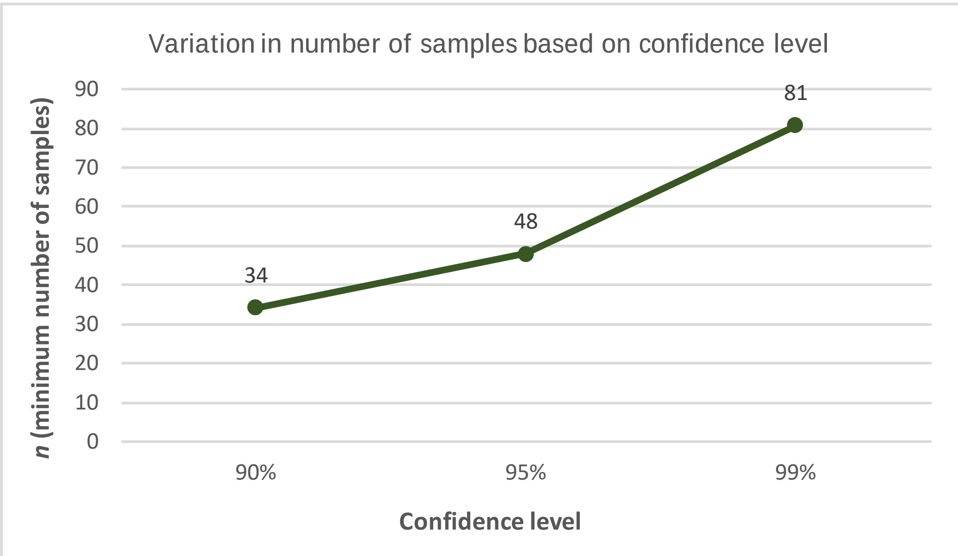


Source: Prepared by the Working Group

Graph 1: Change in the number of samples based on margin of error in a specific case.

As graph 1 shows, and as indicated above, the smaller the margin of error, the larger the sample size.

If we change the values for the confidence level in this example, we obtain the minimum samples shown in the following graph:



Source: Prepared by the Working Group

Graph 2: Change in the number of samples based on confidence level in a specific case.

As graph 2 shows, the higher the confidence level, the larger the sample size.

ANNEX III. SAMPLING PROCEDURE

The waste characterisation procedure is based on a process that takes place from the time the sample is received at the workplace until the results are documented in the corresponding Characterisation Sheet.

The samples can originate in different places:

- Collection vehicle: the material it contains comes from routes selected beforehand as per the methodology described in Section 3.2.3.
- Intake pit at the facility: the material comes from municipal collections, without knowing the exact origin (dates, times, routes, etc.).
- Containers: the material comes from containers selected beforehand to carry out the characterisation.

Depending on these points of origin, the characterisation will be carried out considering certain specifics based on where the sample originated.

1) Taken from collection vehicle:

This procedure is applicable to all the fractions covered in this Guide: light packaging, paper/cardboard, glass, "other" and organic matter (in those cases in which the inorganic fraction is collected separately).

This source of waste is the most common in Spain. According to various works carried out in different fields, there is a commonly recognised and widely used work process that is proposed for the purposes of this Guide.

The procedure consists of the following steps:

- First, the truck is weighed at the plant entrance. This way, the total amount of material collected on a certain route will be known.
- Then, the entire contents of the collection vehicle are dumped on a clean, paved surface, or if that is not available, on a waterproof tarpaulin.

Source: Pilot Plan for characterising household waste: Results report. July 2012.

Image 1: Dumping waste from a collection vehicle

- The waste is then homogenised mechanically (with assistance from a loader or similar) and a 1,000-kg sample is taken from different points and heights on the pile.

- These 1,000 kg of material will be deposited on a clean and paved surface (or atop a waterproof canvas), where it will be mechanically spread out and homogenised.

  All the material must be suitably homogenised to guarantee the most representative sampling possible. If it is homogenised using a loader, care must be taken not to drive over the material so as not to compact it and potentially create leachates, which may be lost. The same applies to glass, which must be handled to avoid breaking it as much as possible.

Source: Pilot Plan for characterising household waste: Results report. July 2012.

Image 2: Homogenising waste using a loader.

There may be cases in which the initial sample is less than 1,000 kg for reasons beyond the control of the study (the collection truck carries less than 1,000 kg). In these cases, proceed in the same way as with 1,000 kg samples, trying to achieve the 250 kg sample to be characterised by quartering.

- The following methodology is then applied to the quarter the waste:

  - It is laid out more or less in a circle and divided into four homogeneous parts.

Source: Pilot Plan for characterising household waste: Results report. July 2012.

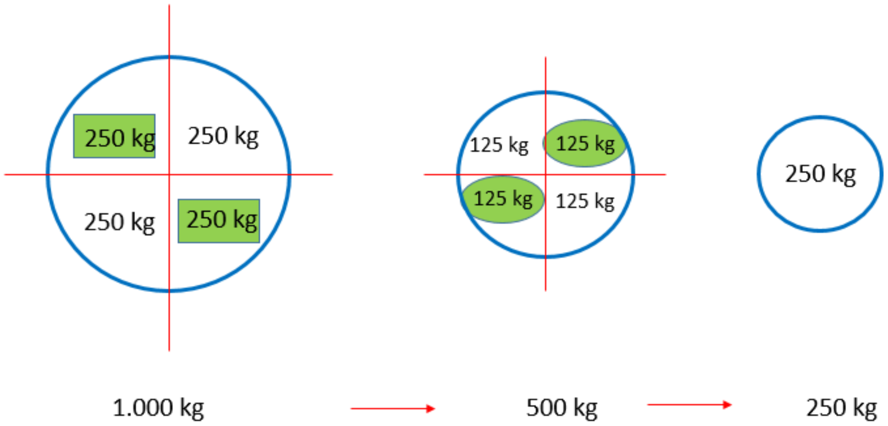
Image 3: Quartering procedure.

- The first quarter is taken using material from two diametrically opposed quarters chosen at random. This material will be spread apart and the closed bags will be opened.
- This material, weighing about 500 kg, will be homogenised and divided into quarters once more.

Source: XXIII Environmental Health Course. Avaliación obxectiva da resposta cidadá coa recollida selectiva de residuos urbáns. November 2007.

Image 4: Homogenising the sample.

- Any bags that are still closed are then opened and, finally, 125 kg will be taken from two diametrically opposite quarters chosen at random. This will yield a 250-kg sample, the contents of which will be separated.



Source: Compiled internally

Image 5: Diagram of the quartering methodology

- Any bags not broken during the homogenisation will be opened manually, taking care to empty their contents as much as possible.

Source: Pilot Plan for characterising household waste: Results report. July 2012.

Image 6: Opening the bags.

Paper/cardboard and glass can be quartered as follows:

Divide the 1,000 kg selected into four equal parts by weight, separating 50 kg from each section in order to obtain a 200-kg sample.

- Once the approximately 250-kg sample is obtained (or 200 kg in the case of glass and paper/cardboard), the contents are taken out of the bags and <u>separated into different fractions</u>.

Source: Pilot Plan for characterising household waste: Results report. July 2012.

Image 7: Separating materials into different fractions.

- The materials will be separated manually. A sorting table with a raised surface should be used to make this process easier.

Source: Pilot Plan for characterising household waste: Results report. July 2012.

Image 8: Manually separating the materials on the sorting table.

- The materials are weighed using a properly verified/calibrated precision scale.

  The total weight of the characterised sample will be obtained by summing the weights of the separated materials.

- If containers are used for each of the materials sorted, they must be tared beforehand. The tares of the containers should be checked on a regular basis.

Source: XXIII Environmental Health Course. Avaliación obxectiva da resposta cidadá coa recollida selectiva de residuos urbáns. November 2007.

Image 9: Containers for separating the materials.

- The results of each sample will be entered in the Characterisation Sheet, which must document the percentages and weights of all the fractions.

- The procedure used must be documented in the Sampling Sheet.

  In the specific case of the **organic fraction**, the waste must be characterised as soon as possible once the material arrives at the treatment plant, not to exceed 24 hours from the time the material is discharged until it is characterised in the months from June to August inclusive, and 48 hours at other times of the year.

  Regarding the **treatment of bulky materials**, given the large size of this fraction compared to the remaining fractions and how its presence could affect the characterisation, these materials have to be processed differently by separating them before the characterisation and allocating them such that the kg from the vehicle, the total kg of bulky waste and the kg of the sample are allocated proportionally.
  In the later stages of the procedure, the bulky items should be removed and added to the other bulky items already removed to obtain the total weight to be distributed.
  One criterion for defining bulky waste is if the sum of the three sides is greater than 1 meter, excluding the fractions collected separately. Examples include furniture (chairs, tables, etc.), construction waste (masonry, pipes, etc.), automotive waste (wheels, seats, bumpers, etc.) and mattresses.
  The different bulky items found should be recorded on the Characterisation Sheet, identified by the subcategory to which they belong.

- The following photographs should also be taken:

  - Of the truck during the unloading (showing the vehicle's licence plate).
  - Of the surface (which must be paved and clean) on which the work will be done.
  - Of the mass of the waste to be characterised (all the material unloaded from the truck).
  - Of the loader homogenising the material unloaded from the truck.
  - Of the quartering processes:
    - Of the 1,000-kg sample, prior to quartering.

- Of the loader doing the first quartering (of the 1,000-kg mass).
- Of the successive quartering processes.
- Of the sampling (approximately 250 kg or 200 kg).

- Of the material sorting process (several representative photographs).
- Of the fractions separated as per the Characterisation Sheet.

2) Taken from intake pit:

This procedure is used in those cases in which knowing the source of the waste is not necessary, such as when the goal of the study is to size or redesign a waste plant. The documents analysed revealed that this method is used especially for the light packaging and "other" fractions.

For these cases, certain variables have to be known, such as:

- Days the waste is received.
- Peak and off-peak reception hours.
- Operating schedule of the plant.
- Average amount of waste entering the plant daily.
- Stay time of the waste in the pit.
- Service outages of the plant.

The characterisation work should be done during three samplings on consecutive days.

This procedure has the same steps as when the waste is taken from collection vehicles, with the exception of the sample taken from the pit, which is described below:

- When the sample is taken from the intake pit, it will be homogenised inside the pit using the claw.

- The claw will be used to obtain approximately 1,000 kg of material. These samples will be taken at various points and at different heights in the mass of waste in the pit.

- These 1,000 kg of material will be deposited on a clean and paved surface (or atop a waterproof canvas), where it will be mechanically spread out and homogenised.

  As for the **treatment of bulky items**, any various bulky items have to be removed, logged in the Characterisation Sheet and identified by the subcategory to which they belong.

Source: Pilot Plan for characterising household waste: Results report. July 2012.

Image 10: Sampling waste from the intake pit.

- The same procedure as that carried out when the waste is taken from a collecting vehicle is then used.
- The following photographs should also be taken at a minimum:
  - Of the mass of waste to be characterised (the entire pit).
  - Of the pit while samples are taken using the claw.
  - Of the surface (which must be paved and clean) on which the work will be done.
  - Of the loader homogenising the material.
  - Of the quartering processes:
    - Of the 1,000-kg sample, prior to quartering.
    - Of the loader doing the first quartering (of the 1,000-kg mass).
    - Of the successive quartering processes.
    - Of the sampling (approximately 250 kg or 200 kg).
  - Of the material sorting process (several representative photographs).
  - Of the fractions separated as per the Characterisation Sheet.

3) Taken directly from the container

This procedure is applicable to all the fractions covered by this Guide. It consists of the following steps:

- The containers are selected beforehand and labelled with their point of origin so that when the characterisation is done, the materials from different points and containers are not mixed.

Source: https://ecoblog.mcp.es/l4r/es/alguien-sabe-que-hay-en-nuestra-basura/

Image 11: Selected containers.

- Upon arrival at the waste plant, each container is weighed and its point of origin is logged.

Source: https://ecoblog.mcp.es/l4r/es/alguien-sabe-que-hay-en-nuestra-basura/

Image 12: Weighing a container.

- The entire contents of each container are then dumped on a clean, paved surface. Samples with a lot of leachate can be characterised directly from the containers.

Source: https://ecoblog.mcp.es/l4r/es/alguien-sabe-que-hay-en-nuestra-basura/

Image 13: Dumping a container.

- This procedure does not involve dividing the waste into quarters; instead, the material is manually separated in all of the containers, one by one.

  As for the **treatment of any bulky items** that are identified inside the containers, they have to be removed, logged in the Characterisation Sheet and identified by the subcategory to which they belong.

- The same procedure as that carried out when the waste is taken from a collecting vehicle is then used.

- The following photographs should also be taken at a minimum:

  - Of the containers being dumped (showing, if possible, the label with the point of origin).
  - Of the surface (which must be paved and clean) on which the work will be done.
  - Of the mass of waste to be characterised (all the material dumped from the container).
  - Of the material sorting process (several representative photographs).
  - Of the fractions separated as per the Characterisation Sheet.

ANNEX IV. GUIDE TO DIFFERENTIATING MATERIALS DURING A CHARACTERISATION

A waste characterisation consists of determining the various fractions that make up waste. This activity is used to ascertain, in detail, what is deposited in the separate collection containers and, based on the results of the process, to take the most appropriate corrective measures.

This document presents the most relevant aspects of the materials included in the Characterisation Sheet, indicating characteristics, instructions for differentiating them and examples, using the maximum breakdown in the Sheet (level 4).

As a summary, the materials that have been included in the annex are listed below:

- Organic and similar matter.
- Cellulose.
- Paper/cardboard.
- Plastics.
- Glass.
- Metals.
- Wood.
- Textiles.
- Batteries.
- Other waste.

Material	Organic and similar matter

Types

This category includes the following types:

Food scraps:
Organic matter is mainly made up of food scraps, such as meat, fish and shellfish waste, egg shells, nuts, coffee grounds, etc. This category also includes food waste.

Garden waste:
This is the material from landscaping gardens and parks.
It consists mainly of branches, leaves, grass, etc.

Other organic matter:
Any organic matter not included in the previous categories.

ORGANIC AND SIMILAR MATTER

Food scraps

Gardening waste

Other organic matter

Image source: www.sevilla.abc.es

Material	Cellulose
Types	
This category includes the following types: **<u>Sanitary textiles:</u>** Includes, among others: • *Diapers.* • *Sanitary pads and tampons.* • *Cotton swabs.* • *Wet wipes.* • *Dental floss.* • *Small waste from household medical treatments (cotton, plasters, bandages, gauze, tape, etc.)* **<u>Other cellulose (tissue):</u>** This category includes the following waste: napkins, tablecloths, kitchen towels, etc. It is important not to confuse this fraction with the paper/cardboard fraction.	

CELLULOSE

Sanitary textile			
Other cellulose			

Material	Paper/cardboard

Mobius loop

Types

This category includes the following types:

Packaging processable with household waste:

This is packaging waste that was once part of a sales unit intended for private consumption.

It includes cardboard and corrugated cardboard packaging: shoe boxes, cereal boxes, TV boxes, etc.

This category includes packaging waste that was part of a certain number of sales units, and is likely to be acquired by individuals for household consumption. They may be corrugated cardboard or paperboard containers that have been used as primary packaging for products such as milk, mineral water, wine, beer, oil, etc.

Commercial/Industrial packaging:

These are primary, secondary or tertiary containers that cannot be purchased by individuals for household consumption.

They correspond to corrugated or paperboard boxes, usually large in size and typically including supplier data. They may not make reference to the number of units of product the boxes hold.

Some examples are:

- *Primary (box containing a car engine, etc.).*
- *Secondary (10-pack of juices, bleach, cleaning products, etc.).*
- *Tertiary (box for transporting a set of secondary packaging).*

Non-packaging paper/cardboard:

Paper/Cardboard not included in the previous categories.

Food/Beverage carton:

This subcategory includes household cardboard packaging for liquid and solid food and beverages (dairy, juices, sauces, etc.).

PAPER/CARDBOARD

Packaging processable with household waste		
Packaging processable with industrial waste		
Non-packaging paper/cardboard		
Food/Beverage carton		

Material	PLASTIC				
Mobius loop					
1 PET	2 HDPE	3 PVC	07 OTHER	5 PP	6 PS
Types					

This category includes the following types:

<u>PET packaging processable with household waste:</u>

The containers have a seam point in the centre of their base and do not include any type of thread inside the neck. They are shiny in appearance, superior to HDPE, and can be transparent and colourless, coloured or opaque.

PETG (copolyester derived from PET) has a finish similar to PVC containers and is more rigid than ordinary PET.

Containers that have a capacity of fewer than 20 litres can be processed with household containers, unless they exhibit characteristics that identify them as commercial/industrial, such as specific products or formats for collective consumption or industrial use. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

Some examples:

- *Soft drink, mineral water bottles.*
- *Trays of food products such as pizza, cold cuts, meat, fish, desserts, fruits and vegetables.*
- *Household cleaning.*
- *Hygiene.*
- *Cosmetics.*

<u>Natural HDPE packaging processable with household waste:</u>

These containers have a straight-line seam that completely crosses the base. Material burr can be seen along the line.

They have a thread inside the neck.

Translucent without coloration.

Containers that have a capacity of fewer than 20 litres can be processed with household containers, unless they exhibit characteristics that identify them as commercial/industrial, such as specific products or formats for collective consumption or industrial use. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

Also included are household containers of this material that were used to hold lubricants or other dangerous products.

- *Milk bottles, smoothies, ... (no colour)*
- *Cleaning products (no colour)*

<u>Coloured HDPE packaging processable with household waste:</u>

These containers have a straight-line seam that completely crosses the base. Material burr can be seen along the line.

They have a thread inside the neck.

Opaque, in different shades.

Containers that have a capacity of fewer than 20 litres can be processed with household containers, unless they exhibit characteristics that identify them as commercial/industrial, such as specific products or formats for collective consumption or industrial use. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

Also included are household containers of this material that were used to hold lubricants or other dangerous products.

- *Cleaning products (coloured opaque container).*
- *Disposable plant pots.*

<u>PVC packaging processable with household waste:</u>

Transparent material.

It may have a bluish hue.

It may come in other shades, such as the red PVC that covers the candles.

When the container is folded, whitish marks appear that remain when the container is returned to its original shape.

There is a line crossing the containers similar to the one shown:

They have a thread inside the neck.

Containers that have a capacity of fewer than 20 litres can be processed with household containers, unless they exhibit characteristics that identify them as commercial/industrial, such as specific products or formats for collective consumption or industrial use. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

Examples:

- *Water bottles.*
- *Oil bottles.*
- *Blister packaging (except medicines)*

<u>FILM (except single-use bags) processable with household waste:</u>

Light and flexible material.

It can be: transparent, translucent, opaque or coloured.

It can be made of HDPE, LDPE, PVC, PP and PS or a combination thereof.

Used to wrap a product.

- *Various food wrappers.*
- *Frozen food bags.*
- *Bags for a large number of products from pens, sheets, etc., to household appliances.*

Films that can be processed with household waste are those that are evidently of a domestic nature in general because they have some identifying element, such as printing (identifying a product type or format for household use), mark or label attached with product data, weight, etc. (for example, supermarket produce bags). In this case, the size does not indicate that the element is of household or commercial/industrial origin, since the material may be cut or split, and there are also similar formats for these two different origins.

Neither rubbish bags nor industrial or commercial film are considered film packaging.

Specific cases of FILM that can be processed with household waste are:

- Stretch or expandable film:
  It is flexible and transparent
  Low Density Polyethylene Composite.
  Used to cover foods.
- Heat shrink film:
  It is flexible and more or less transparent.
  Composed of PVC, Polypropylene, Polyethylene or polyolefin.
  PVC and polyolefin are used in presentation packaging.
  Polyethylene is used in protective packaging.

Commercial/Industrial film packaging:

Light and flexible material.

It can be: transparent, translucent, opaque or coloured.

It can be made of HDPE, LDPE, PVC, PP and PS or a combination thereof.

Commercial/Industrial film is that which is obviously of a commercial or industrial nature in general because it is identifiable through printing, marks or labels that correspond to a product or format for collective consumption or industrial use. In this case, the size does not indicate whether it is of household or commercial/industrial origin, since the material may be cut or split, and there are also similar formats for these two different origins. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we would gain knowledge and experience to improve the separation procedure in the future.

Specific cases of film that may be associated with Commercial/Industrial use are:

- Stretch or expandable film:
  It is flexible and transparent
  Low Density Polyethylene Composite.
  Used to wrap pallets.
  Used to cover foods.
- Heat shrink film:
  It is flexible and more or less transparent.
  Composed of PVC, Polypropylene, Polyethylene or polyolefin.
  PVC and polyolefin are used in presentation packaging.
  Polyethylene is used in protective packaging.

Film (single-use bags):

Those provided or purchased in stores for the consumer/user to transport the merchandise.

This includes produce bags (used to hold fruits, vegetables or bulk products in supermarkets) or any packaging that does not accompany the product when it is placed on the market, but is added to the product at the time of retail sale to the end consumer.

PET commercial/industrial packaging:

The containers have a seam point in the centre of their base and do not include any type of thread inside the neck. They are shiny in appearance, superior to HDPE, and can be transparent and colourless, coloured or opaque.

Containers for Commercial/Industrial use are those that have a volume in excess of 20 litres or that are obviously of a commercial/industrial nature and exhibit an identifying element, printing or label that makes it clear they are products or formats that are specifically for collective use/consumption or industrial use.

If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

Natural HDPE commercial/industrial packaging:

These containers have a straight-line seam that completely crosses the base. Material burr can be seen along the line.

They have a thread inside the neck.

Translucent without coloration.

Containers associated with Commercial/Industrial are those that have a capacity greater than 20 litres. If containers with a lower capacity are found, but it is evident that they are of a commercial or industrial nature, they must be classified as *Natural HDPE Commercial/Industrial*.

Coloured HDPE Commercial/Industrial packaging:

These containers have a straight-line seam that completely crosses the base. Material burr can be seen along the line.

They have a thread inside the neck.

Opaque with colouration.

Containers for Commercial/Industrial use are those that have a volume in excess of 20 litres or that are obviously of a commercial/industrial nature and exhibit an identifying element, printing or label that makes it clear they are products or formats that are specifically for collective use/consumption or industrial use.

If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

Other plastic packaging processable with household waste:

Other household plastic containers that do not have their own fraction (Polystyrene, Polypropylene, Polyurethane, etc.). These materials can be found in any packaging format described above.

They can be packaging for food products or for other uses:

- *Tubs*
- *Trays*
- *Bottles*
- *Yogurt containers*

- *Detergent dispensers*
- *White cork to protect packaged products.*

Other plastic containers that can be processed with household waste are those that are obviously of a household nature, excluding those that, regardless of their size, due to the type of product or format, are for collective use/consumption, in the HORECA sector or in other services, or for industrial use. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

Other Commercial/Industrial plastic packaging:

Other industrial/commercial plastic containers that do not have their own fraction (Polystyrene, Polypropylene, Polyurethane, etc.). These materials can be found in any packaging format described above.

They come in different formats:

- *Food boxes*
- *White cork*
- *Single-dose containers for use in services (hairdressers, HORECA establishments, etc.)*

Other plastic containers that can be processed with commercial/industrial waste are those that are obviously of a commercial/industrial nature and exhibit some identifying element, printing or label that makes it clear they are they are products or formats that are specifically for collective use/consumption or industrial use.

Non-packaging plastic (except garbage bags):

This category includes all plastics that are not packaging, whether household or otherwise.

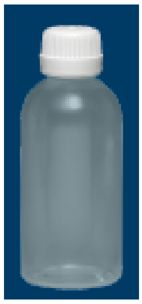
Some examples are: videotapes, CD cases, toys, bowls, etc.

This category does not include garbage bag film or Commercial/Industrial film.

Non-packaging plastic (garbage bags):

This category refers to garbage bags.

PLASTIC

PET packaging processable with household waste		
Natural HDPE PACKAGING PROCESSABLE WITH HOUSEHOLD WASTE:	 Image source: Isoplast	
Coloured HDPE, packaging processable with household waste:	 Image source: Ecoembes	 Image source: Urola packaging
PVC packaging processable with household waste:	 Image source: www.plastic-blister.es	 Image source: www.soplatec.com
FILM (except single-use bags) processable with household waste:		

Commercial/ Industrial plastic film:		
Film (single-use bags):		
PET commercial/industrial packaging		
	Image source: interempresas.net	
Natural HDPE commercial/industrial packaging:		
Coloured HDPE Commercial/Industrial packaging:		
Other plastic containers processable with household waste:		

Other Commercial/Industrial plastic containers:		 Image source: poliex.es
Non-packaging plastics (except garbage bags):		
Non-packaging plastic (garbage bags):		

Material	Glass

Mobius loop

Types

Depending on its format, a distinction is made between:

White glass container:
White glass containers (Moebius 70)
Glass containers include: bottles, jars, jugs, etc.

Coloured glass container:
Coloured glass containers (Moebius 71).
Glass containers include: bottles, jars, jugs, etc.

Glass (Non-packaging):
This category includes light bulbs, pieces of window glass, non-identifiable pieces of glass, armoured glass, windscreens, shields, glass lamps, tableware, opaline glass, mirrors, opaque and coloured glass, glass-ceramics, etc.

The caps from the glass containers will be grouped with their corresponding material. For example: corks with the wood category.

GLASS

White glass container

Image source: www.juvasa.com

Coloured glass container

Non-packaging glass

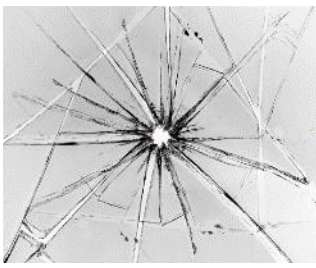


Image source: www.freepik.es

Material	METALS

Mobius loop

40 FE   41 ALU

Types

Depending on its format, a distinction is made between:

<u>Steel packaging processable with household waste</u>

In a characterisation, all domestic packaging made of STEEL (including bimetallic ones) must be included in the steel fraction. This includes steel lids for glass jars and bottle caps made of this material.

Containers that have a capacity of fewer than 5 litres can be processed with household containers, unless they exhibit characteristics that identify them as commercial/industrial, such as specific products or formats for collective use/consumption or industrial use. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

<u>Steel Commercial/Industrial packaging:</u>

Steel containers with a capacity of 5 litres or more are considered commercial or industrial packaging. If containers with a lower capacity are found, but it is evident that they are of a commercial or industrial nature, they must be classified as *Steel Commercial/Industrial Packaging*.

<u>Aluminium packaging processable with domestic waste</u>

These are aluminium containers (beverage cans, aerosol cans, food cans, etc.).

Aluminium foil, designed and intended to be used at the point of sale, is categorised within this fraction.

Containers that have a capacity of fewer than 5 litres can be processed with household containers, unless they exhibit characteristics that identify them as commercial/industrial, such as specific products or formats for collective use/consumption or industrial use. If questionable containers are found, they should be set aside in a pile next to non-questionable containers. Both piles would then be photographed (both in the same photo, but separate), and would then be combined for weighing. This way, we can gain knowledge and experience to improve the separation procedure in the future.

<u>Aluminium Commercial/Industrial packaging:</u>

Aluminium containers with a capacity of 5 litres or more are considered commercial or industrial packaging. If containers with a lower capacity are found, but it is evident that they are of a commercial or industrial nature, they must be classified as *Aluminium Commercial/Industrial Packaging*.

Non-packaging ferrous metals:
This category includes all items made of steel that are not containers, whether household or commercial/industrial.
Some examples of these items are: pipes, kitchen utensils, screws, nails, parts, etc.

Non-packaging non-ferrous metals:
This category includes all items made of aluminium that are not containers, whether household or commercial/industrial.
Some examples of these items are: kitchen utensils, copper pipes, parts, etc.

METALS

Steel packaging processable with household waste

Steel Commercial/Industrial packaging

Aluminium packaging processable with domestic waste

Image source: packaging.enfasis.com

Commercial/Industrial aluminium packaging

Image source: www.boixados.com

Non-packaging ferrous metals		
Non-packaging non-ferrous metals		

Material	Wood

Mobius loop

Types

Depending on its format, a distinction is made between:

Wood packaging processable with household waste

Wooden containers processable with household waste can be: fine wooden boxes, cigar, wine or cheese boxes, ice cream sticks, cork stoppers, etc.

Commercial/Industrial wood packaging

Pallets or thick wood, for example.

Non-packaging wood

This classification includes those items made of wood that are neither household nor commercial/industrial packaging.

Examples include: boards, wood trim, pieces of wood, furniture scraps, etc.

Those elements whose three sides add up to more than 1 meter are excluded. These items will be treated as bulky waste.

WOOD

Wood packaging processable with household waste

Image Source: www.disevil.com

Non-packaging wood

Commercial/ Industrial wood packaging

Material	Textile

Mobius loop

Types

Depending on its format, a distinction is made between:

Textile packaging:
This category includes:

- *Sacks for legumes.*

Non-packaging textile:
This category includes:

- *Clothes.*
- *Footwear*
- *Textile scraps: bags, belts, rags, curtains, towels, cloths, ropes and cords, scraps of clothing, etc.*

TEXTILE

Packaging textiles

Non-packaging textiles

Material	Batteries
Types	
This category includes standard batteries, button batteries, portable accumulators, etc.	

BATTERIES AND ACCUMULATORS

Batteries and accumulators	

Material	Other waste
Types	

Bulky

Bulky waste is that in which the sum of the three sides exceeds 1 meter. Separate and specific collection fractions are excluded.

Examples include furniture (chairs, tables, etc.), construction waste (masonry, pipes, etc.), automotive waste (wheels, seats, bumpers, etc.), mattresses, etc.

Scrap from minor construction.

This is scrap not exceeding 60 kg. It includes brick, plaster, tiles, etc.

Dirt and rubble

Rubble is the remains of construction work.

Ceramics

Refers to ceramic household utensils, such as glasses, plates, cups, flowerpots, etc.

Amount of product in container (solid)

This is the solid product (food remains) that is left in the container once it is used and discarded.

Amount of product in container (liquid)

This is the liquid product (milk, juice, etc.) that is left in the container once it is used and discarded.

Vehicle batteries

Vehicle batteries are classified separately from batteries and accumulators.

Oils

Waste oils are defined as all industrial or lubricating mineral or synthetic oils that are no longer suitable for their intended use.

Examples of these items include: used combustion engine oils, gearbox oils, lubricants, turbine oils and hydraulic oils.

Household oils are also included.

Chemical products: varnishes, paints, glues, solvents, etc.

Includes: varnishes, paints, glues, solvents, etc.

Medicines

This category includes the medicines themselves and the bottles containing them.

Nutritional supplement and liquid nutrition bottles are considered household packaging.

Other (materials not included in any of the above categories)

These are materials not included in any of the previous categories.

Some of the most significant include: sanitary and hospital waste, phytosanitary waste, multi-sided waste (umbrellas, etc.)

Unclassifiable material

Corresponds to that part of the "fines" subsample that, due to its size, clumpiness or moisture content, cannot be assigned to any specific fraction or cannot be separated manually.

OTHER WASTE

Bulky	 Source: www.residuoprofesional.com	**Dirt and rubble**	
Ceramics	 Image source: www.ecologiaverde.com	**Vehicle batteries**	
Oils	 Image Source: Image Source: www.residuospeligrosos10d.blogspot.com	**Medicines**	 www.elnacional.com
Unclassifiable material			
Other (materials not included in any of the above categories)	 Image source: www.miteco.gob.es Image source: www.elcorteingles.es		

Material	WEEE
Types	

The Waste Electrical and Electronic Equipment category includes waste electrical and electronic equipment, its materials, components, consumables and sub-assemblies.

Royal Decree 110/2015, on waste electrical and electronic equipment, specifies 7 categories:

- **Category 1. Heat exchanging devices:**

Refrigerators, freezers, appliances that automatically supply cold products, air conditioners, dehumidifying equipment, heat pumps, oil radiators, and other heat exchangers that use fluids other than water.

Except for CFC, HCFC, HFC, HC and NH3 electrical heat exchangers; electric air conditioners; electrical appliances with oil in loops or capacitors.

- **Category 2. Monitors, screens and devices with a screen area in excess of 100cm^2:**

Screens, televisions, digital frames with LCD technology, monitors, laptops and notebooks.

- **Category 3. Lamps:**

Fluorescent and compact fluorescent bulbs, discharge lamps and LED bulbs.

- **Category 4. Large appliances (with an outer dimension in excess of 50 cm):**

Washing machines, dryers, dishwashers, cookers, electric ranges and ovens, stoves, electric hot plates, musical instruments (except church pipe organs), weaving machines, large office automation equipment, etc.

- **Category 5. Small appliances (with no outer dimension in excess of 50 cm):**

Vacuums, carpet cleaners, sewing machines, lighting fixtures, microwave ovens, ventilation devices, irons, toasters, electric knives, electric kettles, clocks, electric razors, scales, calculators, etc.

- **Category 6. Small IT and telecommunications equipment (no outer dimension in excess of 50 cm):**

Mobile phones, GPS, pocket calculators, personal computers, printers, telephones.

- **Category 7. Large photovoltaic panels (outer dimension in excess of 50 cm):**

Silicon panels.

Panels with cadmium telluride.

WEEE

WEEE		

Image source: www.amazon.es Image source: gestoresderesiduos.org

ANNEX V. PROCEDURE FOR DETERMINING ADHERED MOISTURE/DIRT AND VOLATILE COMPOUNDS.

This annex indicates the process for determining the moisture/dirt and volatile compounds that adhere to waste fractions, from the time the sample is taken until the results are obtained in the laboratory.

Sampling

The procedure of taking waste samples for further testing in the laboratory involves taking approximately 1 kg of each material in question or, if so decided, a complete sample not divided by materials. This last option is not advisable for waste fractions with a highly variable composition, such as the "other" fraction or dry fraction.

Thus, for example, when characterising the packaging fraction, a 1-kg sample of said fraction could be taken before it is characterised and therefore without being sorted by materials, or the samples could be taken once the different materials are sorted, taking, for example, 1 kg of PET packaging, 1 kg of HDPE packaging, 1 kg of Brik packaging, 1 kg of paper/cardboard packaging, etc.

However, before the samples are taken, an agreement should be reached with the laboratory doing the analysis in terms of the specific amounts to take of each material to make sure it satisfies the needs of the analyses that will be carried out.

The samples will be collected by quartering until 1 kg of material is obtained, unless the laboratory recommends another quantity.

In order to ensure the samples taken are both properly preserved and traceable, they must be placed in hermetically sealable plastic bags that are closed so they are as watertight as possible during the transfer to the laboratory. Each bag will be identified at least with the waste to be analysed, date, time, origin and gross weight at origin.

Once the samples are received in the laboratory, they will be weighed again to yield a second gross weight. Samples for which the second weighing is higher than the first, as well as those with a significant weight loss ($W_2 < 0.95W_1$), will be invalidated.

Determination of adhered moisture/dirt

The moisture content is determined mainly for the paper/cardboard, plastics, metals and textiles fractions. It is important to note that there is a wide variability in the data associated with the type of material analysed. Thus, plastic film from bags and cellulose are wastes types that contain the highest amount of moisture/dirt, according to the characterisation studies consulted, with values of 65.7% and 63.05% respectively. The waste with the lowest content is metals, and specifically steel, with a maximum value of 28.6%.

There are certain UNE standards for determining moisture content in the laboratory that are based on determining the percentage of moisture/dirt by drying the waste in an oven at a temperature of 105º, although experience from this type of analysis for household waste shows that there are materials that are affected at this temperature, with the exception of paper/cardboard. Based on this experience, a procedure for determining moisture/dirt is given in this section in which the drying temperature is adapted to the material of the sample in question. In the particular case of paper/cardboard, the moisture/dirt content can be determined using the UNE-EN ISO 287:2018 standard.

Procedure for determining moisture/dirt content (except paper/cardboard)

The following procedure should be used to determine the moisture and/or dirt that has adhered to the waste, which provides a specific temperature and stay time in the oven for each material, depending on its characteristics, the main ones being those indicated below:

Material	PET	HDPE	FILM	PM	STEEL	ALUMINIUM	FBC
Melting Temperature (ºC)	260	135	N.A.	130	1,535	660	130
Temperature (ºC)	90	90	50	90	100	100	90
Stay time (min)	210	210	120	210	120	120	120

This procedure determines the moisture and/or dirt adhered to the waste by means of the percent difference between the net weight (clean and dry) and the gross weight (after it is collected, with adhered dirt and moisture).

The determination begins with conditioning the samples to be analysed by thoroughly cleaning their inner and outer surfaces. The items may be cut as needed to ensure the cleanliness of the packaging in question. The items are cleaned in stages as follows:

- It begins with a pressure wash for 3-4 minutes.
- Next, the samples are placed in a water bath containing a degreaser. The samples are homogenised manually and kept for 5 minutes in this medium.
- Subsequently, the surfaces of the samples are thoroughly cleaned using mechanical methods.
- The samples are rinsed in water for 5 minutes, after which they are left to air dry on an absorbent medium for 10 minutes.
- The samples are subjected to a second rinse in deionised water for 5 minutes, after which they are allowed to air dry on an absorbent medium for 10 min.

In the case of film material, given its characteristics, a special drying treatment must be used, with a manual initial drying with a suitable absorbent, and a second, automatic drying.

Once the samples have been cleaned, they are dried in an oven at a specific temperature and time for each material in question, as follows:

MATERIAL	MAXIMUM TEMPERATURE
Printed paper	105º C (Done using the procedure specified in the UNE-EN ISO 287:2018 standard)
Household paper/cardboard	
Commercial paper/cardboard	
Cellulose	
PET	90º C
HDPE	90º C
FILM (includes all types of film, such as garbage bags)	50º C

PVC + Other plastics	90º C
Steel	100º C
Aluminium	100º C
FBC (Food and beverage carton)	100º C
Textile	90 - 100º C
Non-packaging plastic	90º C
Plastic commercial/industrial packaging	90º C
Commercial/Industrial film	50º C

Finally, the samples are weighed in order to compare the net weight of each sample with its gross weight.

The formula used for the calculation is as follows:

$$\%DM = 100 - \left(\frac{Wn \cdot 100}{Wg}\right)$$

Where

%DM: percentage of dirt-moisture;

W_n: net weight of the sample after drying in the oven;

W_g: gross weight of the sample before drying.

UNE-EN ISO 287:2018 standard

The Paper/Cardboard waste fraction is taken as a reference for determining the moisture/dirt content, bearing in mind that the process as described in the standard is not recommended for samples that do not come from separate collection. It should also be noted that contact with other waste would contribute substances other than water that can interfere with the results.

This method relies on oven drying; however, the process has a unique feature in that the samples are cut beforehand and then placed in the oven in test tubes.

The samples are dried in an oven at 105 ± 2º C, with a weighing and drying process until a constant mass is reached.

The % moisture/dirt content using this method is calculated using the formula below:

$$Hm = \frac{(Mh - Ms) \cdot 100}{Mh}$$

Where

Hm: percent moisture/dirt content of paper and cardboard

M_h: mass of the sample before drying, expressed in grams (g);

Ms: mass of the dried sample, expressed in grams (g).

The percent moisture content is applied to the entire characterised fraction and subtracted from the total gross weight to yield the net weight of each fraction.

Determination of volatile matter content

The determination of volatile matter content is one of the least used laboratory tests in waste characterisations, although this analysis is extremely useful in the physical-chemical determination of the "unclassifiable material" fraction, as it is used to ascertain the composition of this fraction and to correct the results obtained in the characterisation processes.

Volatile compounds are analysed as per the EN UNE-15402:2011 standard. If this analysis is performed, the taking and preparation of samples is to be carried out in accordance with the UNE-EN 15442 and UNE-EN 15443 standards. Likewise, the moisture content must be determined in accordance with the UNE-EN 15414-3 standard in order to correct the moisture content when determining the volatile matter content.

UNE-EN 15402:2011 standard

The method is based on EN 15148 as well as on ISO 562:2010[1]. In it, the volatile matter content is determined as the loss of mass, minus that due to moisture, when the solid recovered fuel is heated in the absence of air under standard conditions.

The process is carried out in a high temperature or muffle furnace, which ensures anoxic conditions and strict temperature control. This device must be heated using electricity and be able to maintain a volume at a uniform temperature of 900ºC ± 10ºC.

During the process, the moisture content of the sample is also determined in order to correct the volatile matter figure. The mineral matter related to the sample can also lose mass under the test conditions. The magnitude of the loss depends on both the nature and quantity of the minerals present.

To determine the weights, a scale sensitive to within 0.1 mg must be used.

A test portion of the general analysis sample is separated to determine the moisture content, at the same time that the volatile matter content is determined. The moisture content must be determined as per EN 15414-3.

[1]UNE-EN 15148:201 standard. Solid biofuels. Determination of the volatile matter content.
ISO 562:2010. Hard coal and coke - Determination of volatile matter.

To determine the volatile matter content, the sample must be exposed to a temperature of 900ºC ± 10ºC for about 7 minutes and then allowed to cool to room temperature. Once cool, it is weighed on a scale accurate to within 0.1 mg.

The sample's volatile matter content is expressed as a mass percent, calculated as follows:

$$V = \frac{100(m_2 - m_3)}{(m_2 - m_1)} - M$$

Where

V: volatile matter content;

m_1: is the mass, in grams, of the empty crucible[2] and its lid;

m_2: is the mass, in grams, of the crucible, its lid and the test portion before heating;

m_3: is the mass, in grams, of the crucible, its lid and the test portion after heating;

M: is the mass fraction of the moisture in the general analysis sample in %.

The percentage of volatile matter content in the characterised sample is calculated by extrapolating the data obtained to the unclassifiable fraction. Most of the volatile matter is assumed to correspond to organic matter, which is why it is added to said fraction.

Example of application

The laboratory determination of parameters such as moisture/dirt and volatile solids complements the waste characterisations, allowing corrections to be made to the data obtained through classification and weighing.

In order to provide an understanding of how this is applied, an example is shown below of how these additional determinations can be applied:

Assume, as an example, that we begin with a characterisation of the "other" waste fraction for which the following composition results have been obtained (note that a 100-kg sample was assumed to simplify the numbers, but as indicated in other sections of the Guide, it is more common to characterise 250 kg or the complete container when doing characterisations of this type):

[2] Ceramic container used in the laboratory for gravimetric analyses that require high temperatures.

Material	Gross mass (kg)
PET	4.80
Film (except single-use bags)	4.30
Steel packaging	2.60
Textile	22.10
Organic matter	50.80
Unclassifiable	15.40
Sample total	**100.00**

Given the resulting materials, it is decided to perform the moisture/dirt analysis as per the procedure indicated above. Furthermore, given the resulting percentage of unclassifiable matter, the analysis of volatile matter content is also carried out so as to determine what percentage of this corresponds to organic matter.

The results provided by the laboratory for the moisture/dirt and volatile solid parameters are shown in the table below:

Material	Moisture/dirt (%)	Volatile solids (%)
PET	27.5	-
Film (except single-use bags)	50.0	-
Steel packaging	15.5	-
Textile	24.0	-
Unclassifiable	-	31.0

The following formulas are used to calculate the masses of the moisture/dirt and volatile solids:

$$Mass\ of\ moisture/dirt(kg) = mass\ of\ the\ material\ (kg) * Moisture/dirt\ of\ the\ material\ (\%)$$

$$Mass\ of\ volatile\ solids\ (kg) = mass\ of\ the\ material\ (kg) * Volatile\ solids\ in\ the\ material\ (\%)$$

The results are given below, obtained using the previous formulas and the laboratory results, for each of the materials:

Material	Moisture/dirt		Volatile solids	
	(%)	(kg)	(%)	(kg)
PET	27.5	1.32	-	-
Film (except single-use bags)	50.0	2.15	-	-
Steel packaging	15.5	0.17	-	-
Textile	24.0	5.30	-	-
Unclassifiable	-	-	31.0	4.77

The mass indicated above, attributed to the volatile solids, will be added to the organic matter. Therefore, the calculation of the net weight of organic matter will correspond to the sum of its gross weight together with the weights of volatile solids, as indicated in the following table:

Material	Mass (kg)
Organic matter	50.80
Unclassifiable volatile solids	4.77
Total organic matter	**55.57**

The net mass of each material corresponds to the gross mass minus the mass of the moisture/dirt and volatile solids. The table shows the net weights of each material:

Material	Gross mass (kg)	Mass of water (kg)	Mass of volatile solids (kg)	Net mass (kg)
PET	4.80	1.32	-	3.48
Film (except single-use bags)	4.30	2.15	-	2.15
Steel packaging	2.60	0.17	-	2.43
Textile	22.10	5.30	-	16.80
Unclassifiable	15.40	-	4.77	10.63
Organic matter	50.80	-	4.77*	55.57
Sample total	**100.00**			**91.06**

*Net mass of organic matter: Gross mass of organic matter + Mass of volatile solids

Finally, the table below shows the gross and net percentages of each fraction.

Material	Gross generation		Net generation	
	(kg)	(%)	(kg)	(%)
PET	4.80	4.80%	3.48	3.48%
Film (except single-use bags)	4.30	4.30%	2.15	2.15%
Steel packaging	2.60	2.60%	2.43	2.43%
Textiles	22.10	22.10%	16.80	16.80%
Unclassifiable material	15.40	15.40%	10.63	10.63%

Organic matter	50.80	50.80%	55.57	55.57%
TOTAL	**100.00**	**100.00%**	**91.06**	**85.68%**
Moisture/dirt	**-**		**8.94**	**8.94%**

ANNEX VI. RECOMMENDATIONS FOR AVOIDING BIASES AND DEVIATIONS IN THE INTERPRETATION OF RESULTS

As a complement to the text contained in the main document of the Guide, below are some recommendations to take into account in the results of the composition studies. It should be noted that most of the biases and deviations stem from the decisions that are adopted when selecting the collection routes from which the samples to be characterised are going to be taken, or when defining the criteria during the characterisation work. In both cases, the considerations proposed both in the main document of this Guide, as well as in its Annexes (specifically, the one on the Sampling Procedure and in the Guide for Differenting Materials in a Characterisation), should be taken into account. As a complement, a synthesis of the most common situations is presented below, as well as some guidelines to follow to obtain the best possible results during the Composition Study. These issues are also set out in the corresponding section of the Guide:

DESCRIPTION	RECOMMENDATION
Regarding the selection of the collection route from which the samples to be characterised are taken	
Lack of segregation of streams in the routes selected for characterisation due to being regarded as representative. This is because the "other" fraction contains municipal waste such as bulky, waste from cleaning streets, parks and gardens, beach cleaning, scrap from minor construction, waste generated by economic activity such as markets, shopping centres, hotels and restaurants, industrial parks, etc.	• Try to select collection routes that, without losing representativeness, do not aggregate streams, which could give rise to incorrect interpretations of the results. • If there is no option to select another route, try to find information about the aggregate streams that are not being studied, and take this into account when interpreting the results in order to estimate any bias that may be present.
Selection, after segmentation, of municipalities considered representative, only to find later that their collections are not separate, but combined with other municipalities	• Try to select municipalities with separate collections, or that at least make it possible to obtain specific weighing data so that the charaterisation can be made specific to the municipality in question and the results are representative and extrapolatable. • When planning the characterisation work, consider changing the route by diverting the truck so that it collects the waste from the selected area/municipality, goes to the plant to unload, and then continues with the route for the remaining areas or municipalities. This is the most appropriate option, as it would yield specific data for the municipality in question.
After segmentation, municipalities deemed representative that do not unload at sorting plants are selected	• Try to choose routes or municipalities that unload directly at the sorting plant, thus avoiding the need to alter the routine collection service, increase costs, and carry out characterisations in sites not equipped for it (lack of technical resources in most cases).

<table>
<tr><th>DESCRIPTION</th><th>RECOMMENDATION</th></tr>
<tr><td colspan="2"><u>In relation to issues of the characterisation process that affect the subsequent extrapolation of results to calculate the composition</u></td></tr>
<tr><td rowspan="7">Differentiation of household and commercial packaging (mainly due to similar formats, loss of segregation information, absence of labels due to fragmented elements)</td><td>• When no clear criteria are available, check other sources of information in the industry in order to assess the decisions made involving the results.</td></tr>
<tr><td>Some examples:
<u>Plastic and metal packaging</u></td></tr>
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DESCRIPTION	RECOMMENDATION
	• When this happens, consider how oversized materials may have affected the results.
	Some examples: **<u>Food protection elements and bags</u>**
	 
	 
Problem fully differentiating packaging and non-packaging streams (affects primarily plastics such as freezer bags, food protection film and aluminium, containers for baking or preserving food, plastic cups and plates).	**<u>Glasses and plates</u>**
	 
	<u>Household aluminium foil</u>
	 
	

DESCRIPTION	RECOMMENDATION
Presence of waste consisting of multi-material waste.	• When waste consisting of several materials is identified, it frequently cannot be separated into fractions, so all the weight is assigned to the most prevalent material. This needs to be taken into account when analysing the results to note that there may be variations in the results obtained for some fractions.
Presence of packaging containing liquid or solid product.	• When this situation occurs, this packaging should be set aside and this information entered in the Characterisation Sheet.
Impossibility of disaggregating the fine fraction consisting of material that is unidentifiable due to its small size.	• Situations may arise in which the fine fraction (the majority of which is usually sand and organic waste) cannot be completely disaggregated, meaning it cannot be allocated to organic waste in its entirety. In these cases, the volatile matter content analysis should be carried out or, failing that, other studies should be checked.

ANNEX VII. REFERENCE DOCUMENTATION

Documentation provided by the Working Group:

- Composition study of the "other" fraction of household origin in Gipuzkoa. Provincial Council of Gipuzkoa. 2018.
- Study of the composition and generation of the "other" fraction in the Canary Islands. Government of the Canary Islands. 2018.
- Procedure for the characterisation study of household waste in the Pamplona region. Mancomunidad de la Comarca de Pamplona y Servicios de la Comarca de Pamplona, S.A. 2018.
- The composition of household waste at the kerbside in 2014-15. Phil Williams. ZERO WASTE Scotland. 2017.
- Study of the generation and composition of household waste in the Autonomous Community of Galicia. Applus Norcontrol. 2016.
- Study of the generation and composition of household waste in the Community of Madrid. Eurocontrol. 2016.
- Study of the current situation of household waste management in Spain and proposals to achieve the 2020 recycling targets set out in Directive 2008/98/EC. Spanish Federation of Municipalities and Provinces (FEMP). 2015.
- CARADEME. Guide pour la realisation de campagnes de caracterisation des dechets menagers. ADEME (Agence De l'Environnment et de la Maitrise de l'Energie). 2014.
- Estudi de la composició dels residus municipals a Catalunya. Generalitat de Catanluya, Departament de Territori I Sostenibilitat. Waste Agency of Catalonia. 2014
- Study of the composition of the "other" waste fraction in the Canary Islands. Government of the Canary Islands. 2014
- Actualisation du guide de mise en oeuvre d'une campagne locale de caractérisation des déchets ménagers et assimilés. ADEME (Agence De l'Environnment et de la Maitrise de l'Energie). 2013.
- Pilot plan to characterise urban waste of household origin. Ministry of Agriculture, Food, and the Environment. 2012.

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- Report on the macroscopic characterisation of biowaste. Usurbil. GIPUZKOAKO HONDAKINEN KUDEAKETA S.A.U. 2019.
- Diagnosis of food waste and needs of disadvantaged groups in Gipuzkoa. Provincial Council of Gipuzkoa. 2017.

- Caractérisation des Déchets Ménagers et Assimilés. SMITOMGA. 2016.
- Municipal solid waste composition: Sampling methodology, statistical analyses, and case study evaluation. Waste Management. Edjabou, V. M. E., Jensen, M. B., Götze, R., Pivnenko, K., Petersen, C., Scheutz, C., & Astrup, T. F. (2015).
- Technical guide. Municipal waste management. Conde del Valle de Salazar Foundation, School of rural Engineering (Polytechnic University of Madrid). Spanish Federation of Municipalities and Provinces (FEMP). (2015).
- Guidance on the Methodology for Waste Composition Analysis - For local authorities commissioning waste composition analysis of municipal waste. Report. Parfitt, J, Griffiths, P & Reid, Tim. Zero Waste Scotland, 2015.
- Composition and characterisation study of solid urban waste in the Autonomous Community of the Canary Islands. Government of the Canary Islands. 2010.
- Metodologias para a quantificação e caracterização física dos resíduos sólidos urbanos. Universidade Nova de Lisboa. 2005.
- Programme for Municipal Waste Characterisation Surveys. Final Report. Environmental Protection Agency, Ireland. 2005.
- Methodology for the Analysis of Solid Waste (SWA-Tool). User Version. European Commission. 2004.
- Composition and characterisation study of urban garbage in the Autonomous Community of the Canary Islands. General Report. Government of the Canary Islands. Office of Territorial Policy and the Environment. 2001.
- Municipal Waste Characterisation; Wexford, Ireland. Environmental Protection Agency, Ireland. 1996.

Standards and other documents:

- UNE-EN 14346:2007 Standard. Characterization of waste. Calculation of dry matter by determining the dry residue or water content.
- UNE-EN 14899:2007 Standard. Characterization of waste. Taking of waste samples. Outline for the preparation and application of a sampling plan.
- UNE-EN 15402:2011 Standard. Solid recovered fuels. Determination of the content of volatile matter.
- UNE-EN 15414-3:2011 Standard. Solid recovered fuels. Determination of moisture content using the oven dry method. Part 3: Moisture of the sample for general analysis.
- UNE-EN 15442:2012 Standard. Solid recovered fuels. Sampling methods.
- UNE-EN 15443:2011 Standard. Solid recovered fuels. Methods for preparing the laboratory sample.
- UNE-EN 20287:1996 Standard. Paper and cardboard. Determination of moisture content. Oven-drying method (ISO 287:1985)

- UNE-CEN/TR 15310-1 IN:2008 Standard. Characterization of waste. Sampling of waste. Part 1: Guidance on selection and application of criteria for sampling under various conditions.
- UNE-CEN/TR 15310-2 IN:2008 Standard. Characterization of waste. Sampling of waste. Part 2: Guidance on sampling techniques.
- UNE-CEN/TR 15310-3 IN:2008 Standard. Characterization of waste. Sampling of waste. Part 3: Guidance on procedures for sub-sampling in the field.
- UNE-CEN/TR 15310-4 IN:2008 Standard. Characterization of waste. Sampling of waste. Part 4: Guidance on procedures for sample packaging, storage, preservation, transport and delivery.
- Norme AFNOR NF X30-408 Décembre 2003. Déchets ménagers et assimilés-Méthode de caractérisation-Analyse sur produit brut.
- ASTM Method D5231-92. Standard test method for determination of the composition of unprocessed municipal solid waste. American Society for Testing and Materials.
- Protocol de caracterització de la FORM (Facció Orgànica procedent de la recollida selectiva dels Residus Municipals) procedent de la recollida selectiva dels residus municipals. Waste Agency of Catalonia.

European legislation:

- Commission Delegated Decision (EU) 2019/1597 of 3 May 2019 supplementing Directive 2008/98/EC of the European Parliament and of the Council as regards a common methodology and minimum quality requirements for the uniform measurement of levels of food waste.
- Commission Implementing Decision (EU) 2019/1004 of 7 June 2019 laying down rules for the calculation, verification and reporting of data on waste in accordance with Directive 2008/98/EC of the European Parliament and of the Council and repealing Commission Implementing Decision C(2012) 2384.
- Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste.
- Directive (EU) 2018/849 of the European Parliament and of the Council of 30 May 2018 amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment.
- Directive (EU) 2018/852 of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste.
- Directive (EU) 2018/850 of 30 May 2018 amending Directive 1999/31/EC on the landfill of waste.
- Commission Decision of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and of the Council.
- Directive 2012/19/EU of 4 July 2012 on waste electrical and electronic equipment (WEEE).

- DIRECTIVE 2008/98 of 19 November on waste and repealing certain Directives.
- DIRECTIVE 2006/66/EC on batteries and accumulators and waste batteries and accumulators.
- Directive 1999/31/EC of 26 April 1999 on the landfill of waste.
- DIRECTIVE 94/62/EC of 20 December on packaging and packaging waste.
- Directive 91/689/EEC of 12 December on hazardous waste.

National legislation:

- ROYAL DECREE 293/2018 of 18 May on reducing the consumption of plastic bags and creating the Register of Producers.
- Royal Decree 110/2015 of 20 February on electrical and electronic waste.
- Law 22/2011 of 28 July on waste and contaminated soil.
- ROYAL DECREE 106/2008 of 1 February on batteries and accumulators and the environmental management of their waste.
- ORDER MAM/304/2002 of 8 February publishing the waste recovery and disposal operations and the European List of Waste.
- ROYAL DECREE 1416/2001 of 14 December on packaging of plant protection products.
- LAW 11/1997 of 24 April on packaging and packaging waste.
- ROYAL DECREE 833/1988 of 20 July approving the Regulation for the implementation of Law 20/1986, Basic Law on Toxic and Hazardous Waste.

ANNEX VIII. PROPOSED TECHNICAL GUIDELINES FOR GOVERNMENT AGENCIES TO CONSIDER IN THE BIDDING SPECIFICATIONS OF CONTRACTS FOR WASTE CHARACTERISATION SERVICES.

The purpose of this Annex is to propose a series of technical guidelines to consider in the mandatory specifications when contracting services involving waste composition studies.

This document does not refer to administrative guidelines, focusing only on technical considerations for contracting services and taking into account the contents indicated in this Guide.

Recommendations are provided in relation to the following aspects:

- Purpose and Scope
- Work to perform
- Work methodology
- Deliverables
- Human and material resources
- Other considerations

1. Aspects related to the Purpose and Scope of the work

- PURPOSE: The tender will include a brief and concise description of the purpose of the contract. Some examples may be:
    - The purpose of the contract will be to conduct a study to determine the composition of municipally managed waste in *(specify study area)*.
    - The purpose of the contract will be to determine the input waste at a plant (include plant typology).
    - The purpose of this contract is to provide a waste characterisation service for the different fractions collected in (specify contract area).
- SCOPE: Specifically include those aspects related to the geographic scope - waste stream, temporal and material scope.
    - Geographic scope of the study: specify the territorial scope for which the composition is requested, be it a municipality, neighbourhood, Consortium/Association, Autonomous Community or any other territory served by a waste treatment facility.
    - Specify the waste stream(s) involved in the characterisation (it could be all the usual collection streams, the stream of "other" waste, the light packaging stream, etc.).
    - Temporal scope: specify the timeline spanned by the results and that will thus determine the period over which the characterisations will be carried out.

- Material scope: specify the works to be carried out, listing them, and then describe them in the Technical Specifications (hereinafter TS) or Technical Annex of the tender or elsewhere, according to the procedure followed by the contracting body.

  Examples of the specific contents of the work to be performed in a supra-municipal tender include:

  - Proposal for segmenting the municipalities that are part of the study based on different parameters (unless a study with this scope already exists) and selection of the municipalities in which the characterisations representing each stratum will be carried out, if applicable.
  - Determination of the number of characterisations to be carried out in each municipality selected, with a justification of the error values and the confidence level obtained. These values can be set in the specifications (preferred option) or the minimum number of characterisations (or the maximum amount) can be specified, in which case the winning bidder should indicate the error margin and confidence level that would be achieved with the proposed sample distribution.
  - Performance of the characterisations, including compilation of information from the municipalities in question to arrange the logistics, coordinate with the different agents to take samples and solve any incidents, perform the sampling.
  - Conducting complementary moisture/dirt tests, or, where appropriate, a proposal to use existing references to obtain the gross and net composition.
  - Calculate the generation and total gross and net composition.
  - Preparation of partial reports and/or final report of results.

2. Aspects related to the work to be performed

Below is a proposal of those aspects that should be specified and/or defined in the TS.

- Proposed municipal segmentation.

  Specify how the municipalities are to be segmented, if applicable to the study area, since this area could range in size from a neighbourhood, a municipality, a particular route or any other area that is deemed not to require said segmentation.

  If the municipalities do have to be segmented, the following options exist:

  - If a previous segmentation study is available, the TS would contain a proposal of representative local entities and a selection of the municipalities where the characterisations would be done.
  - If a previous segmentation study is not available, the TS would specify that the contractor has to do a segmentation study of the study area, based on the methodology followed in this Guide, and propose the municipalities in each stratum where the characterisations will be carried out.

- Determination of the number of characterisations to carry out.

  Different options can be proposed in the TS to determine the number of characterisations needed:

- Preferably, the desired error margins and confidence levels will be specified, with the bidder calculating the number of characterisations that will have to be done for each municipality selected. When doing these calculations based on the desired error margin and confidence level, the statistical calculations provided in this Guide will be taken into account.

- A minimum number of characterisations or, as an alternative, the maximum budget of said characterisations can be specified. The bidder will propose how to allocate the various characterisations among the selected municipalities, indicating the error margin and confidence level that said distribution would yield. The bidder, in this case, could offer a number of characterisations greater than the minimum indicated.

In both cases, the TS would specify the statistical calculation methodology indicated in this Guide, based on the formula for calculating the number of samples and the different situations to consider in each case.

- Doing the characterisations.

  Some important aspects to consider during the characterisation work include:

  - The methodology to use when characterising the waste streams can be specified in the TS. Said methodology could be included in an Annex to the TS.

    Another option would be to include in the TS that the bidder propose the methodology to use based on the various characteristics of the study and the waste streams in question.

  - The Tender should specify the steps to take if the indicated procedure cannot be followed or if there are any other problems in this regard. As an example, the Tender can state that in case of a problem, incident or any other cause that makes it impossible to follow the methodology specified, the study coordinator will be informed.

  - As concerns the information to be gathered, the Tender will specify that the contractor of the work will have to gather the information on the municipalities, identify the different streams managed by each local entity, and coordinate with the different agents to take the samples and resolve any incidents.

    The Tender should also specify that the contractor must ensure that the conditions and resources of the place where the characterisation is carried out are suited for this task or for identifying what elements will be necessary to do the work.

  - The TS should specify the Sampling or Field Sheet to be used in the characterisations. The Sheet indicated in this Guide can be included or specified in the TS.

  - As in the above case, the Characterisation Sheet should also be stipulated in the TS. For the breakdown of the characterisation sheet, different aspects will be taken into account, such as the objective of the study, the budget available, the desired confidence level, etc.

    The Characterisation Sheet provided in this Guide should be stipulated in the Tender.

- Complementary moisture/dirt tests

  As in the case of the characterisation of waste streams, the TS should contain a single criterion to determine and quantify the adhered moisture/dirt or volatile solids, including the methodology to be followed. As an example, the instructions in Annex V of this Guide can be used.

Regarding the number of complementary tests to be carried out, the following options, or a combination thereof, can be used:

- Stipulate in the Tender the number of complementary tests to be performed and on which fractions. For example: 1 out of 10 characterisations.

- Propose the use of bibliographic data to obtain the percentages of moisture/dirt in the different fractions, as long as they can be shown to be valid for the geographic area in question.

- Calculate the generation and total gross and net composition.

  One of the following options should be included in the Tender:

  - Stipulate in the Tender the calculations of the gross and net generation and total composition based on the calculations provided for this purpose in this Guide.

  - Note that the contractor has to specify the calculation procedure it will use to determine the total gross and net composition.

- Preparation of partial reports and/or final report of results.

  The TS should stipulate that the following reports are required:

  - Preparation of partial reports defining the temporal nature according to the objective of the works, for example: partial four-month reports on the results of each stratum in the supra-municipal waste composition studies.

  - Preparation of final report on the results, with the time frame defined in the scope of the works.

  The reports indicated above must have annexes with the results of the field work, the complementary tests, if they were performed, and the calculations of the gross and net results.

3. Aspects related to the work methodology

The TS should stipulate the work methodology to be used, mainly in terms of organisation, communication and times.

The TS will include at least the following aspects:

- *Project kick-off/initial meeting.*

  Before the characterisation work proper, the TS should specify the holding of a preliminary meeting between the technical department and the contractor in order to, mainly, plan the work and provide the information necessary to carry out the work.

- *Work planning.*

  The deadlines for completing the work should be set, as should the partial and final delivery dates.

  The TS should require the bidder to present a plan for the work to be carried out, breaking down each of the phases or tasks involved in the performance of the work, and providing milestones for the partial and final deliveries.

Along with this plan, the bidder should be asked for a work organisation chart specifying the work coordinator as well as the composition of the various teams, both in the field and in the office.

- *Communication and action protocols in case of an incident*

  The Tender should include a communication protocol to be followed should any incident occur over the course of the work.

- *Work quality control system*

  In order to ensure the quality control of the work and identify possible deviations, the Tender should require the use of a quality control system or quality assurance plan.

4. Aspects involving the deliverables

The way in which the results of a waste composition study are presented may differ, depending on the recipients of the study or how it will be disseminated. In any case, it is always advisable to prepare a final document that provides traceability and proof of the methodology used and the results.

Regarding the characterisations, the TS should stipulate the minimum documentation that must be delivered. Regarding the different formats to present, the bidder should indicate in its proposal which ones will be used over the course of the work.

- *Characterisation sheets for each sample*.

  Along with each sheet, a photographic annex should be requested in order to provide evidence of the process in question.
  By way of example, some of the photographs that may be included in the Tender are as follows, and may vary depending on the methodology used to do the characterisations:

  - Photograph of the lorry while unloading, or a photograph of the waste in the discharge pit, pile or containers being sampled.
  - Photograph of the clean and paved surface on which the work will be carried out.
  - Photograph of the mass of waste to be characterised.
  - Photograph of the loader homogenising the discharged material, if applicable.
  - Photograph of the initial sample before it is quartered, if applicable.
  - Photograph of the loader doing the initial quartering of the mass of waste, if applicable.
  - Photograph of the four quarters, once the initial quartering is complete.
  - Photograph of the mass of waste (sample).
  - Photograph of the mass of waste spread out to ease the process of opening the bags.
  - Photograph of the homogenisation prior to second quartering.
  - Photograph of the second quartering.
  - Photograph of the four quarters once the second quartering is complete, showing the sectorisation.

- Photograph showing all the separated classified fractions, once the materials are verified.
- Photograph of each classified fraction, once the materials are verified.

If a section of fines is left over once the materials have been separated, the following should be requested:

- Photograph showing the initial fraction of unclassifiable material, or "fines".
- Photograph of the sample taken from the initial pile, and which will be used to characterise said pile.
- Photograph of each classified fraction.

- *Final report*.

The TS should specify the minimum content of the final report on the work. As an example, the following minimum contents are proposed:

1. Goals and scope of the study.
2. Background.
3. Conduct of the work.
    - Selection and distribution of samples.
    - Characterisation procedure.
    - Complementary tests.
4. Results.
5. Conclusions and interpretation of results.
6. Annexes (Results of the characterisations and complementary tests, calculations for the sample size, photographic documentation, calibration certificates, etc.)

The TS should require the delivery, along with the final report, of the calculation sheets (Excel format) for the various data detailed in the report to ensure the traceability of the final results.

5. Aspects related to human and material resources

Specify the minimum human and material resources required for the proper execution of the work, based on the tasks that were described beforehand in the TS and on the goal of the work.

- *Human resources*.

Indicate the minimum staff necessary to do the characterisation tasks proper, as well as the office work (mainly involving the preparation of reports). Accordingly, and considering the contents of this Guide, a minimum team of two field technicians per characterisation is recommended.

The technicians should be properly trained, and thus the following documentation should be requested:

- Certificate of training on the procedure to be used in the field, as well as on how to fill in the Sampling Sheet and the Characterisation Sheet, and on the Material Differentiation Guide.

- o Adequate training on Occupational Hazard Prevention, including the risks associated with the work to be carried out and the proper use of Personal Protective Equipment.

Regarding the use of Personal Protective Equipment, the TS should stipulate the minimum requirements. Although a specific risk analysis is recommended in each case, the contents of section *3.2 Human Resources* of this Guide, can be used as guidance.

- *Material resources.*

The minimum material resources required for the correct performance of the work should be specified.

As a result, the TS should inform the bidders of the following aspects:

- o Material resources available to carry out the work.
- o Minimum material resources of each characterisation team and geographic area.
- o Calibration and/or verification certificates for those devices that require one, especially for the scales used in the characterisations.

Examples of the material resources used to do the work are provided in Section *3.2.2 Material resources* in this Guide.

As concerns the laboratory work for the complementary tests, the TS should request verification that the laboratory used is certified to do the analyses required and has sufficient capacity to carry out the necessary tests.

This section on human and material resources should also specify that the contractor is responsible for any costs associated with the work stemming from the results of the selection of municipalities to be studied, such as possible route deviations, the performance of the characterisations in the summer, as well as any other possible costs related to both technical and human resources.

6. Other considerations

Below are other considerations that should be considered for inclusion in the tender documentation:

- *Check of the characterisation results. Contingency in the event of an incident.*

The TS may include the procedure to follow in the event of an incident involving the sampling process or any other incident related to the work in question.

One possible course of action to take in the event of an incident could be to inform the study coordinator assigned by the contracting entity, who has the power to make decisions, so that the best way to resolve any incidents can be proposed, assessed and determined.

- *Computer software to carry out the work and present the results*

The TS may require the bidder to develop a computer tool (documentary platform, app, etc.) to conduct the field work, manage the documents or present the results.

- *Bid evaluation procedure*

Describe the process to be used to disclose the offers, correct any documentation, and separately assess 1) the documentation that must be evaluated according to weighted criteria based on a value judgment, and 2) the documentation that must be evaluated according to quantifiable criteria through the simple application of formulas, in that order.

- *Monitoring and inspection of the work*

The TS may provide an option for the government agency to, using internal or external resources, monitor and inspect the work carried out pursuant to the contract. In this sense, it would be important to specify that the contractor must accommodate any such inspection work.

- *Deliverables*

In addition to the minimum deliverables that should be included in the TS, and indicated above, the TS may also require that a presentation (PowerPoint or similar) be included detailing the methodology used and the results obtained.

- *Additional points of interest*

It may be beneficial to have the bidders provide the following documentation:

  - Previous experience on jobs of a similar nature.
  - Implementation of Quality and Environmental Management Systems (for example: ISO 9001, ISO 14001, EMAS, etc.)
  - For work spanning a large area, the proximity to said area of the offices or work teams of the bidder.