

Review

FUNDAMENTALS OF WASTE CHARACTERISATION SAMPLING ACCORDING TO CEN/TR 15310

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Abstract

Waste characterization is a fundamental prerequisite for making informed decisions regarding waste treatment, recovery, and disposal. Because waste materials are generally heterogeneous and it is impractical to analyse an entire waste population, representative sampling is essential for obtaining reliable analytical results. This paper presents a review of the main principles and requirements for waste sampling based on the CEN/TR 15310 series of technical reports and other relevant literature. Particular attention is given to the process of developing a sampling plan, including the definition of testing objectives, identification of the population to be sampled, assessment of spatial and temporal variability, selection of appropriate sampling approaches, determination of statistical parameters, and specification of practical sampling instructions. Different sampling patterns and considerations related to increment size, sample size, and the use of composite or individual samples are also discussed. The review highlights the importance of understanding waste heterogeneity and applying statistically sound sampling strategies to ensure representative results. Properly designed sampling plans contribute significantly to the reliability of waste characterization data and support compliance with regulatory and technical requirements.

Keywords: CEN/TR 15310:1-5, Variability, Sampling plan, Waste characterisation.

INTRODUCTION

According to the Law on Waste Management of the Republic of Serbia, waste represents "any matter or object that the holder discards, intends or is required to discard". Waste is created as a consequence of various human activities, including industrial production, construction works, agricultural activities and everyday activities of the population [1].

Reliable data on the characterization of the waste is needed to enable a decision to be made on the appropriate way in which it should be treated, recycled or disposed of. However, for practical and economic reasons, it is impossible to analyse the entire series of wastes to be managed. That is why it is necessary to carry out sampling of waste material. A waste sample represents a certain amount of waste separated from a larger mass of waste in a way that

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ensures that its properties faithfully represent the characteristics of the entire amount of waste from which it was taken. Therefore, smaller parts, also known as samples, must be collected and brought to the laboratory for further analysis [2–3].

Such materials are generally heterogeneous; therefore, the test program should specify the amount of material for which the characteristics of interest will be determined. There are three main steps in the process of sampling waste materials: preparation of the sampling plan, sampling in the field in accordance with the sampling plan and transport of samples to the laboratory for testing [4–9].

DEFINING THE SAMPLING PLAN

The objective of sampling is to collect representative samples that accurately reflect the composition of the waste. The preparation of a sampling plan includes defining the objectives of the investigation, determining the parameters and scope of testing, gathering information about the waste, establishing safety measures, and selecting the appropriate sampling method and technique [4–9]. The main statistical steps in defining a sampling plan are given in Table 1.

Table 1 Main statistical steps in defining a sampling plan for a testing programme

Step	Subject
Specify the objective of the Testing Programme	
1	Specify the objective of the Testing Programme
Develop the Technical Goals from the objective	
2	Define the population to be sampled
3	Assess variability
4	Select the sampling approach
5	Identify the scale
6	Choose the required statistical approach
7	Choose the desired reliability
Determine the practical instructions	
8	Choose the sampling pattern
9	Determine the increment/ sample size
10	Determine the use of composite or individual samples
11	Determine the required number of samples
Define the Sampling Plan	
12	Define the Sampling Plan

Specify the objective of the Testing Programme is a general statement of its overall purpose. The objective must be clearly defined before selecting a sampling strategy, as it is the primary step in determining the type and quality of information to be obtained from sampling. Some examples of test objectives are:

- basic characterisation, which consists of a thorough determination of the behaviour and characteristics of the required material;
- compliance testing, which consists of periodic testing to determine compliance with specific requirements or reference conditions (legal or contractual);

- on-site verification, which consists of a “quick check” method to determine consistency with other tests or other formulated documentation.

In most cases, test objectives are too general to provide detailed instructions for designing a sampling plan, so it is necessary to develop technical objectives from the objective [4–9].

Developing technical goals for the objective translates the general objectives of a testing programme into specific sampling and data analysis requirements. They provide the basis for selecting statistical tools and defining practical sampling instructions, including the material to be sampled, the scope of testing and the required confidence level [4–9].

Defining the population to be sampled - The term “population” is a statistical term used to define the total amount of material from which information is sought through sampling. Defining the population should be one of the first steps in developing a sampling plan.

Overall population and population - It is usually impractical to sample the total population, especially if it is an overall population that represents the entire production of an industrial plant over its entire existence. Therefore, it is common to define the “population” as a convenient subset of the total population – e.g., a month’s ash production may represent the typical production performance of a waste incineration plant. It is important to emphasise that the correct selection of the population depends on the experience and judgment of the interested parties and that this is not a statistical task. It is also important to define the population explicitly in time and/or space. If this is not done, it is impossible to predict that the sampling will be completed in a representative manner.

Sub-population - A problem may arise if it is difficult or impossible to access certain parts of the population during sampling. In such circumstances, it is useful to define a subset of the population – a “sub-population” – which limits the sampling to a more convenient area. A sub-population is therefore a specific part of the population that is intended to be sampled and is considered to sufficiently characterise the population. It is important to understand that the resulting samples may be representative of the defined sub-population. [4–9].

Assessing variability - A key element in the design of a testing program is the requirement to understand the major components of variability in the population to be sampled. In general, variability is a characteristic of waste that cannot be changed without extensive waste manipulation. Variability may be **spatial**, arising from heterogeneity within the material, or **temporal**, resulting from changes in the production over time. Spatial variability may occur within or between layers of a waste body, while temporal variability may be cyclic, driven by known factors, or random (mostly unknown) [4–9].

Selecting the sampling approach - There are two primary approaches to sampling: Probabilistic sampling and judgmental sampling. The use of a probabilistic sampling approach is always recommended where a quantifiable level of reliability is required for the population being tested. The basis of the probabilistic sampling approach is that each element within the population has an equal chance of being selected by the sampling process. This implies that the entire population is available for sampling, even if, for example, there is a large amount of material. In contrast, in the case of the judgmental sampling approach, samples are taken at best on a partially probabilistic basis and at worst on a non-probabilistic basis. The most common reason for choosing this approach is when it is impossible to sample

the entire population for whatever reason. Judgmental sampling can also be used when a specific location or subject is being targeted. Judgmental sampling results in sampling of a sub-population. However, within that sub-population, it may be possible to achieve a probabilistic approach, which is always advised, as at least the results will be representative of that sub-population [4–9].

Identifying the scale - The „scale” is a crucial element that defines a sampling program. It defines the minimum amount (mass or volume) of material below which variations are considered insignificant. For example, if the scale is defined as a barrel of waste, then variations in any characteristic of the waste within the barrel are not of concern. The amount of spatial variability in a population cannot be quantified without defining the scale at which that variability occurs. For example, the variability at the gram level of material in a sub-population is greater than the variation at the kilogram level. Depending on the object of the testing program, the sampling scale may be equal to the size of individual particles (for granular materials), or the size of the sub-population or population. The scale may be defined in terms of time frames - daily, annual, etc [4–9].

Choosing the required statistical parameter - A statistical parameter is any numerical characteristic of a population - a mean or standard deviation, percentile, etc. A key step in planning a testing program is to specify the statistical parameter to be estimated. The choice also affects the type of sampling and the number of samples required. When testing is aimed at basic characterisation, the examination will most likely require measures of variability and extreme behaviour of key constituents. Sometimes a large number of samples is needed to meet these requirements. When the objective is compliance testing, the choice of statistical parameter is usually predetermined by the compliance regulation, as is the size of the scope that the material must meet. Mean values and percentiles are usually used. In the case of on-site verification, the investigation will focus either on measured values in relation to a compliance level that must not be exceeded, or simply “present-absent” measurement of the attribute.

Choosing the desired reliability - The reliability of a testing program is a general term that encompasses three statistical concepts - “bias”, “precision” and “confidence interval”. The objective of the testing program will influence the degree of confidence that is considered acceptable, but the final selection of confidence criteria is almost always a compromise between expectations and cost.

Given the important decisions that are based on the findings of the basic characterisation test, it is suggested that the confidence should be as high as possible. In contrast, for the “quick check” method of on-site verification, the achieved confidence will in many cases be low. A unique feature of probabilistic sampling is that it allows a range of deviation, also known as a confidence interval, to be placed around the estimate of any parameter. The semi-width of the confidence interval is usually known as the ‘precision’. This depends on:

- the desired level of confidence;
- the variability in the population or subpopulation
- the sampling scheme;
- the number of samples chosen;

- the assumed statistical probability distribution in the population; [4–9].

Determining the Practical Instructions - From the objective of the sampling plan, technical objectives are developed that are more detailed. The technical objectives must be translated into practical instructions that are given to the sampler before sampling [4].

Choosing the sampling pattern - The sampling pattern defines where, when and how the required samples are selected from the population. Figure 1 illustrates sampling patterns of probabilistic and judgmental sampling.

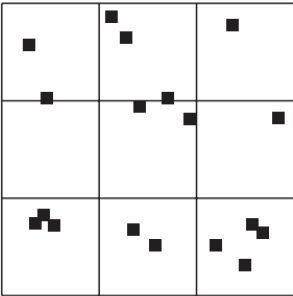
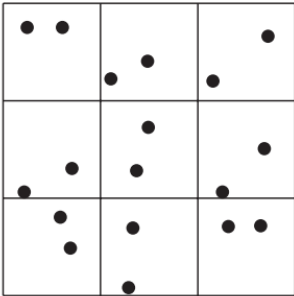
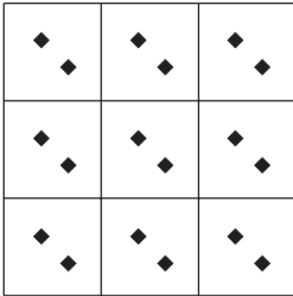
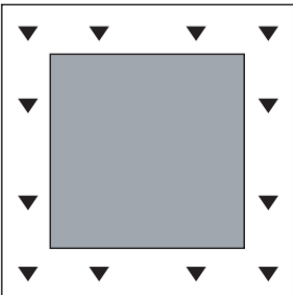
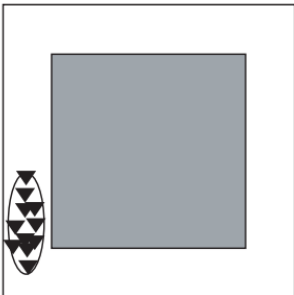
Simple random sampling	Stratified random sampling	Systematic sampling
		
Judgemental sampling (1)	Judgemental sampling (2)	
		

Figure 1 Sampling patterns of probabilistic and judgmental sampling [4]

With simple random sampling, every portion of the population has the same (small) chance of being selected as a sample. However, the resulting samples will not necessarily be very evenly spread across the population. In stratified random sampling, a predetermined number of samples are uniformly distributed across a predefined number of parts of the population.

With systematic sampling, samples are distributed evenly throughout the population, starting from a randomly selected starting point (to meet the requirements of probability sampling - that each element of the population has an equal chance of being sampled).

Judgemental sampling encompasses various sampling patterns that generally differ in the extent to which they deviate from a probabilistic sampling approach. Option (1) in Figure 1 represents a type of judgemental sampling that is based on a probabilistic approach, but only for a portion of the population. In contrast, the pattern for option (2) is completely biased. It provides no information about the waste, except in the immediate vicinity of the samples, and nothing can be concluded about the quality of the selected portion of the population [4].

Determination of the increment and sample size - An increment is the amount of material (mass or volume) that is obtained through one single sampling action. It is not analysed as a separate unit, but is combined with other individual samples to form a composite sample.

The degree to which we have to take account of the increment and sample size will very much depend on the type of waste material sampled. The minimum increment size of an individual sample is governed by the need for the sampling device to accommodate all particle sizes. In contrast, there is no practical need for a minimum size when sampling liquids, as the particle size is at the molecular level [4].

The minimum increment and sample size are not relevant for creating a sampling plan for **liquid materials**, as the potential differences are at the molecular level compared to the sample size. When forming composite samples, the sample size will be determined by the number of individual samples and their size, which in turn depends on the dimensions of the sampling equipment [4]. **Powdery materials and sludges** have small particle sizes, while sludges also have a certain amount of liquid. Provided that the sampling equipment allows the entry of all particles contained in the material, then there are no additional requirements for the minimum size of individual samples. Similarly, considering the small particle size in this type of material, differences between individual particles will not have a major effect on the characteristics of the sample, because in practice, the sample consists of a very large number of particles, and there are no additional requirements for the minimum size of individual samples. With this in mind, the sample size will be determined by the amount of material the laboratory requires to perform the test, while the dimensions of the sampling equipment will determine the size of the individual samples. As with liquids, when forming composite samples, the sample size will be determined by the number of individual samples and their size [4].

When sampling particulate or granular material, the minimum size of the individual sample must be taken into account. The size of the sampling equipment opening must be large enough to allow entry of all particles present in the material. In practice, the opening of the sampling equipment must be at least three times the diameter of the largest particle. For practical reasons, the diameter of the largest particles can be substituted by the size of the (estimated) 95-percentile of the particle size distribution.

The actual size of the samples and individual samples depends not only on the minimum size of the samples and individual samples, but also on:

- The amount of material required by the laboratory to perform the analysis;
- The number of increments in the composite sample (when increments are taken);
- the relation between the mass of the minimum increment size and the minimum sample size (in relation to the number of increments in a composite sample) [4].

The use of composite versus individual samples - The objective of the testing program, and in particular the choice of statistical parameter, dictates the choice between composite and individual samples, i.e. which type of sample will generate more relevant data.

Note that there is a difference in meaning between an increment sample that forms a composite sample and the sample that is obtained from a single sampling operation.

When an approximate indication of the quality of the material is sufficient to meet the objective of the test, as in e.g. on-site verification, where one or at most a few samples would suffice, then the cost of analysis and sampling is low. Conversely, a significant number of individual samples need to be taken if a reliable estimate of the mean quality value for one or more composite samples is required. Such an approach may be acceptable for compliance testing (where compliance is relative to the mean concentration). In this case, the cost of sampling may be high, but the cost of analysis would be low. When a significant number of samples are taken to give a realistic estimate of the quality of the material and to provide information on the degree of heterogeneity of the material, as in the case of basic characterisation, the cost of both sampling and analysis will be high. [4–9]

Defining the Sampling Plan - The previous chapters of this paper were intended to contribute to the definition of a sampling plan. The various choices and decisions made are brought together in a single document that is called a sampling plan and represents the initial step in the sampling process in a broader sense.

CONCLUSION

Representative sampling is essential for obtaining reliable waste characterisation data. Due to the inherent heterogeneity of waste materials, the preparation of a well-defined sampling plan is necessary to ensure sample representativeness and reduce uncertainty. The CEN/TR 15310 series provides a systematic framework for defining sampling objectives, assessing variability and selecting appropriate sampling strategies. Proper implementation of these principles improves the quality of analytical results and supports regulatory compliance and informed waste management decisions.

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